

## RESEARCH ARTICLE

# First massive mucilage event observed in deep waters of Çanakkale Strait (Dardanelles), Turkey

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### Abstract

During the regular surveys on coral monitoring for setting their developmental level, health status and likely threats responsible for mortality, a massive mucilage phenomenon was identified in the largest coral habitats in the Çanakkale Strait (Dardanelles) in December 2020. This study was performed to determine the effect of mucilage event on corals mainly observed at the depth level of 39-51 m in two stations, one in the European and the other in the Anatolian side of the strait. A massive mucilage with expanding cloud and floc types of aggregates was detected only in the Eceabat region (European side). A false-benthos mucilage was also identified at depths 4-20 m in the following control surveys. The current report is of the first circalittoral observation of this damaging event in the northernmost region of the Mediterranean Sea. Previous records of massive mucilage were reviewed and the first deep infralittoral record of massive mucilage event in 2008 is also described.

**Keywords:** Mucilage, zoobenthos, coral, ecology, Turkish Straits System

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### Introduction

Mucilage, also known as marine snow, aggregated mass, foam accumulation, formation of flocs, cloud or mucilaginous and mucous agglomeration (Suzuki and Kato 1953; Riley 1963; Lancelot 1995; Rinaldi *et al.* 1995), is described as particulate organic materials mainly occurred some gelatinous or creamy particles or mass (Precali 2005). It also forms a false-benthos in which a huge number of these particles almost fully cover the littoral zone (Stachowitsch *et al.* 1990).

Some investigations showed that these formations are composed of exopolymeric substances produced by marine algae (Zingone and Wyatt 2005; Xu *et al.* 2013).

The origin of mucilage in marine environment is mainly referenced to two agents such as planktonic organisms and benthic filamentous algae (Schiaparelli *et al.* 2007). Lately, mucilage has frequently been associated among the most harmful impacts on marine benthic communities like corals, coralligenous and seagrass beds due to its negative effects such as covering facies becoming entangled and suspending physiological processes, likely causing anoxia in time (Castelli and Prevedelli 1992; Rinaldi *et al.* 1995; Mistri and Ceccherelli 1996; Giuliani *et al.* 2005; Lorenti *et al.* 2005; Djakovac 2006; Devescovi and Iveša 2007; Aktan *et al.* 2008; Topçu and Öztürk 2015; Cramer *et al.* 2018; Piazzzi *et al.* 2018). It is also negatively affecting pelagic fishery (Giani *et al.* 2005). The timing of mucilage occurrence is mostly unexpected and variable, as previous studies regarding massive events were reported both in summer and winter (Devescovi and Iveša 2007). It should be stated that understanding the ecological changes during the mucilage events that badly affect the planktonic abundances is also crucially important for further monitoring of food chain in marine habitats (Yılmaz 2014).

