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A review of the phytoplankton in south Moroccan Atlantic waters

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Abstract

A review of the taxonomic composition of phytoplankton in coastal waters of the south Moroccan Atlantic coast was undertaken to consolidate our understanding of the ecology of these organisms in the region. The study is based on the analysis of phytoplankton between 2002 and 2014 in Three sites: Imessouane bay, Agadir bay and Shoreline Aglou-Sidi Ifni. A total of 283 species of phytoplankton belonging to two groups, diatoms (161 species) and dinoflagellates (122 species) were reported from all study sites. The maximum number of taxa (215) was observed in the bay of Agadir. The results show there is a clear dominance of diatoms, followed by dinoflagellates in all stations. The presence of potentially harmful species was detected in all selected sites, these mainly belong to the genera (*Pseudo-nitzschia*, *Dinophysis*, *Prorocentrum*, *Gymnodinium*, *Lingulodinium* and *Alexandrium*). This reflects the importance of regular coastal surveillance to protect the consumer of fishery products in the event of possible contamination.

Keywords: Phytoplankton, Moroccan Atlantic coast; *diatoms*; *dinoflagellates*.

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1. Introduction

The Moroccan Atlantic coast is subject to the influence of coastal upwelling which is at the origin of the nutrient enrichment of the area [1]. These resources promote the growth of phytoplankton populations. Consequently, this zone is characterized by a very important fishery wealth [2].

Phytoplankton, the primary producers of the marine environment, is a key element in understanding the dynamics of the food web in an ecosystem [3]. Their close coupling with the environment and their short generation time would allow us to discern the patterns of their response and recovery to environmental disturbances more easily than higher organisms far from harvestable in the food chain.

The present review aims to (i) present an account on the constituents of the phytoplankton in The Moroccan Atlantic coast, (ii) identify potential toxic species recorded from these waters and (iii) to make comparisons of phytoplankton diversity between sites with different hydrological conditions.

2. Materials and methods

This study is based on the analysis of phytoplankton between 2002 and 2014 by the authors [4-6]. The three sites studied are located on the Atlantic coast and are subject to a Mediterranean climate characterized by mild winters and hot summers.

- Imessouane site (30 ° 50 ’N, 9 ° 49’ W): An area known worldwide for the astonishing beauty of its beach, tourism represents an important sector of activity in this site (nautical and aquatic sports). Imessouane Bay has an artisanal fishing port [7].
- Agadir site: Three stations bordering the bay of Agadir were selected: Cap Ghir, Tifnit and Sidi Rbat were selected. These are sites rich in natural deposits of mussels Mytilus galloprovincialis and Perna perna, and which receive a fluvial input during the wet season. Cape Ghir station (30 ° 37 ’N, 09 ° 50’ W) is distinguished by a significant manifestation of upwellings, especially in summer. Tifnit station (30 ° 12 ’N, 09 ° 37'60’ ’W) and Sidi Rbat station (30 ° 05’ N, 09 ° 40 ’W) are located in a tourist and artisanal fishing area.
- The Aglou-Sidi Ifni coastline (29° 46′ 30″ N, 9° 52′ 01″) is characterized by significant fishery richness and a natural deposit of mussels and is home to one of the three first pilot marine protected areas in Morocco. It is the Massa Marine Protected Area (AMP-Massa). This coastline of the Guelmim-Oued Noun region belongs to the arid bioclimatic stage. Over the last 20 years, this region has experienced a disruption of seasonal rainfall and a clear warming trend of around 0.7 °C [8].

The water samples were collected in the subsurface in selected stations, with a weekly to monthly frequency, preserved in formalin and examined under inverted microscopy according to the

sedimentation method [9].

3. Results and discussion

3.1. Taxonomic composition

Diatoms and dinoflagellates constitute the main groups of phytoplankton in the three sites studied. This is the case in other coastal marine ecosystems of the Moroccan Atlantic coast [10-11].

