Development of three different mucilage events along the coast of western Istria in 2024

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Introduction

Mucilaginous are a consequence of phytoplankton polysaccharide secretions produced during long periods of calm, sunny weather and in waters with a strong pycnocline [1]. These amorphous aggregates are made of various particulate organic matter forms, such as macro-flocs, stringers, clouds, creamy surfaces, and gelatinous layers. Although this natural phenomenon has been reported in several parts of the Mediterranean [2-4], these events occur are particularly frequent and intense in the northern Adriatic Sea [5], as they were recorded many times in the past three centuries, with notable intensity in 1990s and early 2000s exerting adverse effects on the local ecology, fishing, and tourism [6].

The mucilage matrix forms favourable conditions for the microbial growth, including human pathogens [6]. Hypoxia and anoxia caused by mucilage microbial degradation and physical smothering [7] increased the mortality of benthic organisms [8]. Depending on stage and oxygen levels, mucilage aggregates can become rich with toxic sulfide and other sulfur compounds [9,10]. These compounds are essential in polymerization and vulcanization processes, influencing filament formation and enhancing their structural stability [9]. Additionally, mucilage can encourage the toxic algae growth, accumulate pollutants and their bioaccumulation in seafood [6]. Therefore, investigating the dynamics formation and the succession stages of mucilage will help us understand the factors driving its occurrence and develop strategies to predict and mitigate adverse effects on ecosystems, fisheries, and human health.

Materials & Methods

The development stages of 3 major mucilage events (Jun-Aug 2024) in the northern Adriatic Sea were monitored along the coast of Rovinj-Rovigno western Istria (45.0812° N, 13.6387° E). Formations were documented using a GoPro Hero 4 camera while hydrographic parameters (temperature, salinity) measured *in situ* using a multiparametric probe (Hanna ™ Instruments) at 0, 1, 1.5, 2, 3 and 4 m depths. Measurements and observations in the deeper waters (18-30 m) were obtained by scuba divers. The hydrographic data were processed using SURFER 13 (Golden Software). Additionally, samples at the beginning of the events (Jun, Jul) were checked under a light microscope.

Discussion

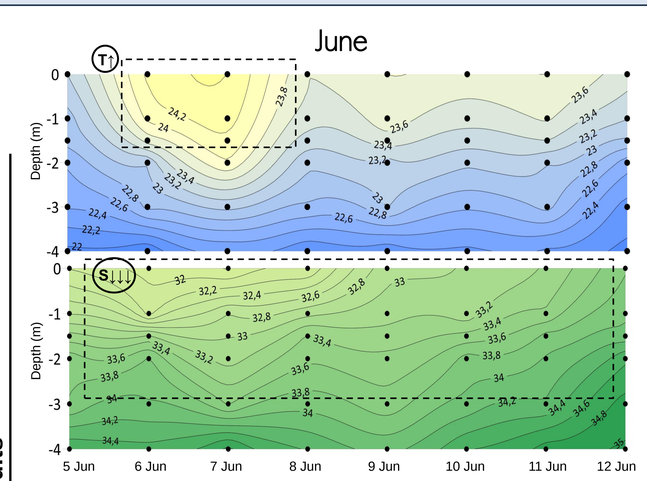
The mucilage events occurred after a series of extremes: intense phytoplankton blooms, high temperature (T), low salinity (S), and stable meteorological conditions. The phytoplankton community represented a diverse array of regularly occurring taxa. Particularly abundant were pennate diatoms, and among them, *Cylindrotheca closterium*, which was reported earlier in relation to mucilage events in the area [11]. As literature indicated [6], the mucilage matrix in June entrapped several potentially harmful taxa, such as diatoms Pseudo-nitzschia sp. and dinoflagellates *Alexandrium* sp. and Prorocentrum cordatum, while in July, bigger dinoflagellates such as *Tripos* (*Ceratium*) sp. were observed more frequently.