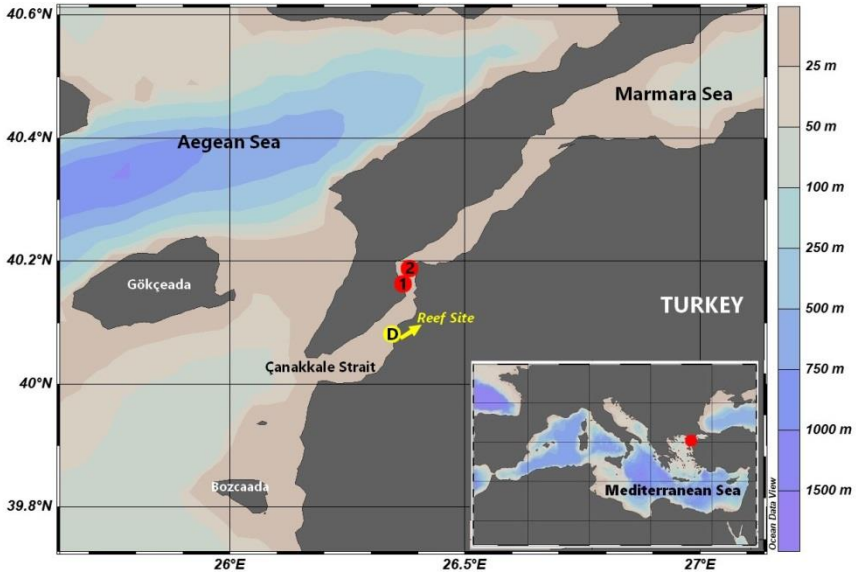
There are a series of large-scale mucilage events reported in history regarding the oceanic, naval and, in broad sense, the epicontinental sea regions of the world (Lancelot 1995; McKenzie *et al.* 2002; Najdek *et al.* 2005; Schiaparelli *et al.* 2007; Nikolaidis *et al.* 2008; Fukao *et al.* 2009; Misic *et al.* 2011; Fernandes and Frassão-Santos 2011). In Turkish seas, the first observation of massive mucilage effect was reported from the Sea of Marmara in 2007 (Aktan *et al.* 2008). Recent findings showed that the phenomenon was overwhelmingly effective throughout the Turkish coasts, including the Turkish Straits consisting of the Marmara Sea, Istanbul Strait and Çanakkale Strait (Aktan *et al.* 2008; Polat Beken *et al.* 2010; Zengin *et al.* 2010; Yüksek and Sur 2010; Aktan and Topaloğlu 2011; Balkıs *et al.* 2011; Altın *et al.* 2015; İşinibilir Okyar *et al.* 2015; Toklu Alıçlı *et al.* 2020; Keleş *et al.* 2020), causing a critical increase in public attention due to the alarming impacts in pelagic fishery (Tüfekçi *et al.* 2010). Within the Mediterranean Sea, such a phenomenon was also referred to an unusual event historically, massively affecting fishing nets by clogging and named as "mare sporco" in 1797 (Fonda Umani *et al.* 2007). The negative effects of this formation and its relations to climate change and eutrophication in the marine environment have been receiving much more research interests recently (Rinaldi 1992; Danovaro *et al.* 2009; Laffoley and Baxter 2016).

In this study, the effects of mucilage formation on coral habitats in the Çanakkale Strait was studied for the first time.

Additionally, the current investigation also reports the first recurring case of mucilage that observed twice within a three-month period both for surface and deep waters of the survey stations.

## Materials and Methods

The Çanakkale Strait, also known as the Dardanelles, is an important water channel that connects the Aegean Sea to the Sea of Marmara and forms a vital habitat for a large variety of the Mediterranean-originated marine animals throughout the coastal depths on both sides (Figure 1). Rocky substrates in the middle part of the European side of the strait create rare biodiversity hotspots consisting of some species group of key importance, such as colonial hard corals, gorgonians, coralligenous and sponge assemblages. Some of them act as primary biotope for sheltering and breeding for other aquatic life (Özalp 2013).

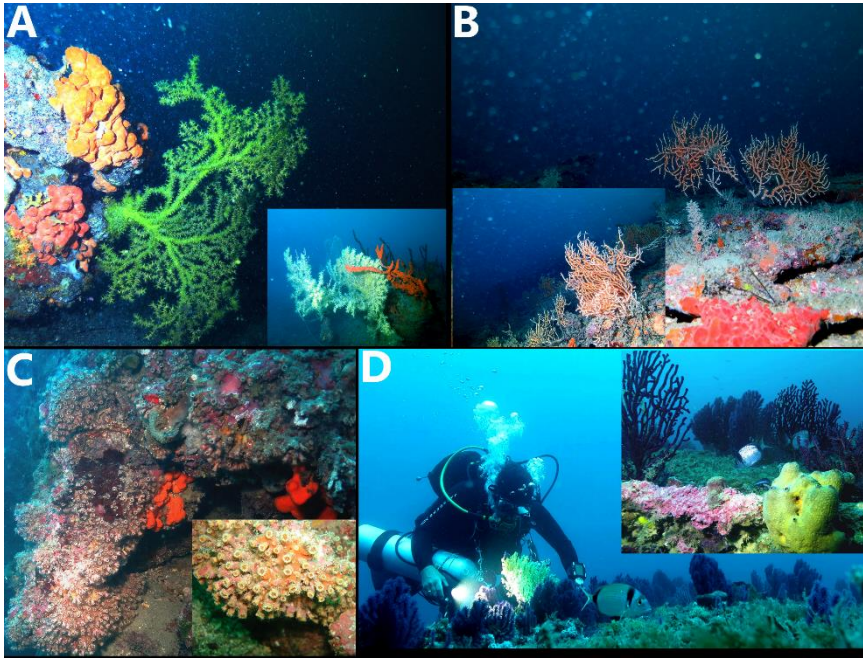


**Figure 1.** Map of the study sites (1: Eceabat station, 2: Nara station, D: the only largest reef site of the endangered coral *Cladocora caespitosa* in the Turkish Straits System)(Schlitzer 2018).

