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SHORT COMMUNICATION

The impact of the massive mucilage outbreak in the Sea of Marmara on gorgonians of Prince Islands: A qualitative assessment

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Abstract

In autumn 2020, a large mucilaginous outbreak was recorded in the entire Sea of Marmara and lasted until summer 2021. Mucilaginous aggregates in the water column and the impacts on gorgonians were qualitatively monitored at Prince Islands. Suspending and drifting mucilaginous aggregates in several forms and sizes were present from April to July 2021. All four main gorgonian species present in the area were observed to be covered with mucilage; some colonies were still healthy, some showed total mortality, while others had partial mortality. The population of the red gorgonian *Paramuricea clavata* was already severely declined in the area and might be expected to be the worst impacted. Gorgonian populations in the area could potentially recover but the recurring nature of mucilage outbreaks might prevent a recovery by rejuvenation as mucilage deposition mainly impact young colonies. Considering with accelerating climate-driven changes, mucilage outbreaks would probably recur in this semi-enclosed sea with clearly altered environmental conditions. The ecological status is clearly alarming and effective measures need to be taken urgently to prevent the formation of another large-scale and long-lasting mucilage event. The implementation of the recent Action Plan for the conservation of the Sea of Marmara could highly improve the conditions if genuinely applied throughout the basin.

Keywords: Mucilaginous, sea fan, sea snot, benthos, coralligenous

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Mucilaginous aggregates consist of exopolymeric compounds released by marine organisms under stress, mainly single-celled microalgae in the pelagic environment and filamentous algae in the benthic environment; the colloidal

properties of these compounds evolve them into a gelatinous organic material, commonly called as marine snot or mucilage that can reach great dimensions and cover large areas (Giani *et al.* 2005; Aktan *et al.* 2008; Balkıs *et al.* 2011). The occurrence and magnitude of marine mucilage outbreaks seem to increase in worldwide coastal areas and become a great concern due to negative ecological and socio-economical impacts. The increasing frequency of mucilage outbreaks was shown to be closely associated with temperature anomalies in the Mediterranean Sea and therefore might be expected to increase even more in response to accelerated climate-driven sea surface warming (Danovaro *et al.* 2009). A particularly large mucilage phenomenon has occurred in the Sea of Marmara in 2007-2008 and several diatoms and dinoflagellates were identified as the main contributors (Tüfekçi *et al.* 2010; Balkıs *et al.* 2011, 2013; Toklu-Alıçlı *et al.* 2020). The mucilage event lasted throughout the year except summer months and had severe ecological impacts on benthic organisms (Aktan *et al.* 2008) together with socio-economic impacts particularly on fisheries (Yentur *et al.* 2013). In autumn 2020 a large mucilaginous outbreak was recorded in the entire Sea of Marmara (Özalp 2021), covered great distances along the coasts, lasted on sea surface until June 2021 and was identified as "one of the worst mucilage outbreaks ever" (Savun-Hekimoğlu and Gazioğlu 2021).

Prince Islands coasts located in the northeastern Sea of Marmara, characterized by rich marine biodiversity, were highly covered by mucilaginous aggregates during 2020-2021 outbreak. Mucilaginous aggregates that end up deposited on sea bottom may cause severe damage to benthic organisms by reducing light availability to algae and by suffocating sessile invertebrates including gorgonians (Schiaparelli *et al.* 2007; Piazzi *et al.* 2018); moreover the degradation of this organic material may cause locally hypoxic and even anoxic conditions (Precali *et al.* 2005). Depositing mucilage is easily entrapped by gorgonian branches positioned perpendicularly to currents and can cause necrosis of the coenenchyme, possibly leaving the axial skeleton bare (Mistri and Ceccherelli 1996a; Giuliani *et al.* 2005). Small colonies are the most sensitive size and show high mortality while larger colonies display mortality depending on the extent of damaged area by mucilaginous cover; those large colonies with a damaged area less than 50 % might eventually recover once the mucilage disappears (Mistri and Ceccherelli 1996a). On the other hand, a large and unexpectedly exclusive microbial biodiversity was reported in marine mucilage with pathogenic species that were absent in surrounding seawater (Danovaro *et al.* 2009). Therefore the deposition of aggregates on gorgonians and other benthic sessile organisms might also cause infections that can damage these organisms.

