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Phytoplankton biomass and main functional groups of the Sele river mouth (Southern Italian Tyrrhenian coast) in a severe drought period

Francesco Bolinesi[1], Luciano Ferrara[2], Michele Arienzo[3] and Olga Mangoni[1*]

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***Correspondence:** olga.mangoni@unina.it https://orcid.org/0000-0001-7789-0820

Affiliations:
1 Department of Biology University of Naples Federico II, Naples, Italy
2 Department of Chemical Sciences, University of Naples Federico II. Naples, Italy
3 Department of Earth Sciences, Environment and Resources, University of Naples Federico II, Naples, Italy

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Abstract

The phytoplankton community structure of the terminal stretches of the Sele river, one of the most important rivers of the southern Tyrrhenian coast of Italy, was investigated. Main functional groups and total biomass were determined from samples collected in proximity of drainage channels and under a period of severe drought. The overall sampling area was characterized by a strong vertical stratification driven by intrusion of seawater, with large hypoxic or anoxic areas near the bottom. High concentrations of Chl-a up to 95.73 µg/l were observed in the surface water layer (0.1-1.0 m depth) characterized by oxygen oversaturated waters. Cryptophytes and diatoms were the dominant groups, but high variability of minor groups was observed among stations. Results highlighted critical ecological conditions suggesting the need for further studies to cope with the high variability of such a complex system, particularly the utilization of more appropriate sampling scales.

Keyword: Eutrophication, phytoplankton, chemotaxonomy, biodiversity, river ecosystem

Riassunto

In questo studio è stata analizzata la struttura della comunità fitoplanctonica, in termini di gruppi funzionali principali e di biomassa totale, nel tratto terminale del Sele, uno dei fiumi più importanti della costa meridionale italiana, durante un periodo di grave siccità. I punti di campionamento sono stati posizionati nei pressi dei canali di drenaggio che affluiscono nel fiume. Complessivamente, l'area di campionamento è stata caratterizzata da una forte stratificazione verticale indotta dall'intrusione di acqua di mare sul fondo, dove sono state riscontrate ampie zone ipossiche o anossiche. Sono state riportate concentrazioni di Chl-a elevate, fino a 95,73 μg/l, e lo strato di acqua superficiale compreso tra 0,1 ed 1,0 m di profondità era caratterizzato da acque soprasature di ossigeno. Criptofite e diatomee erano i gruppi dominanti, ma è stata osservata un'elevata variabilità dei gruppi funzionali minori tra le stazioni. I risultati suggeriscono la presenza di punti critici nel tratto finale del fiume Sele, ed è quindi importante approfondire con ulteriori studi le dinamiche ecologiche di questo sistema complesso, sulla base di scale di campionamento adeguate.

Parole chiave: Eutrofizzazione, fitoplancton, chemotassonomia, biodiversità, ecosistema fluviale

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Introduction

Sele river is the second largest river in southern Italy in terms of average water volume, second to Volturno. Its lower part is located within a wide alluvial coastal plain, with a drainage basin of 3235 km^2 and a solid flow of 500,000 m^3/yr (Cocco et al., 1989). This territory has a relevant interest from the point of view of the interaction between natural and anthropic dynamics, to such an extent that allows to this relationship as a paradigmatic example of the interaction between natural dynamics and a cultural niche. In particular, it must be highlighted a territorial feature which is not unique to the Piana del Sele, but it is present in several other Mediterranean coastal context, that is to show dynamics that range from the regional scale to the entire Mediterranean basin in terms of anthropic history. The history of the human presence in the Piana del Sele is well documented since the Eneolithic and went on with more or less relevant events to the present day. The literature regarding the anthropic settlement in the Piana del Sele and the more relevant aspects of the evolution of its natural features are reported in a rich series of paper leaving both with the settlement history (Ferrara & Greco, 2017) and the morphological evolution of its physical features (Alberico et al., 2012). As for more recent times, starting from the mid-nineteenth century, it has undergone intense agricultural exploitation up to the current levels of over-exploitation. Along with the agriculture, a zootechnical activity was carried out based on the water buffalo, since middle age. In this general frame, it has to be mentioned the relevance of both natural and artificial drainage structures, all leading to the river Sele. The point in which these channels reach the river were the object of the present paper. The construction of a dense net of artificial drainage channels and the presence of the Dam of Persano strongly influenced both the coastal erosion and the river environment (Alberico et al., 2012; Arienzo et al., 2020). The Dam of Persano is located 16.2 linear km from the river mouth, and was built between 1929 and 1932, creating a basin of 1.5 million m^3 which affects the downstream sediment deposition causing the consequent retreat of the coast (https://www.bonificadestrasele.it/site/wp-content/uploads/2017/12/Relazione-Diga.pdf).