Phytoplankton identified in Imessouane Bay comprised a total of 74 species (51 Diatoms, 23 Dinoflagellates) **(Table 1)**. Diatoms formed the most dominant taxa and contributed to the total population, they represent over 70% of total species **(Figure 1).**

In Agadir Bay, the total specific richness of phytoplankton is made up of 4 groups dominated by diatoms with 110 taxa followed by dinoflagellates with 100 taxa. The species belonging to the sillicoflagellates and coccolithophorids represent only 2% of the total listed species **(Figure 1).**

In Aglou Sidi-Ifni Coastline, 110 species have been recorded. the identified dinoflagellates are composed of 46 taxa and the diatoms are composed of 60 taxa. The silicoflagellates are represented by 4 species while the coccolithophorids are represented by only one species **(Table 1 and Figure 1).**

Table 1. Phytoplankton taxa recorded in Imessouane Bay, Agadir Bay and Shoreline Aglou-Sidi Ifni (A: Diatoms; B: Dinoflagellates; C: Silicoflagellates; D: Coccolitophoridae; E: Raphidophyceae).

-A-			
Species/Taxa	Aglou	Imessouane	Agadir
Amphisolenia inflata	+	-	-
Apodinium mycetoides	+	-	-
Aulacodiscus kittonii	-	+	-
Bacillari paradoxa	-	+	-
Bacteria strumhyalinum	-	+	-
Biddulphia mobiliensis	+	-	-
Chaetoceros peruvianus	-	+	-
Chaetoceros wighamii	-	+	-
Chattonella antiqua	-	+	-
Climaconeis lorenzii	-	+	-
Corethron sp	-	+	-
Coscinodiscus wailesii	-	+	-
Cylindrotheca closterium	-	+	-
Detonula pumila	-	+	-
Diploneis bombus	-	+	-

Eucampia sp	+	-	-
Fragilaria oceanica	+	-	-
Grammatophora marina	-	+	-
Guinardia sp	+	+	-
Helicotheca sp	-	+	-
Hemidiscus cuneiformis	+	-	-
Leptocylindricus sp	+	-	-
Licmophora abbreviata	-	+	-
Lithodesmium undulatum	-	+	-
Melosira granulata	+	-	-
Melosira moniliformis	+	+	-
Melosira sp	+	-	-
Melosira varians	+	-	-
Navicula cryptocephala	+	-	-
Navicula distans	-	+	-
Navicula menisculus	+	-	-
Navicula seriata	+	-	-
Neocalyptrella robusta	-	+	-
Nitzschia bilobata	+	-	-
Nitzschia seriata	+	-	-
Odontella sp	+	+	-
Pleurosigma sp	-	+	-
Pseudo nitzschia australis	+	-	-
Pseudo-nitzschia multseries	+	-	-
pseudo-nitzschia pungens	+	-	-
Rhizosolenia bergonii	-	+	-
Rhizosolenia calcar	+	-	-
Rhizosolenia imbricata	-	+	-
Rhizosolenia semispina	+	-	-
Schroederella delicatula	+	-	-
Skeletonema sp	+	-	-
Striatella agardh interrupta	+	-	-
Striatella sp	+	-	-
Surirella sp	-	+	-
T. nitzschioide	-	+	-
Thalassionema sp	+	-	-
Trachysphenia australis	-	+	-
Achnanthes brevipes	-	-	+
Actinoptychus sp.	-	-	+
Amphora egregia	-	-	+
Amphora sp.	-	-	+
Anaulus creticus	-	-	+

Asterionella japonica	-	-	+
Asterionellopsis glacialis	-	-	+
Asteromphalus sp.	-	-	+
Biddulphia alternans	+	-	+
Biddulphia pulchella	+	-	+
Biddulphia sp.	-	-	+
Biddulphia tuomeyi	-	-	+
Cerataulina dentata	-	+	+
Cerataulina pelagica	+	-	+
Chaetoceros affinis	-	-	+
Chaetoceros atlanticus	-	+	+
Chaetoceros cf. brevis	-	-	+
Chaetoceros constrictus	-	+	+
Chaetoceros costatus	-	-	+
Chaetoceros curvisetus	-	+	+
Chaetoceros danicus	-	+	+
Chaetoceros decipiens	+	+	+
Chaetoceros diadema	-	-	+
Chaetoceros didymus	-	+	+
Chaetoceros gracilis	-	-	+
Chaetoceros lacinosus	+	-	+
Chaetoceros lauderi	-	-	+
Chaetoceros lorenzianus	-	+	+
Chaetoceros mitra	-	-	+
Chaetoceros socialis	-	-	+
Chaetoceros sp	-	+	+
Chaetoceros teres	-	-	+
Chaetoceros tortissimus	+	-	+
Climacosphenia moniligera	-	-	+
Cocconeis sp.	-	-	+
Corethron criophilum	-	-	+
Coscinodiscus granii	+	+	+
Coscinodiscus jonesianus	-	-	+
Coscinodiscus radiatus	+	-	+
Coscinodiscus sp	+	+	+
Dactyliosolen blavyanus	-	-	+
Dactyliosolen fragilissimus	-	-	+
Detonula confervacea	-	-	+
Diploneis sp.	-	-	+
Ditylium sp.	-	-	+
Eucampia zodiacus	+	-	+
Fragilaria striatula	-	-	+