Among these facies extraordinarily occurring at some special sites mainly under the circalittoral zone between 34-65 m in depth, the largest habitats of the scleractinian and gorgonian corals of the Çanakkale Strait such as *Polycyathus muelleriae*, *Savalia savaglia*, *Paramuricea clavata* and *Eunicella cavolini* are observed (Figure 2).

The survey sites were periodically examined by scientific divers from 31 December 2020 to 3 March 2021. During the monthly periodic coral monitoring

at the coral-rich areas of the strait (Eceabat: 40°18'08"N, the European side-26°22'18"E, Nara: 40°11'53"N-26°23'45"E, the Anatolian side), the first massive mucilage at Eceabat region in floc and cloud types was detected on the branches and corallites of gorgonian and hard coral species on 31 December 2020. The after-effects of this first mucilage event given above and the second reoccurring of mucilage formation were also recorded on 3 March 2021. All coral individuals counted at the sites were photographed and recorded with an underwater video camera both before and after the mucilage events to monitor the health status and likely mortality effects on their body parts. The largest individuals of *S. savaglia* and *P. clavata*, severely affected by mucilage, were also measured with a plastic ruler *in situ*.



**Figure 2.** A view from healthy communities of gorgonian and hard corals in Eceabat and Nara regions, 2020 (A-B: Gorgonian habitats of *Savalia savaglia* and *Eunicella cavolini* in the beginning of mesophotic zone at survey sites; C: Colony habitats of the Scleractinian coral *Polycyathus muelleriae*; D: Scientific diver monitoring in the largest reef site of *Paramuricea clavata* of the Çanakkale Strait-Captain Franco wreck).

## Results

During the study, the weather was windy and the current speed at 0-14 m depth was not more than 2 knots, although the main regime at Eceabat and Nara regions can be 4.5 knots, but rarely 5 knots at these depths along the shore of Kilitbahir coasts (Özalp and Alparslan 2016). There was no current detected at over 39 m

depth where the coral species were observed. Bottom currents can rarely exceed 3 knots at the measurement sites even at 30 m depth, with countercurrents effective at 5-14 m depth, which are highly variable. The studied stations present in two sides of the strait representing the circalittoral zone between 39-51 m depths, are highly significant locations due to the large quantities of coral fauna, such as *S. savaglia*, *P. clavata* and *P. muelleriae*. A scleractinian coral species, *P. muelleriae*, also has the largest community in the Çanakkale Strait. They fully cover the rocky zones in Eceabat region, sheltering many other invertebrates inside the colonies. Meanwhile, *S. savaglia* and *P. clavata* also support the precious feature of marine biodiversity in the region (Özalp and Alparslan 2016). Since 2019, there has been monitoring of gorgonians at the studied sites aiming to determine the development of branches and growth rates.