The significant geomorphological alteration of Sele mouth and the presence of pollutants has been documented recently by Arienzo et al. (2020) with conspicuous loads of organic matter deriving from anthropogenic activities over the entire system. One of the most important effects of pollutants on rivers ecosystems is a net increases in primary production processes, including an excessive growth of phytoplankton biomass, as a result of nutrient supply (mainly phosphorus and nitrogen). The impact of nutrient enrichment on rivers is often season specific and complicated by their dynamic nature (Newman et al., 2005). Rivers are highly selective environments, where flow rate and turbidity are the two critical factors limiting the development of phytoplankton communities so that only a relatively small number of genera can achieve dominance (Rojo et al., 1994; Reynolds 1994a). One of the reasons why phytoplankton represents a significant component of primary production only in slow-moving rivers of lowland regions, is that the retention time of water is longer than the generation time of the plankton (Lampert & Sommer, 1997). The dominance of centric diatoms and coccal green algae in lowland regions has been explained by Reynolds et al., (1994a), as a consequence of the dynamics of vertical mixing of a turbid and turbulent water column, that selects species with the appropriate traits (Reynolds & Descy, 1996; Gray 1989).

Due to the lack of information on the phytoplankton community of the river waters, a study was carried out along its terminal stretch (the final 3 km) in order to contribute to fill these gaps. The relationship between phytoplankton and biomass with water chemical and physical properties was evaluated in proximity of the confluence of several drainage channels during a period of severe drought when the river mouth appeared completely occluded by sediment deposition impeding any water exchange with the open sea.

Material and Methods

A one day sampling was carried out on July 31, 2017 in the Sele river, in proximity of drainage channels in the first 3 km from the mouth. A total of 9 stations were sampled, from the mouth to the inner part of the river (Fig. 1; Tab. 1), for the determination of phytoplankton biomass, main functional groups and physical and chemical properties of the water. Salinity, temperature (°C), and saturation percentage of dissolved oxygen (%) profiles were acquired by an Idromar XMAR212 probe interfaced with a GPS (Garmin Map 78S). In order to assess the phytoplankton biomass and diversity in terms of chemotaxonomical groups, at each station (except stations 1, 3 and 6) 2 l of surface water were collected with a Niskin bottle for pigment spectra determination. One litre of water was then drawn from the Niskin and filtered on GF/F Whatman filters (25-mm diameters and 47-mm) for spectrofluorimetric and HPLC analyses (Vidussi et al.,1996; Mangoni et al., 2016). Filters were stored in -20°C until the analyses in laboratory. The amount of chlorophyll-a (Chl-a) was used to indicate the total phytoplankton biomass, while the contribution of the main phytoplankton groups to the total Chl-a was estimated on the basis of the concentrations of biomarker pigments, using the CHEMTAX software as indicated by Mangoni et al., (2008).