Grammatophora sp.	-	-	+
Guinardia delicatula	+	-	+
Guinardia flaccida	-	-	+
Guinardia striata	+	+	+
Guinardia striata	-	-	+
Gyrosigma sp.	-	-	+
Hemiaulus sinensis	-	-	+
Hemidiscus sp	+	-	+
Lauderia annulata	+	+	+
Lauderia borealis	+	+	+
Leptocylindricus danicus	+	+	+
Leptocylindrus minimus	-	+	+
Licmophora gracile	-	-	+
Licmophora sp	+	+	+
Lyrella sp.	-	-	+
Mastogloia achnanthioides	-	-	+
Mastogloia grana	-	-	+
Melosira nummuloides	-	-	+
Melosira sulcata	+	-	+
Navicula agnet	-	-	+
Navicula elegans	-	-	+
Navicula sp	+	-	+
Nitzschia closterium	+	-	+
Nitzschia longissima	-	-	+
Nitzschia sp	+	-	+
Odontella mobiliensis	-	+	+
Odontella regia	-	-	+
Odontella sinensis	-	-	+
Paralia sulcata	-	+	+
Pleurosigma directum	+	+	+
Pleurosigma normanii	-	-	+
Pseudo-nitzschia delicatissima	+	-	+
Pseudo-nitzschia seriata	-	-	+
Pseudo-nitzschia sp	+	+	+
Rhizosolenia alata	-	+	+
Rhizosolenia delicatula	-	-	+
Rhizosolenia fragilissima	-	-	+
Rhizosolenia hebetata	-	-	+
Rhizosolenia pungens	-	-	+
Rhizosolenia robusta	-	-	+
Rhizosolenia setigera	-	-	+
Rhizosolenia sp	+	+	+

Rhizosolenia stolterforthii	-	-	+
Rhizosolenia styliformis	+	-	+
Rhizosolenia temperei	-	-	+
Schroederella schroederi	-	-	+
Skeletonema costatum	+	-	+
Stephanopyxis sp	+	-	+
Streptotheca thamensis	-	-	+
Striatella unipunctata	+	-	+
Surirella fastuosa	-	-	+
Tabellaria fenestrate	-	-	+
Thalassionema frauenfeldii	-	-	+
Thalassionema nitzschioides	-	-	+
Thalassiosira decipiens	+	-	+
Thalassiosira delicatula	-	-	+
Thalassiosira rotula	-	-	+
Thalassiosira sp	+	-	+
Thalassiothrix sp.	-	-	+
Triceratium alternans	-	-	+
Triceratium sp.	-	+	+
Trigonium formosum	-	-	+

-B-			
Species/Taxa	Aglou	Imessouane	Agadir
Alexandrium affine	+	-	-
Alexandrium catenella	-	+	-
Alexandrium minutum	-	-	+
Alexandrium sp	+	-	+
Amphidinium sp.	-	-	+
Amylax diacantha	-	-	+
Blepharocysta sp.	-	-	+
Ceratium breve	-	-	+
Ceratium candelabrum	-	+	+
Ceratium compressum	-	-	+
Ceratium furca	+	+	+
Ceratium fusus	+	+	+
Ceratium gravidum	-	+	-
Ceratium horridum	-	-	+
Ceratium humile	-	-	+
Ceratium inflatum	-	-	+
Ceratium kofoidii	-	-	+
Ceratium lineatum	+	+	+