The qualitative study was effectuated at Prince Islands coasts (Figure 1) where there are four main gorgonian species; the red gorgonian *Paramuricea clavata* is rather rare in the area, present occasionally in small bunches (Topcu and Öztürk 2015). *Eunicella cavolini* on the other hand can form locally dense facies that can reach up to 35 colonies.m^{-2} (Topcu unpubl. data). The other two gorgonians in the

area are Mediterranean endemic species found normally at depths below 50 m but are relatively abundant in Prince Islands as from 20 m due to the peculiar oceanographic conditions in the Sea of Marmara (Topcu and Öztürk 2015). Gorgonian species in the Sea of Marmara are known to have suffered from previous mucilage events in 2007/2008 at Prince Islands (Topcu and Öztürk 2015) and from the ongoing mucilage of 2020/2021 as from December 2020 in the Çanakkale Strait (Özalp 2021).

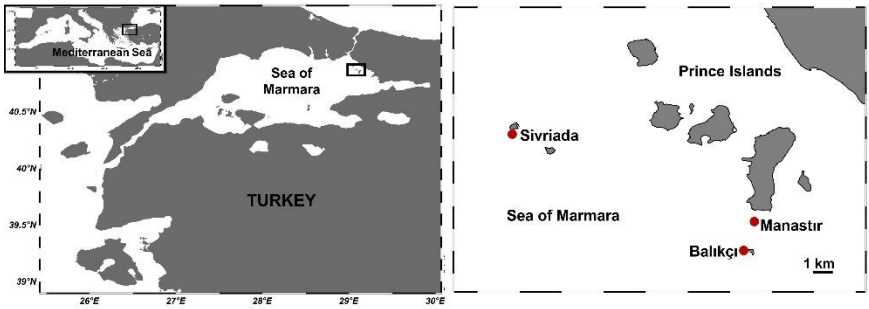

Figure 1. Location of Prince Islands and diving spots (red dots)

Mucilaginous aggregates in the water column and the impacts on gorgonians were qualitatively monitored with the help of local volunteer divers at Prince Islands, as from the intensification of the mucilage in April 2021. Suspending and drifting mucilaginous aggregates in several forms and sizes were present all over Prince Islands coasts from April to July 2021 (Figure 2). Most gorgonians were covered with mucilaginous aggregates, some colonies were still healthy, some colonies showed total mortality, while others had partial mortality (Figure 3). Local divers occasionally visited gorgonians to shake off the hanging mucilage but suspending and drifting mucilaginous aggregates were continually deposited on sea bottom and repeatedly covered gorgonians until the end of July. Some colonies showed signs of necrosis beneath the mucilaginous sheet (Figure 3).

The four gorgonian species present in the area displayed different responses to mucilage stress. *Spinimuricea klavereni* and *Paramuricea macrospina* colonies were the first to die off as previously reported following the stress due to excessive sedimentation event (Topcu *et al.* 2019). However, these two species started to reappear in the area soon after the damage and have relatively recovered so far (Topcu pers. observ.). On the other hand, *P. clavata*, at decline since the 1970s at Prince Islands (Topcu and Öztürk 2015), was highly impacted by the excessive sedimentation and the population in the area was severely affected (Topcu *et al.* 2019). The few red gorgonian colonies that were still present in this area seem also highly impacted by the present mucilage event, displaying total mortality at some locations by May 2021. *Eunicella cavolini* was the least impacted species during the excessive sedimentation and seems to cope much better with the mucilage as well, with colonies still alive appearing when the

mucilaginous deposits were shaken off from the colony surface. *Savalia savaglia*, false black coral, colonies were also covered with mucilaginous aggregates but were yet alive in July 2021. The status of gorgonian colonies will be monitored in a quantitative survey in September 2021.