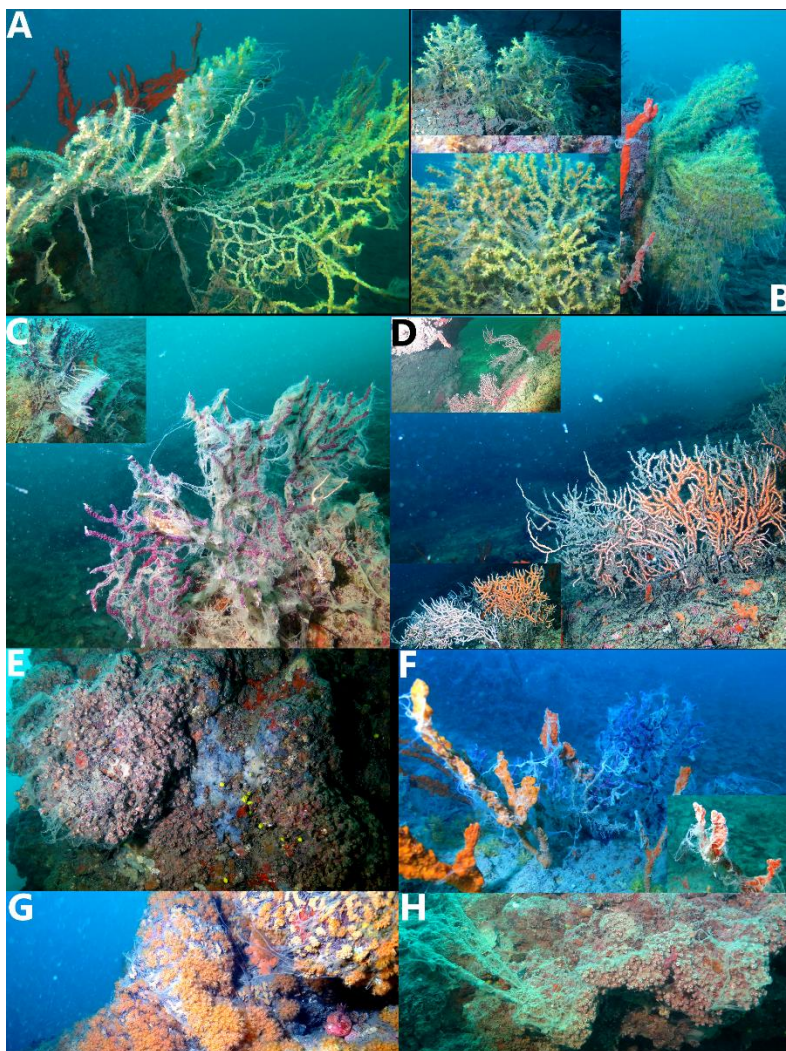
The largest *S. savaglia* individual at Eceabat region was measured as 117 and 104 cm, in height and width (diameter), respectively, during the current study. Additionally, Nara region was identified as the main habitat of *E. cavolini* in the strait. In the survey site at Eceabat, 11 individuals of gorgonian (4 *S. savaglia*; 7 *P. clavata*) and 3 colonies (*P. muelleriae*) were found as affected severely (100%), fully covered by flocs of mucilage on their branches and corallites, while other 5 individuals of *P. clavata* were under influence over 90%. There also found some sponge individuals under the effect of cloud-type mucilage on their upper points of branches. In Nara region, 24 individuals of *E. cavolini* were identified as in the rate of over 50%, likely being affected slightly more than those colonies in Eceabat region (Figure 3).

The station at Eceabat region with the highest gorgonian abundance was examined twice by the scientific diving team on 4 February 2021 and lastly on 3 March 2021 after the first recording of mucilage event. In the first investigations performed in December 2021, showing the covering effect of floc and cloud types of mucilage on branches and corallites of coral colonies was the main aim, while the following surveys in the next months were planned to monitor the after-effect of mucilage aggregation at the site. During the monitoring in February 2021, although the mucilage no longer existed on pelagic and littoral zone in the area, full mortality on some branches in eight individuals of *P. clavata* due to the mucilage was observed, while there was no effect detected on *S. savaglia* and hard coral colonies (Figure 4A-B). In the surveys conducted on 3 March 2021, an overwhelming-scale mucilage formation, was recorded both on the infralittoral and circalittoral zone at Eceabat region for the second time.