Ceratium longirostrum	-	-	+
Ceratium lunula	-	-	+
Ceratium macroceros	+	+	+
Ceratium pentagonum	+	+	+
Ceratium sp	+	-	+
Ceratium teres	-	-	+
Ceratium tripos	+	+	+
Corythodinium constrictum	-	-	+
Dinophysis acuminata	+	+	+
Dinophysis acuta	+	-	+
Dinophysis caudata	+	+	+
Dinophysis fortii	-	-	+
Dinophysis norvegica	-	-	+
Dinophysis rotundata	+	-	+
Dinophysis sacculus	+	-	+
Dinophysis tripos	-	-	+
Diplopelta parva	-	-	+
Diplopsalis lenticula	-	-	+
Ensiculifera sp.	-	-	+
Exuviella compressa	+	-	-
Exuviella marina	+	-	-
Goniodoma sp.	-	-	+
Gonyaulax birostris	-	+	-
Gonyaulax diacantha	-	-	+
Gonyaulax diegensis	-	-	+
Gonyaulax digitale	-	-	+
Gonyaulax polyedra	+	-	-
Gonyaulax polygramma	+	-	+
Gonyaulax sp.	-	-	+
Gonyaulax spinifera	+	-	+
Gonyaulax tamarensis	-	-	+
Gonyaulax triacantha	-	-	+
Gymnodinium catenatum	-	-	+
Gymnodinium mikimotoi	+	-	+
Gymnodium sp	+	+	+
Gyrodinium spirale	-	-	+
Heterocapsa circularisquama	+	-	-
Heterocapsa niei	-	-	+
Heterocapsa sp.	-	-	+
Heterocapsa triquetra	-	-	+
Katodinium sp.	-	-	+
Lingulodinium polyedrum	+	-	+

Lingulodinium sp	+	-	-
Micracanthodinium setiferum	-	-	+
Noctiluca scintillans	+	-	-
Oblea sp.	-	-	+
Ornithocercus sp.	-	-	+
Ostreopsis lenticularis	-	-	+
Ostreopsis sp	+	-	+
Oxytoxum caudatum	-	-	+
Oxytoxum crassum	-	-	+
Oxytoxum gracile	-	-	+
Oxytoxum scolopax	-	-	+
Pentapharsodinium sp.	-	-	+
Peridiniella sp	+	-	+
Peridinium diabolus	+	-	-
Peridinium grani	-	+	-
Phalacroma mitra	-		+
Phalacroma rotundatum	+	-	-
Phalacroma sp	+	-	+
Plectodinium nucleovolvatum	+	-	-
Polykrikos sp.	-	-	+
Prorocentrum balticum	-	-	+
Prorocentrum compressum	-	-	+
Prorocentrum dentatum	-	-	+
Prorocentrum gracile	-	-	+
Prorocentrum lima	-	-	+
Prorocentrum micans	+	+	+
Prorocentrum minimum	-	-	+
Prorocentrum rostratum	-	-	+
Prorocentrum scutellum	-	-	+
Prorocentrum sigmoides	+	-	-
Prorocentrum sp	+	-	-
Prorocentrum triestinum	+	-	+
Protoceratium sp	+	-	-
Protoperidinium caudatum	+	+	-
Protoperidinium conicoides	+	-	-
Protoperidinium conicum	-	-	+
Protoperidinium curvipes	-	-	+
Protoperidinium denticulatum	-	-	+
Protoperidinium depressum	-	+	+
Protoperidinium diabolum	+	+	-
protoperidinium divergens	+	+	+
Protoperidinium excentricum	-	-	+

Protoperidinium globulum	-	-	+
Protoperidinium hirobis	-	-	+
Protoperidinium islandicum	-	-	+
Protoperidinium minutum	-	-	+
Protoperidinium mite	-	-	+
Protoperidinium oceanicum	-	-	+
Protoperidinium pentagonum	-	-	+
Protoperidinium pyriforme	+	-	-
Protoperidinium quarnerense	-	-	+
Protoperidinium sp	+	-	+
Protoperidinium steinii	-	-	+
Protoperidinium thorianum	-	-	+
Ptychodiscus inflatus	+	-	-
Pyrocystis lunula	-	-	+
Pyrocystis pseudonoctiluca	+	-	-
Pyrophacus sp	-	+	+
Scrippsiella sp	+	-	+
Scrippsiella trochoidea	+	+	+
Torodinium robustum	-	-	+
Torodinium sp.	-	-	+

-C-			
Species/Taxa	Aglou	Imessouane	Agadir
Dictyocha crux	-	-	+
Dictyocha fibula	-	-	+
Dictyocha octonaria	+	-	+
Dictyocha speculum	-	-	+

-D-			
Species/Taxa	Aglou	Imessouane	Agadir
Calyptrosphaera globosa	+	-	-
Syracosphaera sp.	+	-	+