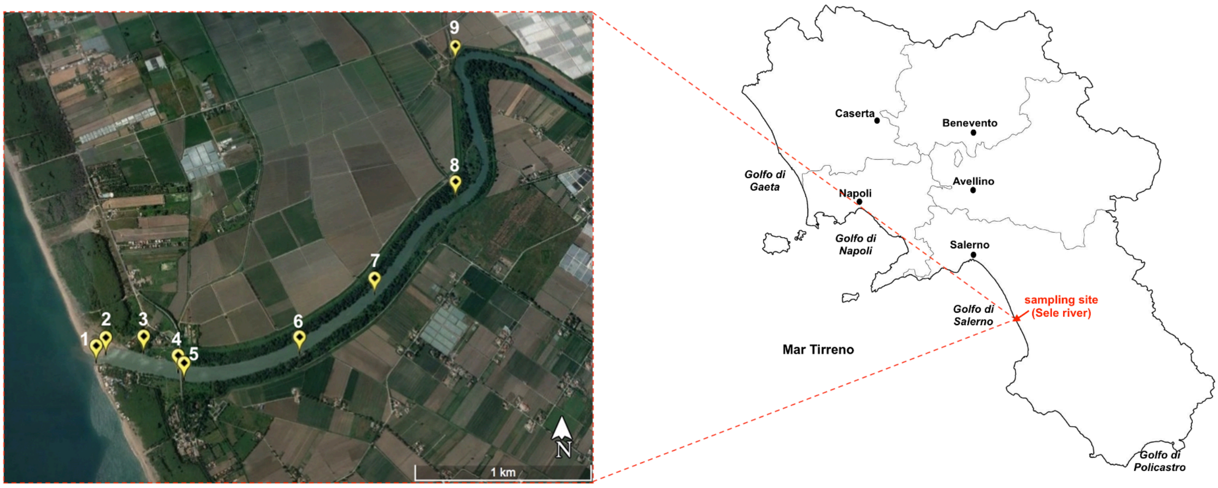

Figure 1: The terminal stretch (final 3 km) of the Sele river, with sampled stations (yellow mark).

Table 1: Sampled stations and related coordinates.

Station	Latitude N	Longitude E
1	14,943003	40,481503
2	14,943663	40,481942
3	14,946342	40,482025
4	14,948773	40,481002
5	14,949187	40,480607
6	14,957369	40,482022
7	14,963108	40,485324
8	14,970075	40,491178
9	14,971769	40,500494

Results

Fig. 2 displays the vertical and longitudinal distributions of salinity, temperature, and saturation percentage of dissolved oxygen. The distribution of salinity shows the presence of a strong water stratification, with a net halocline between 1.5 and 2 m depth, except at station 8, and at the mouth of the river where tidal movements exerted a strong influence (Fig. 2a). The first 1.5 m