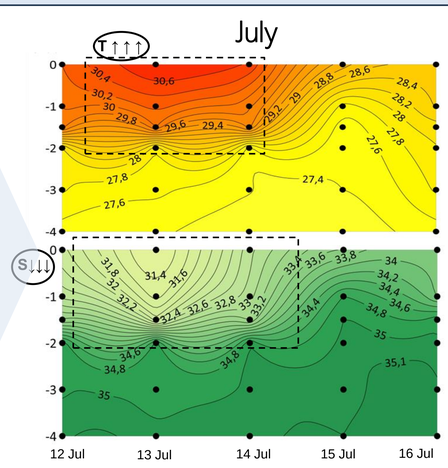
Spatial distribution and duration of the events increased progressively from June to August. They all started with a formation of microflocs (a few mm) in the upper layer (0-4 m) which in 1-2 days accumulated at the surface. In June, phytoplankton bloom lasted several days, forming macro-flocs (~1-3 cm) at the surface as a strong, shallow water pycnocline was lacking. Within a week, the aggregates matured and sunk deeper into the thermocline and vanished without reaching sea bottom. In the later coastal events (Jul and Aug), blooms appeared suddenly, accumulating mucilage on the surface a day after phytoplancton blooming. Presumably, mucilage formation started westwards, offshore, and was transported eastwards. Indeed, the extremely low S and high T in the upper layer support this hypothesis since the major freshwater input is the Po River in the NW Adriatic. Freshwater intrusion created a shallow pycnocline (Jun: 1.5 m, Aug: 3.5m), favoring the accumulation of mucilage along it and at the surface. In later events (Jul, Aug), the initial phase accumulated at the surface assumed a steady foam-like structure, different from the discrete macro-flocs in June. When the intrusion of riverine waters decreased, the pycnocline weakened, allowing mucilage to sink covering benthic life. High concentrations of surface active substances (xantan/dextran), mainly in particulate forms, were present during all events indicating an intense microbiological activity.

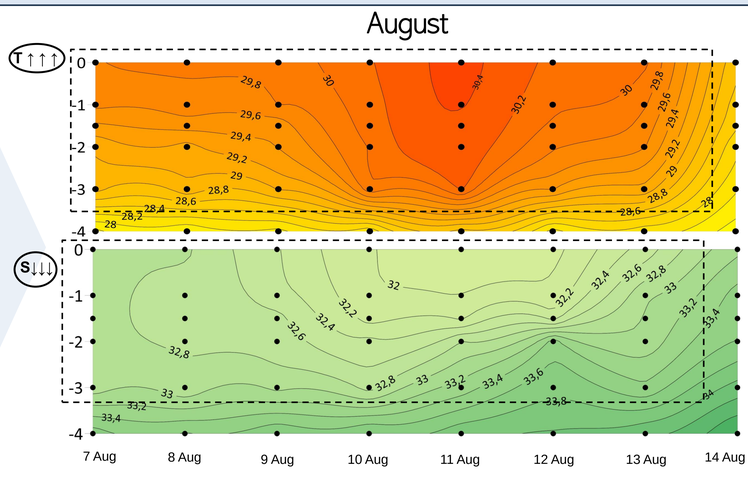
Conclusion

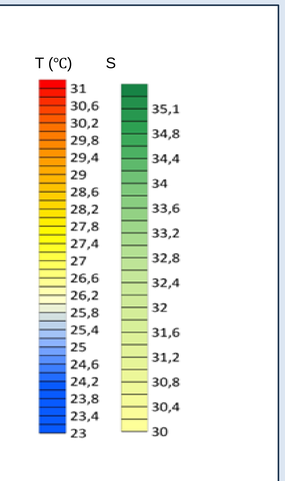
The three mucilage events display consistent structural changes and vertical distributions, indicative of varying organic matter quality and quantity. As material matured, it became more refractory, persisting for weeks and eventually sinking, covering the benthic life. These events were primarily shaped by the interplay of different physical parameters and the quality of phytoplankton excreta. Moreover, the events in Jun and August closely resembled the most intense events (late 1980s&90s) that caused the greatest environmental and economic damage. We suspect that global change factors such as the intense heat triggered phytoplankton's metabolic activity, which benefited from the freshwater intrusion due to extreme precipitation affecting rivers. Thus, if extreme preceding conditions continue, we can expect similar outcomes and mucilage formations.