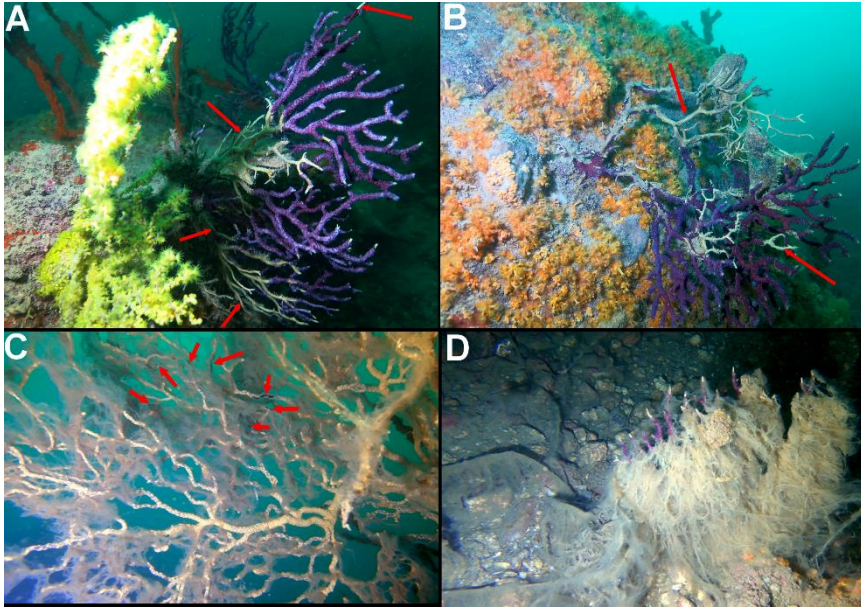
It was revealed severe mortality on some branches in two individuals of *S. savaglia*, despite that there was no dead part on branches observed in the survey in February. Additionally, 12 individuals of *P. clavata* were fully covered (100%) by mucilage on their branches, which were hardly visible *in situ* (Figure 4C-D). During the surveys, the underwater visibility was as low as 4 and 2 m at depths of 0-5 m and 5-32 m, respectively, due to intensive formation of cloud mucilage.



It was not more than 5 m at depths of 33-51 m. Although the condition of wind was mild on surface, the bottom current was much stronger reaching over 4 knots affecting the depth up to 30 m and there were also some countercurrents at shallow depths above 10 m. The seawater temperature at the surface and in the littoral zone in Eceabat region was 9°C and 12°C, respectively.



**Figure 3.** Mucilage event recorded in the circalittoral zone of coral-rich habitats in Eceabat and Nara regions, the Çanakkale Strait in 31 December 2020 at 39-51m depth. A-B: *Savalia savaglia*, C: *Paramuricea clavata*; D: *Eunicella cavolini*; E: *Polycyathus muelleri*; F: Sponge *Axinella cannabina* and *P. clavata*; G: *Parazoanthus axinellae*; H: *P. muelleri*.



**Figure 4.** Monitoring the effects of mucilage on coral habitats.

A-B: Mortality of some branches of *Paramuricea clavata* recorded on 4 February 2021 (Eceabat region); C-D: the second mucilage event recorded on 3 March 2021 and mortality of some branches of *Savalia savaglia* colonies (Eceabat region).

**Table 1.** The effect of mucilage between December 2020 and March 2021

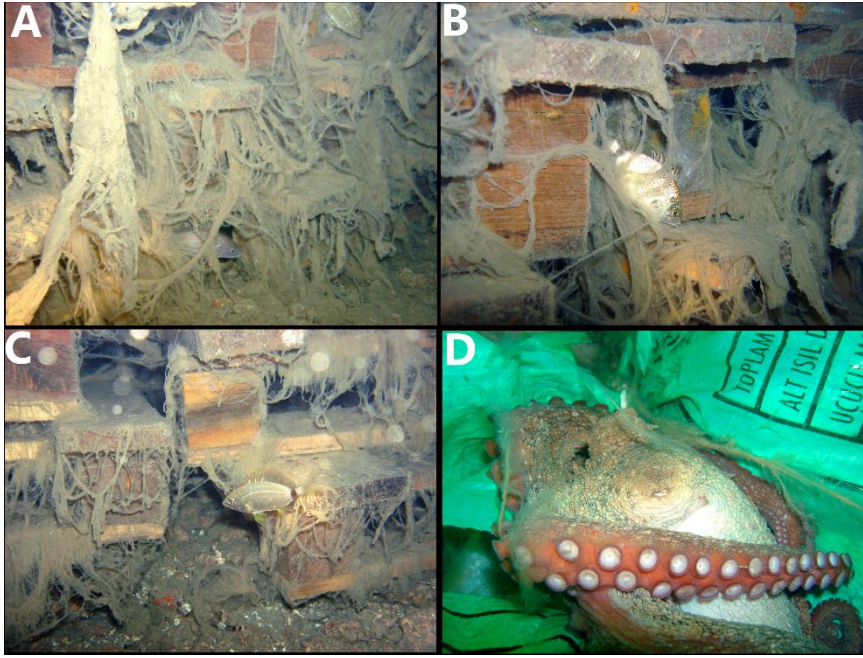
Species	Mucilage Type*		Mortality	
	First	Last	4 Feb 2021	3 Mar 2021
<i>Polycyathus muelleriae</i>	f,c	fb	-	-
<i>Savalia savaglia</i>	f,c	f,c,fb	-	+
<i>Paramuricea clavata</i>	f,c	fb	+	++
<i>Eunicella cavolini</i>	f,c	f,c	-	-
<i>Axinella cannabina</i>	f,c	f,c	-	-
<i>Parazoanthus axinellae</i>	f,c	f,c	-	-