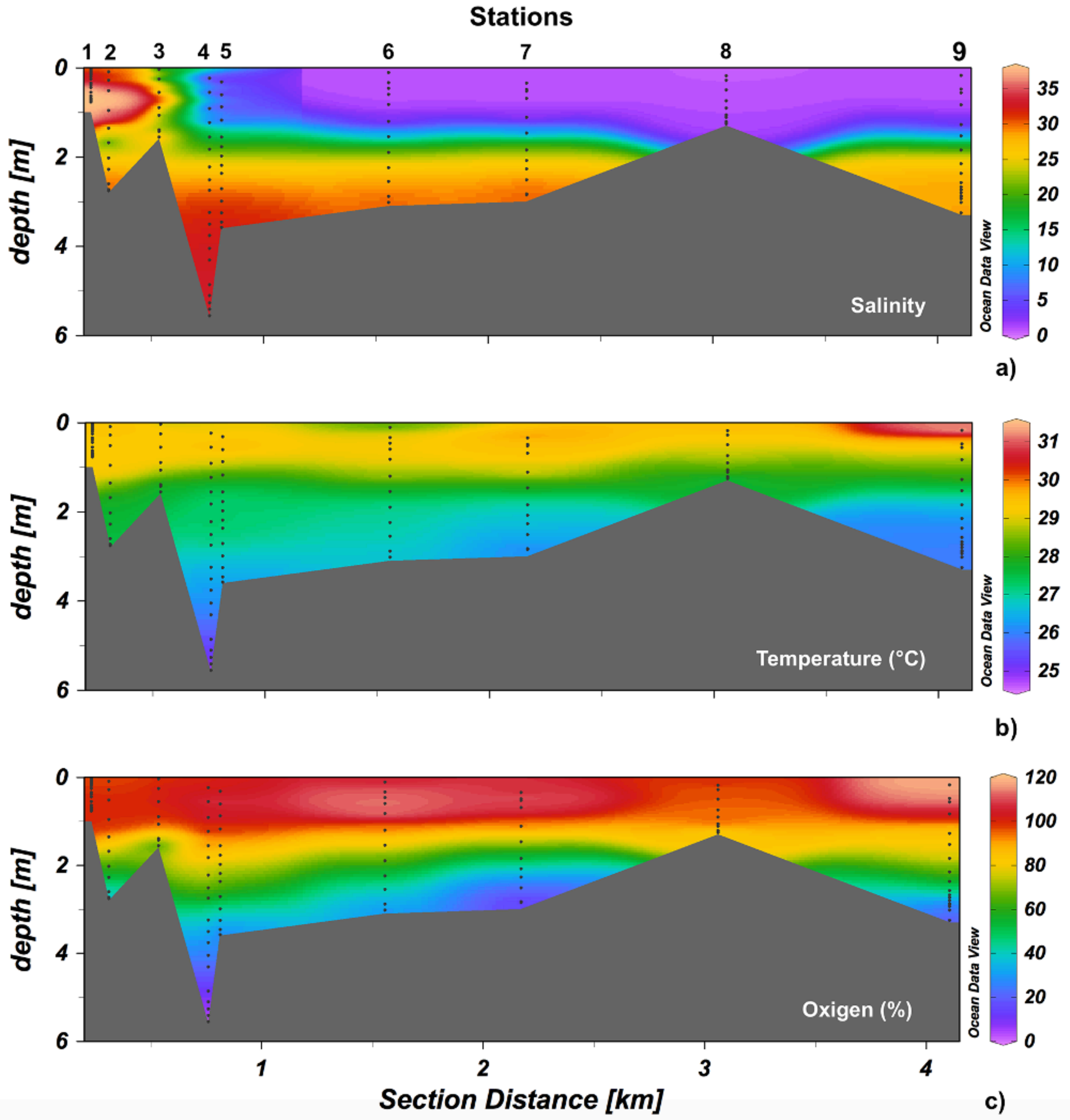

Figure 2: Vertical and longitudinal distributions of: a) salinity, b) temperature, and c) percentage of dissolved oxygen. The colour on the Z axis indicates the range of variability of each variable.

water layer between stations 3 and 9 was characterized by freshwater with values ranging from 1.5 to 8; below this water depth, salinity strongly increased forming a sharp halocline (~0.3 m thickness) with 15-20 units higher than the mean level of the surface layers. Except for station 8, the bottom layer was characterized by the presence of salty water. Within this stratified structure, the observations reveal the presence of a clear increasing gradient of salinity from the inner part toward the mouth and from the surface to the river bed, with higher values between stations 1 and 2 (about 100 m apart) as a consequence of tidal inflow. The temperature trend was similar at all stations with values slightly decreasing from the surface to the bottom and ranging from a minimum of 24.59 at station 4 (5.5 m) to a maximum of 31.34°C at station 9 (0 m) (Fig. 2b). The saturation percentage of dissolved oxygen showed the presence of three distinct layers: a 0- 1.0 m layer characterized by oversaturated oxygen conditions and up to 117% at station 9, located in the inner part of the sampling area (Fig. 2c); a 1.0-2.5 m layer characterized by a strong gradient, with values from 100% at 1.0 m to 65% at 2.0 m; a layer below 2.5 m depth characterized by severe oxygen depletion, especially at the deeper stations, with values reaching the minimum of 1.5% at station 4.

The mean value of Chl-a was 62.72 µg/l, with values ranging from 15.05 µg/l at station 2 to 95.73 µg/l at station 8, showing higher values in the inner part of the river (Fig. 3). Chemotaxonomic composition revealed that diatoms and cryptophytes were the dominant functional groups, with the former dominating at stations 4, 7, 8 and 9, and the latter at stations 2, 5, and 8 (Fig. 4). The presence and abundance of other groups strongly differing among stations.