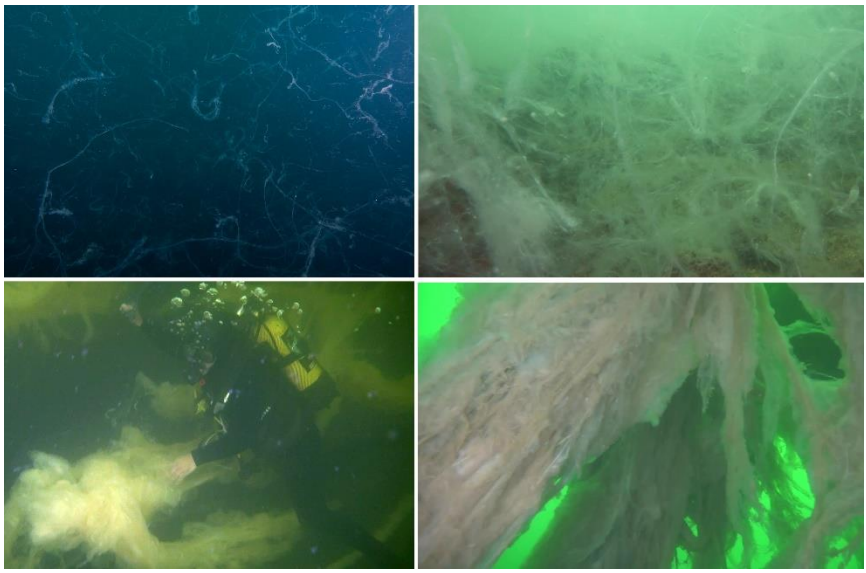

Figure 2. Various forms and sizes of suspended and drifting mucilaginous aggregates at depths 12-25 m in May 2021 (top pictures) and July 2021 (bottom pictures). Photos: Ferhan Coşkun (top left), Serço Ekşiyan (top right and bottom pictures)

The entrapment of mucilaginous aggregates by gorgonian branches might cause tissue necrosis that may lead to colony death but may eventually protect the organisms living under the gorgonian canopy from suffocating; therefore gorgonian forests may limit the damage from suffocation to many associated benthic invertebrates, at expense to themselves (Ponti *et al.* 2018). We can thus assume that the decreased gorgonian population in Prince Islands in the last 40 years due to various anthropogenic impacts (mainly from industrial fishing but also excessive sedimentation in the last couple of years [Topcu and Öztürk 2015; Topcu *et al.* 2019]) might have worsened the impact on local coralligenous community. The red gorgonian was reported to recover from damage caused by mucilage in a few years through recruiting juvenile colonies (Mistri and Ceccherelli 1996b) and similar recovery might possibly be expected for other Mediterranean gorgonians once mucilage stress is eliminated. However, the recurring nature of mucilage outbreaks (e.g. as observed in the Adriatic Sea and other locations in the Mediterranean) might prevent gorgonians from recovering by rejuvenation of the population if we consider that small colonies generally display total mortality following mucilaginous deposition. Gorgonians are important engineering organisms that highly influence the structure and diversity

of benthic assemblages, contributing to the 3D complexity of the habitat (Cerrano *et al.* 2010; Ponti *et al.* 2016; Rossi *et al.* 2017). The loss of gorgonians may lead to a simplification of the assemblages and a shift from crustose coralline algae to filamentous/turf algae assemblages, decreasing complexity and resilience of coralligenous bioconstructions (Rossi 2013; Ponti *et al.* 2014; Piazzi *et al.* 2021). Considering with accelerating climate-driven changes, mucilage outbreaks would probably recur in the Sea of Marmara, a semi-enclosed sea with clearly altered environmental conditions. The recent declaration of gorgonian-rich marine protected area (MPA) in Prince Islands (by the decision number 3817, Article 109 of the Presidential Decree No. 1, published in the Official Gazette dated 10/04/2021 and numbered 31450) was a promising progress for the conservation of gorgonian forests in the area but MPAs are unfortunately ineffective measures to impacts from mucilage outbreaks.