**Note:** \*First: The first observation on 31 December 2020; Last: the last observation on 3 March 2021. f: flocs, c: clouds, fb: false-benthos; \*\*: more severe mucilage effect leading some branches to fully death branches

## Discussion

On 31 January 2008, the largest mucilage case was recorded in the infralittoral zone (Özalp 2009), in which the first false benthos-type of massive mucilage covered almost 100% on numerous substrates at 24 m depth off the harbor regions of Çanakkale and Nara (Figure 5). The effect on the infralittoral benthos, however, was not described in Özalp (2009). In present study, the effect on biota is presented. The surface currents at Nara region is one of the fastest flow reaching over 4.5 knots.





**Figure 5.** The first infralittoral-based mucilage event recorded in the Çanakkale Strait (Nara region) in 31 January 2008. A-B-C: The first observation of false-benthos type of mucilage on wooden artificial reefs and affected fish species (*Sciaena umbra*, *Diplodus annularis*) in the site; D: *Octopus vulgaris* and the suspended formation of mucilage literally known as cloud.

The only agricultural runoff, known as Umurbey Creek and other likely discharges originating from numerous farming areas around Karacaören close to Nara region, may also be one of the reasons for the mucilage formation.

In January 2008, the mucilage forming a false-benthos at 24 m depth (Underwater Sports Club Artificial Reef of ÇSK, Nara location) lasted for two months until the early of March 2008 and then unexpectedly reoccurred in the same region in October 2008 (Özalp 2009). Although the formation observed in October 2008 by Yentur *et al.* (2013) at different stations (Guzelyali, Abide), the starting date of the phenomenon in Nara region (January 2008) was not reported before in the literature (Özalp 2009).

The mucilage occurrence in the infralittoral zone in the middle part of the Çanakkale Strait (Nara region), first recorded in January 2008 by Özalp (2009) and studied in detail between October 2008 and August 2009 in the lower parts of the strait (Yentur *et al.* 2013) lasted about 18 months in the strait. Mucilage occurrence surely shows a periodic characteristic in the Çanakkale Strait as seen in January 2008 and August 2009 (Özalp 2009). Another study in 2015 regarding



the occurrence of mucilage in shallow water reported its negative impact on fishing nets (Altın *et al.* 2015). A case on mucilage formation with a serial plankton bloom in the Sea of Marmara was also reported in recent years (Ergül *et al.* 2018). Additionally, the last monitoring surveys at Eceabat region revealed that the second mucilage occurrence in March 2021 (more severe) was recorded again after two months (31 December 2020) from the first occurrence report of mucilage in the area, causing a false-benthos condition in the infralittoral zone, death in several branches of *S. savaglia* and unhealthy coral colonies of *P. clavata*.

The historical records also show recurring observations since the 1800s in an area where it is recorded formerly (Molin *et al.* 1992; Degobbi *et al.* 1999). The main reasons of this formation are mostly linked to rising temperatures, eutrophication and changing nature in marine environments (Lancelot 1995; Rinaldi *et al.* 1995; Schiaparelli *et al.* 2007; Danovaro *et al.* 2009). In recent studies (Taş *et al.* 2016), eutrophication originating from the terrestrial discharges from the Black Sea was presented as the main factor in forming high planktonic density in the Çanakkale Strait, meaning likely triggering the mucilage increase (Turkoglu and Oner 2010; Turkoglu and Erdogan 2010).