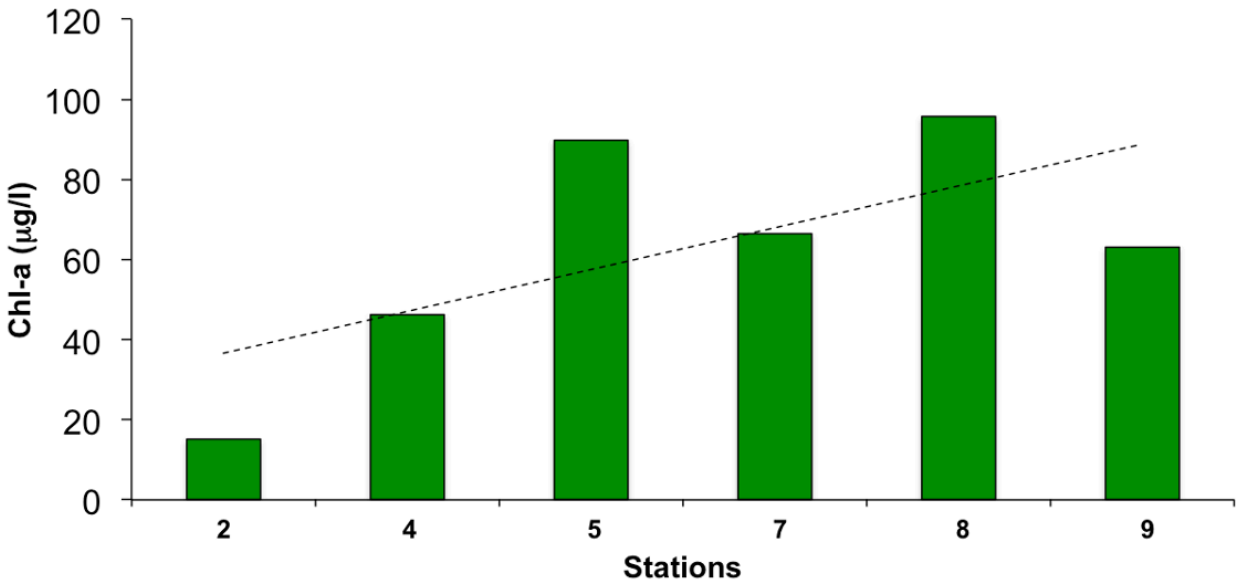

Figure 3: Phytoplankton total biomass (Chl-a, µg/l) at each sampled station, with related regression line (black points). For technical problems, some data stations were not considered for the elaborations.

Rapidophytes were completely absent at station 4, cyanophytes were only present at station 2 and xantophytes were only present at station 8 and 2. Dinoflagellates were absent at stations 8 and 2, while prasinophytes were only present at stations 4, 5 and 7.

Discussion

Phytoplankton is commonly used as an ecological indicator in the assessment of anthropic impact on freshwater environments since phytoplankton blooms are usually the result of excessive nutrient loading and extended water residence time induced by the artificial flow control (Paerl et al., 2007; Reynolds, 2003; Waylett et al., 2013). Not surprisingly, the study of phytoplankton in rivers is a required quality element in the WFD (Directive 2000/60/EC of the European Parliament and of the Council) establishing a framework for the Community action in the field of water policy.

Although the presence of human settlements on the Sele river date back to the second millennium B.C. (Bronze Age), a significant anthropic influence on the evolution of the area started around the middle of 19th century with the construction of a first set of artificial drainage and irrigation channels, that have allowed the development of intensive agricultural and livestock sectors. The presence of a stratification characterized by a salty and