-E-			
Species/Taxa	Aglou	Imessouane	Agadir
Fibrocapsa japonica	+	-	-

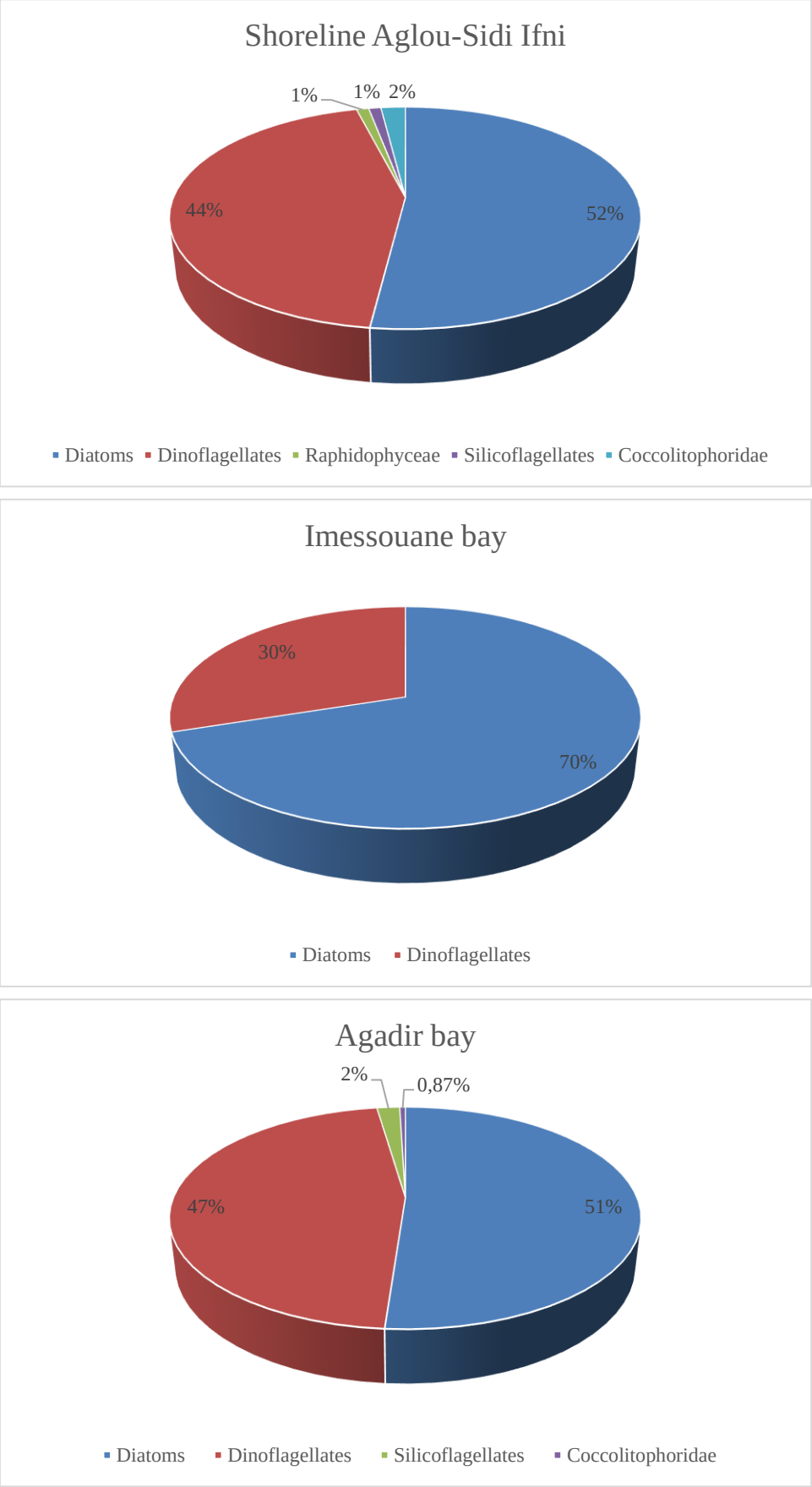

Fig 1. Proportion of phytoplankton groups identified in the studied areas

The maximum number of taxa (215) was observed in the bay of Agadir. This richness may be related to the enrichment of the area in nitrogen and phosphate matter, resulting from the leaching of agricultural land in the watershed in winter and by the upwelling process in summer. this phenomenon constitutes a source of food for the area which results in a significant specific richness of phytoplankton [5]. A comparison in total numbers of phytoplankton species between the three sites mentioned in this review and different coastal waters of Morocco is given in **Table 2.**

In the present study, diatoms were generally dominant at almost all the sites. Natij et al. (2014) [12] also observed the predominance of diatoms followed by dinoflagellates during their study on phytoplankton community in Oualidia lagoon (south Moroccan Atlantic). This agrees with the results of [3,10].