Close to the present study area, the mucilage was first observed in October 2007 in the Sea of Marmara (Aktan *et al.* 2008). This massive event from the mentioned region and organisms causing it were then extensively studied (Altuğ *et al.* 2010; Tüfekçi *et al.* 2010; Balkıs *et al.* 2011; Çiftçi Türetken *et al.* 2016; Taş *et al.* 2016, 2020; Keleş *et al.* 2020; Terbiyık Kurt *et al.* 2020; Toklu-Alicli *et al.* 2020). The first harmful effect of mucilage formations on the gorgonian coral *S. klavereni* was also examined in the Sea of Marmara in 2011 (Topçu and Öztürk 2015).

The regular site surveys conducted by scientific divers revealed that there were temperature anomalies in seawater observed both on the surface and bottom zone (Eceabat, Nara) in the strait since 2008, likely unveiling a mild increase and abnormality regarding the circalittoral data measured in Eceabat coral habitats regularly in December.

In December 2020, an increase of 2°C was recorded for the first time on the sea bottom temperature although it was usually measured as 14°C in general for 6 months. There are also other anomalies measured at the same stations as the highest values of sea water temperatures (Table 2) for 2014 (14-18°C) and a prominent effect was also seen between two water zones for the first time as 7°C in 2007. Although the lowest values ever recorded from the area can be subjected to the event named "extreme cold weather wave 2017" reported lately from the Turkish territorial (Acar Deniz and Uslan 2018), the highest value of 18°C in 2014 and 16°C in December 2020 showed abnormality for the strait. It is indicated that the mucilage outbreaks increased in the last 20 years in the Mediterranean Sea is mostly associated with the temperature fluctuations (Danovaro *et al.* 2009). It is also reported that food chain system and planktonic

dynamics in marine environment may tend to be unexpected changes due to massive existence of mucilage in the seas and oceans (Lancelot 1995).

**Table 2.** Sea water temperatures based on the data of two dive computers (UW Uwatec Galileo/Suunto Stinger)

Months	Year	Temperature (°C)		Remark
		Depth Zone 36.8-51 m	Depth Zone 0-5 m	
<b>Jan</b>	2008*	10	8	Mainly
<b>Dec</b>	2012**	14	10	reflecting
<b>Dec</b>	2013**	14	12	comparative
<b>Dec</b>	2014**	18	14	data
<b>Dec</b>	2015**	14	12	measured in
<b>Dec</b>	2016**	14	-	December
<b>Jan</b>	2017**	7	7/5.6 <sup>#</sup>	
<b>Dec</b>	2018**	14	-	
<b>Dec</b>	2019**	14	12	
<b>Dec</b>	2020**	16	13	
<b>Feb</b>	2008*	-		Mainly
<b>Jan</b>	2012***	13.62	7.7	reflecting
<b>Feb</b>	2013**	-	-	comparative
<b>Feb</b>	2014**	-	-	data
<b>Feb</b>	2015**	12	9	measured in
<b>Feb</b>	2016**	12	8	February with
<b>Feb</b>	2017**	-	-	one
<b>Feb</b>	2018**	12	8	exceptional
<b>Feb</b>	2019**	12	8	measuring by
<b>Feb</b>	2021**	14	12	YSI prop***

**Note:** \*: MSc thesis study (Özalp 2009); \*\*: Periodic measurements of the current paper;  
#: The additional data is represented the temperature value recorded in February 2017  
in the Sea of Marmara, Mola Islands-Bandırma (Özalp 2021);  
\*\*\*: YSI prop data measured on January 18, 2012.

Although the data of January 2008 presented in the current study show no specific temperature fluctuations for that period of time, the data of 2014, 2017 and 2020 had some clear anomalies for both the bottom and surface values. Although they are not significantly high.