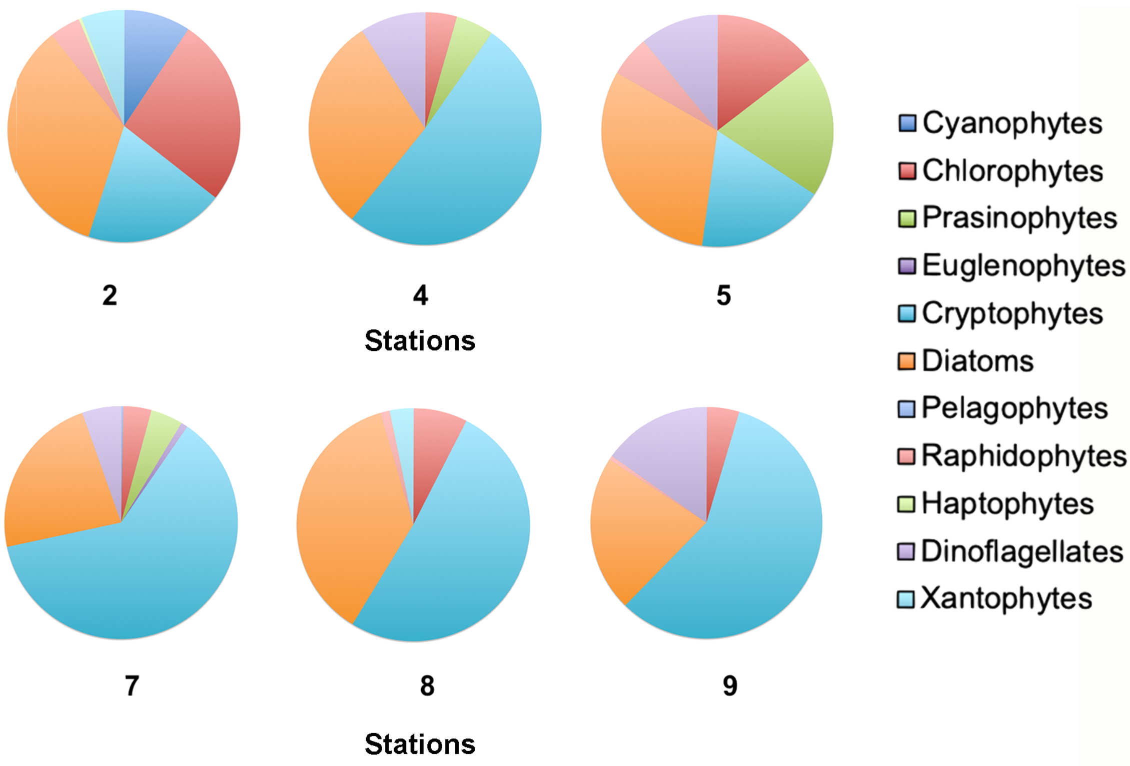

Figure 4: Phytoplankton total biomass (Chl-a, µg/l) at each sampled station, with related regression line (black points). For technical problems, some data stations were not considered for the elaborations.

dense layer of sea waters at the bottom represents an important physical and chemical barrier affecting the functioning of this system. Our sampling was carried out when the mouth of the river was completely occluded by sediments (Fig. 5) preventing an exchange with the sea and strongly contributing to the development of the eutrophic status of the river, as an effect of the ensuing the water retention time and preventing the enlivening of the river deeper waters. This feature is absent at stations 1 and 2 due to the interstitial inflow through the sandbar. The mean value of phytoplankton biomass was high with a mean of 62.72 (±27) µg/l over the entire sampled stretch. This, together with the presence of anoxic conditions in deeper layer represent critical conditions for the benthic assemblages, that otherwise, could be potentially involved in algal removal by filtering or grazing activities (Newman et al., 2005). The observed large variability of the main functional groups over a limited space indicated that drainage channels could significantly contribute to shape the phytoplankton community. The dominance of diatoms agrees with data reported in literature (Reynolds & Descy, 1996; Genkal 1997), but the high percentage of cryptophytes represents a novel observation. The lack of information on the Sele river ecosystem, and the limited number of stations analyzed, does not allow an exhaustive interpretation of phytoplankton community structure and dynamics in such a

Figure 5: July 31, 2017. The mouth of the Sele river occluded by sediments.

complex ecosystem. However, our data clearly suggest the presence of a high heterogeneity in terms of physical-chemical and biological properties of waters, mainly due to strong anthropogenic pressures (Arienzo et al., 2020). Although it is not possible at the moment to interpret the data in a coherent overall picture, they nevertheless constitute a significant starting point to improve our knowledge on the environmental status this area. Further research has been planned in order to define the temporal and spatial dynamics of phytoplankton community. To this end, it is necessary to use appropriate temporal and spatial scales of investigation in order to frame the system in relation to human pressures (Reynolds 1994b) and, considering that the management of large rivers requires a balance between human needs and ecological integrity. As the Sele River plays a central role not only in biodiversity but also in the economy and culture of its catchment area, the deepening of the knowledge of its environmental conditions, of the origins of the criticalities observed in view of a recovery plan for this transitional environment is now an avant-garde objective on which the authors intend to pursue.

In conclusion the relevant aspects of this preliminary study can be represented by 1) the confirm diatoms as the main component of river phytoplankton; 2) the significant presence, in our case, in the composition of the community of other groups, such as cryptophytes; 3) the temporal limitation of our sampling period; 4) the physiognomy of the river phytoplankton community represents a firs reference point to the evolution of the community following regimes of higher discharge by the river in the annual hydrographic cycle.

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Author contributions

Conceptualization: F.B, O.M., L.F., M.A. Data curation: F.B, O.M. Formal analysis: F.B, O.M. Investigation: F.B., L.F. Methodology: F.B, O.M. Resources: O.M. Writing – original draft: F.B., L.F., M.A., O.M. Writing – final draft preparation: F.B., L.F., M.A., O.M.

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