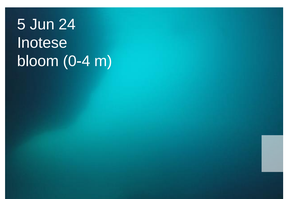
Results



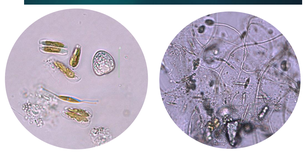


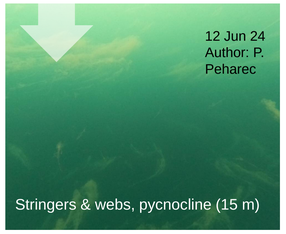


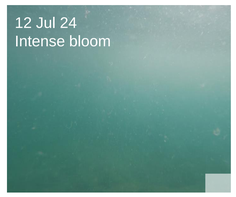



5 Jun 24
Inotese bloom (0-4 m)

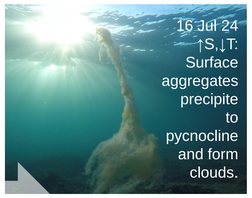

7 Jun 24
Aggregates formation.


Phytoplankton community (light microscopy 40x): dinoflagellate Prorocentrum cordatum (left), dense web of diatoms, mostly *Cylindrotheca Closterium* (right).

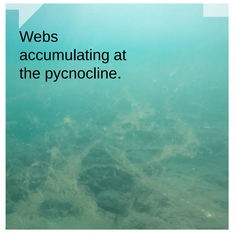

12 Jun 24
Author: P. Peharec
Stringers & webs, pycnocline (15 m)

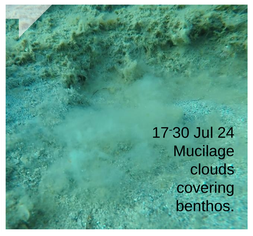

12 Jul 24
Intense bloom

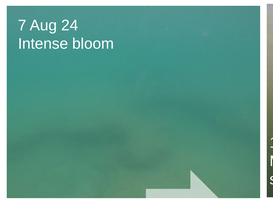

14 Jul 24
Maturation and separation, surface-pycnocline.

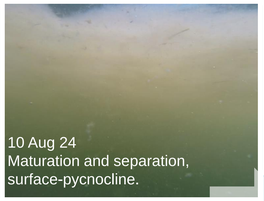

16 Jul 24
↑S,↓T: Surface aggregates precipite to pycnocline and form clouds.

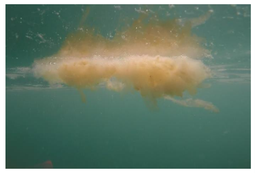

13 Jul 24
Whitish foamy aggregates at the surface.

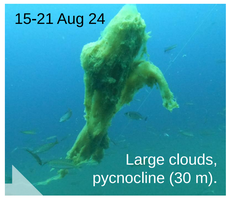

Webs accumulating at the pycnocline.

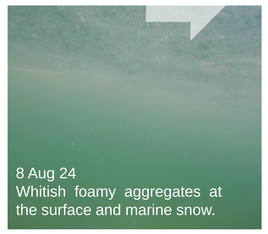

17-30 Jul 24
Mucilage clouds covering benthos.

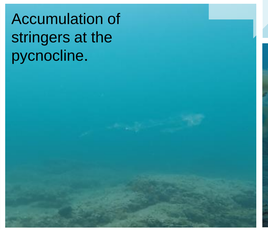

7 Aug 24
Intense bloom


10 Aug 24
Maturation and separation, surface-pycnocline.

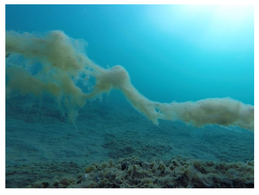


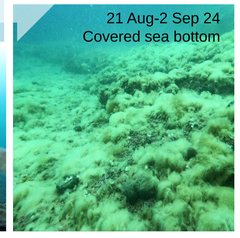

15-21 Aug 24
Large clouds, pycnocline (30 m).


8 Aug 24
Whitish foamy aggregates at the surface and marine snow.


Accumulation of stringers at the pycnocline.

14 Aug 24
Formation of surface and pycnocline mucilage clouds.




21 Aug-2 Sep 24
Covered sea bottom

Literature

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Acknowledgements

We thank P. Peharec for the scuba diving pictures and observation, dr.sc. N. Iveša for additional data and observations from southern Istria, and P. Malusa' for assisting during *in situ* monitoring. Moreover, A.B. is funded by European Union's Horizon Europe Research and Innovation Programme under grant agreement No 101060072 (ACTNOW).