Hydrography in the study areas (Eceabat, Nara) is also important in understanding the mucilage suspension and distribution between the infralittoral and circalittoral zone. At the station in Eceabat, sea bottom slope is flat at the pre-infralittoral between depths of 0-4 m, while it shows 45° of inclination at a depth level 5-21 m. There also existed some specific points with steep continental slopes reaching 80°, where the strong bottom current and countercurrent frequently varying due to weather are still effective reaching to depths of 30-35 m. The bottom current at coral habitat (39-51 m) is mild below 0.5 knots. The bottom slope in the infralittoral of the second station in Nara region is slightly deepened with 30° of

inclination between 0 and 35 m. However, the floor slopes steeply (over 60-80°) down from a depth range of 35-38 m to 65 m. Some unusual rocky substrates with 90° also exist, where the gorgonians (*S. savaglia*) occur densely. The deepest point of the strait (113 m) is located in Nara region as well (Gökaşan *et al.* 2008). The bottom currents at the circalittoral zone, there are variable reaching up to 2 knots, while the surface flows, also known as having a strongest regime in the strait, may rarely be above 5 knots even in rough weathers.

The main cause regarding the origin of mass mucilage formation of 2007 in the Marmara Sea is given as the high number of phytoplankton and benthic algal blooms (Aktan *et al.* 2008; Balkıs *et al.* 2011; İşinibilir Okyar *et al.* 2015; Ergül *et al.* 2018), which is also considered to be associated the first mucilage event reported from Nara in January 2008.

The likely extension from Izmit Bay to the Çanakkale Strait of the first mucilage event observed in mid-autumn 2007 was also presented formerly in Aktan *et al.* (2008).

It should be stated that since mucilage affects benthos severely forming anoxic conditions in marine habitats (Stachowitsch 1984; Mistri and Ceccherelli 1996; Ciglenečki *et al.* 2003; Giuliani *et al.* 2005; Aktan *et al.* 2008; Cerrano and Bavestrello 2008; Topçu and Öztürk 2015), further analyses are needed to better understand the ongoing process that is likely to have a negative impact on the health status of the region. Because mucilage may possibly lead to mortality of all colonies (Zavodnik 1977 cited in Stachowitsch *et al.* 1990) by blocking their plankton-dependent feeding, likely penetrating and/or the mechanism of polyps on branches of gorgonians and corallites of hard coral colonies.

Recent surveys showed that since the formation occurred again on 3 March 2021, and stays for an unknown period as suspended and/or forming a false-benthos, there is a potential high risk of mortality in corals. Further investigations, thus, are crucially needed.

It is also suggested that temperature anomalies in the region should be regularly monitored by specific underwater data loggers as to understand ecological changes, since it is unclear whether global warming is indeed one of the main effects in the Çanakkale Strait.

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# Çanakkale Boğazı'nın derin sularında ilk büyük çaplı müsilaj olayı

## Öz

Mercanların gelişimleri, sağlık durumları ve mortaliteden sorumlu muhtemel tehditlerin belirlenmesi amacıyla düzenli olarak yapılan izleme çalışmalarında, Çanakkale Boğazı'nın en geniş mercan habitatlarında 2020 Aralık ayı sonlarında büyük boyutlu bir müsilaj olayı tespit edilmiştir. Bu çalışma, çoğunlukla 39-51 metre derinlik aralığında dağılım yoğunluğu oluşturan mercanlar üzerindeki müsilaj olayının etkilerini belirlemek amacıyla, biri Avrupa diğeri Anadolu yakası olmak üzere boğazın iki farklı istasyonunda gerçekleştirilmiştir. İlk olarak Eceabat bölgesinde kaydedilen büyük çaplı oluşumda, müsilajın bulutsu ve topak toplulukları daha yaygın gözlenmiş ve müsilaj olayının başlangıcından sonra gerçekleştirilen kontrol çalışmalarında 4-20 metre arası derinliklerde sahte dip yapısı belirlenmiştir. Bu rapor, Akdeniz'in en kuzey bölgesi bazında değerlendirildiğinde bu zarar verici olayın ilk sirkalittoral gözlemi niteliğindedir. 2020 yılına ait yeni verilere ek olarak, bu çalışma aynı zamanda 2008 yılında bölgede tespit edilen büyük çaplı müsilaj oluşumunun ilk derin infralittoral kaydını temsil etmektedir.

**Anahtar Kelimeler:** Müsilaj, zoobentos, mercan, ekoloji, Türk Boğazlar Sistemi

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