Figure 3. A *Spinimuricea klavereni* colony that was yet alive in May at Balıkçı (A); a *Paramuricea cavolini* colony almost entirely denuded (purple arrow) and few colonies of *P. macrospina* with partial mortality in June at Manastır (B); *P. clavata* colonies with necrosed tissue (white circle) in July at Manastır (C); *Eunicella cavolini* colonies covered with mucilaginous aggregates in July at Balıkçı (D); alive (orange arrow) and dead (white arrow) *E. cavolini* colonies in June at Sivriada (E); false black coral *Savalia savaglia* entirely covered with mucilaginous aggregates but alive in July at Balıkçı (F). Photos: Ferhan Coşkun (E), Serço Ekşiyan (A, B, C, D, F)

The ecological status of the Sea of Marmara is clearly alarming and effective measures need to be taken urgently to prevent the formation of another large-scale and long lasting mucilage event. Recently an Action Plan for the conservation of the Sea of Marmara was announced by the Ministry of Environment and Urbanisation and its implementation could highly improve the conditions in the Sea of Marmara, if genuinely applied throughout the basin by all municipalities, industrial plants and other relevant institutions.

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Marmara Denizi'nde oluşan şiddetli deniz salyasının Prens Adaları gorgonları üzerindeki etkisi: Nitel bir değerlendirme

Öz

2020 sonbaharında, Marmara Denizi'nin tamamında büyük bir deniz salyası (müsilaj) olayı kaydedildi ve yaz aylarına kadar sürdü. Bu çalışmada, Prens Adaları'nda su kolonundaki müsilajlı agregalar ve gorgonlar üzerindeki etkiler niteliksel olarak izlendi. Nisan-Temmuz ayları arasında çeşitli biçim ve boyutlarda askıda ve sürüklenen müsilaj agregaları mevcuttu. Bölgede bulunan başlıca dört gorgon türünde kolonilerin müsilajla kaplı olduğu, bazı kolonilerin hala sağlıklı olduğu, bazılarının tam ölüm gösterdiği, diğerlerinin ise kısmi ölüm gösterdiği gözlemlendi. Bölgedeki gorgonlar arasında popülasyonu geçmiş yıllardan beri ciddi ölçüde azalmış bulunan kırmızı gorgon *Paramuricea clavata* türünün en kötü etkilenen tür olması beklenebilir. Müsilaj etkisinin sona ermesiyle birlikte, bölgedeki gorgon popülasyonları yeni/genç kolonilerin sayıca önemli artışı (rejüvenasyon) yoluyla iyileşebilir, ancak müsilaj çökelmesi öncelikle küçük kolonileri etkilediği için, gelecekte tekrarlanan müsilaj olayları iyileşmeyi önleyebilir. Hız kazanmış olan iklim kaynaklı değişiklikler göz önüne alındığında, açıkça bozulmuş durumda olan çevresel koşullara sahip bu yarı kapalı denizde müsilaj olayları muhtemelen tekrarlayacaktır. Ekolojik durum açıkça endişe vericidir ve bu kadar büyük ölçekli ve uzun süreli bir müsilaj olayının tekrarlamasını önlemek için acilen etkili önlemler alınması gerekir. Marmara Denizi'nin korunmasına yönelik yeni Eylem Planının havza genelinde gerçek anlamda uygulanması, koşulları büyük ölçüde iyileştirebilir.

Anahtar kelimeler: Müsilaj, deniz dalı, deniz salyası, bentos, koralijen

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