Sites	Number of species	Periods	References
Maritime area of Aglou	89	April 2013-June2013	[13]
Bay of Imessouane	74	May 2009-july 2009	[4]
Bay of Agadir	215	Sept 2002-Sept 2003	[5]
Bou Regreg estuary	307	Mar 1999-Mar 2001	[14]
Massa estuary	105	Mar 2009-Mar 2010	[15]
Moulay bousselham lagoon	35	Oct 2003-Sep 2004	[11]
Nador lagoon	311	Nov 2007-Aug 2008	[16]
Oualidia lagoon	127	June 2011-May2012	[12]
Areas of the Moroccan Atlantic coast localized between 32°30'N and 24°N	142	January 2002-July 2002	[3]
Maritime area of Aglou	104	April 2014-June2014	[6]

3.2. Potential harmful species

The study of the phytoplankton community in the bay of Imessouane revealed the presence of certain potentially toxic or harmful species responsible for coloured waters. These species belong to different genera among which: the genus *Pseudo-nitzschia*, *Dinophysis*, *Prorocentrum* and *Alexandrium*, the species of these genera were detected several times during the study but always with low concentrations.

In the maritime area of Aglou, high densities of toxic species belonging to the genera *Alexandrium* and *Dinophysis* have been recorded. This coincides with alerts PSP (Paralytic Shellfish Poisoning)

and DSP (diarrheic shellfish poisoning) reported during the study period, National Fisheries Research Institute (INRH) in its health surveillance system for shellfish production areas. (2015).

In Agadir bay, several toxic species have been observed: *Alexandrium minutum* has been observed in the spring at all stations around Agadir Bay. Toxic blooms due to the presence of *Dinophysis cf. acuminata* accompanying the colored waters appeared in September in Tifnit and Sidi Rbat. A proliferation of *Gymnodinium mikimotoi* and *Prorocentrum micans*, and *Lingulodinium polyedrum* in October at Cap Ghir. An exceptional proliferation, from *Dinophysis* cf. *acuminata* was detected in winter.

These harmful phytoplankton species were also recorded in several coastal waters of Morocco: Tahri Joutei [17] observed high concentrations of *Alexandrium minutum* at Oued Laou in the Moroccan Mediterranean. Bennouna et al. [18] reported the presence of *Alexandrium spp*. in the lagoon of Oualidia (Atlantic coast). Akallal et al. [19] mentioned the presence of *A. tamarense* in small quantities between Moulay Bousselham and Témara.

Gymnodinium catenatum was also observed in Oued Laou by Tahri Joutei [17]. Akallal et al. [19] reported the existence of *Gymnodium catenatum* in low quantities between Moulay Bousselham and Témara. Barbara-Sanchez and Gamboa-Maruez [20] observed the presence of *Gymnodinium catenatum* annually along the coasts of Sucre State (Venezuela).

Akallal et al. [21] reported the presence of *Lingulodinium polyedrum* in spring in reduced quantities in the coastline between Mehdia and Témara. Lassus et al. [22] reported a toxic bloom caused by this species in summer in the coasts of Antifer in France. Poletti et al. [23] reported maximum abundances of this species throughout the Adriatic coast.

Conclusion

The main objective of this paper is to build a summary baseline for any further study of phytoplankton stands in the south Moroccan Atlantic. Determining the taxonomic composition of these primary producers, in fact, improves knowledge of the biodiversity of the marine ecosystem.

Phytoplankton of the three areas studied is composed in its majority of rare species, we note a dominance of diatoms over all the other classes of algae.

The highest number of species was recorded in the bay of Agadir, this is probably linked to the enrichment of the area in nitrogenous and phosphate materials, resulting from the leaching of agricultural land in the watershed.

The species capable of the three forms of nuisance, namely the secretion of toxins, the deoxygenation of the environment and the lesion of the gill tissues of fish, were observed in the three areas studied but at

different concentrations. These species belong to different genera among which: the genus *Pseudo-nitzschia, gymnodinium, Lingulodinium, Dinophysis, Prorocentrum* and *Alexandrium*. This highlights the importance of continuous surveillance of the coastline throughout the year to better protect the consumer of fishery products in the event of possible contamination.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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