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Harmful Algal Blooms (HABs) and Black Mussel *Mytilus galloprovincialis* (Linnaeus, 1758) Culture in Izmir Bay (Iskele-Urla)-Turkey: Preliminary Results on the Annual Feeding Cycle Using a Qualitative Approach

Aynur Lok[1,]*, Gülnur Metin[2], Sefa Acarli[3], Philippe Goulletquer[3]

[1] Ege University, Fisheries Faculty, Department of Aquaculture, 35100 Izmir, Turkey.
[2] Ege University, Fisheries Faculty, Department of Fisheries and Processing Technology, 35100 Izmir, Turkey.
[3] Canakkale Onsekiz Mart University, Gokceada School of Applied Sciences, Gökçeada, Çanakkale, Turkey.
[4] Centre IFREMER, Rue de l'Ile d'Yeu, BP 21105, 44311 Nantes Cedex 03, France.

* Corresponding Author: Tel.:+90.232 3111010; Fax: ;
E-mail: aynur.lok@ege.edu.tr

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Abstract

Considering the filtration capacity of mussels to qualitative particle selection, our study focused directly on ingested species by assessing mussel stomach content of various size classes (1-5 cm) over a year (August 97-June 98) rather than monitoring seawater samples. Different size of mussels (1, 2, 3, 4, 5 cm in length) was sampled monthly from the sides of fish cage floats in Urla-Izmir. Stomach contents were analyzed under microscope and different plankton species were grouped taxonomically. Bacillariophycea, Dinophyceae, Oxyphceae, Euglenophyceae as phytoplanktonic species were observed in the stomach contents of mussels as well as zooplanktonic species including Ciliata, Cladocera, Copepod, bivalve and gastropod larvae. Over the sampling period, according to the Bray-Curtis similarity test mussels' stomach for all sizes was of similar content except in August and October.

Keywords: Mussel, *Mytilus galloprovincialis*, harmful, phytoplankton, stomach content, Aegean Sea.

Zararlı Alg Patlamaları ve İzmir Körfezi'nde (İskele-Urla) Kara Midye *Mytilus galloprovincialis* (Linnaeus, 1758) Kültürü: Kalitatif Yaklaşımla Yıllık Beslenme Döngüsü Üzerine İlk Sonuçlar

Özet

Bu çalışma midyelerin filtrasyon kapasitesi dikkate alınarak partikül seleksiyonunun kalitatif belirlenmesi amacıyla yapılmıştır. Bu amaçla yıl boyunca su örneklemesi yapılmaksızın farklı boy gruplarındaki midyelerin mide içerikleri incelenerek tüketilmiş türler saptanmıştır. Farklı boy midyeler (1, 2, 3, 4, 5 cm) Urla-İzmir'deki balık kafeslerinin yüzdürücülerinden aylık olarak toplanmıştır. Mide içerikleri mikroskop altında incelenmiş ve farklı plankton türleri taksonomik olarak gruplanmıştır. Mide içeriğinde fitoplankton olarak Bacillariophycea, Dinophyceae, Oxyphceae, Euglenophyceae, zooplankton olarak Ciliata, Cladocera, Copepod, bivalve ve gastropod larvaları tespit edilmiştir. Bray-Curtis benzerlik testine göre örnekleme boyunca tüm farklı boy gruplarındaki midyelerin mide içerikleri, Ağustos ve Ekim ayı hariç benzerlik gösterdiği saptanmıştır.

Anahtar Kelimeler: Midye, *Mytilus galloprovincialis*, zararlı, fitoplankton, mide içeriği, Ege denizi.

Introduction

Suspension feeding bivalves are of considerable importance as primary consumers of plankton in many marine systems and they play a significant role in the energy transfer between trophic levels (Navarro and Thompson, 1996). The growth rate of suspension-feeding bivalves is dependent upon a number of endogenous and environmental factors (Bayne and Newell, 1983), especially the amount of food ingested, which depends upon the food availability, filtration activity and selection process (Page and Hubbard, 1987; Richoux and Thompson, 2001). Food availability is correlated with phytoplankton dynamics (Dolmer, 2000). Variability in suspension-feeding activity by bivalves, particle processing under different environmental conditions including temperature range, seston concentration and particle quality have been extensively reported in the literature (Bayne *et al*., 1989).

Moreover, harmful algal blooms have become a global concern in recent decades, being also a key factor in limiting aquaculture development or/and questioning its sustainability in several areas. Intoxications associated with shellfish consumption are well known and these have been directly linked

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with marine phytoplankton that produces toxins which can accumulate to significant levels in shellfish.

Aquaculture in Turkey has drastically increased over the last years, mainly using cage culture (*Sparus aurata* and *Dicentrarchus labrax*) in open seas. Mussels are abundant all around the fish cages, consuming the natural plankton distributed at the near vicinity of the culture growout facilities, and therefore is a leading candidate for multi-trophic culture. Although it is the most common bivalve species around the Turkish coastline, no information has been available on the specific food items used by the black mussel *Mytilus galloprovincialis* in Turkish waters.

While an integrated management approach to develop aquaculture is recommended to maximize overall yield and to limit effluents impacts (Chopin and Robinson, 2006), relatively little information is available on the phytoplankton dynamics within an integrated aquaculture system including finfish cages with co-existing shellfish culture in open seas (Neori *et al*., 2004). The feeding behavior of the black mussel in response to natural particle assemblages is also of interest for mussel farm site-selection as well as to estimate the ecosystem carrying capacity for a sustainable aquaculture (Newell *et al*., 1989).

Consequently, it is well recognized that harmful phytoplankton species are affecting numerous shellfish rearing areas and markets over the world, leading state managers to enact temporarily closures to avoid such human illness following shellfish consumption (James *et al*., 2003).

This study aims at determining the seasonal variability on plankton composition of stomach contents of mussels and the occurrence of ingested plankton especially harmful phytoplanktonic species susceptible to produce toxins in cultured black mussels of various size classes over a year, at further demonstrating the need to address this question by complementary studies and eventually a specific monitoring project. Due to the likely occurrence of particle selection during the filtration process, our study focused on ingested particles rather than on hydrological monitoring samples. Our study represents the first qualitative assessment of feeding items of the black mussel in Izmir Bay (Aegean Sea).

Material and Methods

Mussels were sampled on a monthly basis from August 1997 to June 1998 to investigate the feeding activity and to detect occurrence of harmful phytoplanktonic in Urla-Iskele (Figure 1). Plankton variability in the black mussel stomachs will be specified to provide general information on plankton community by indirect determination method in Urla-Iskele (Izmir Bay, Turkey). Since our study mainly aimed to detect presence or absence of potential harmful species, the monthly time scale was considered as suitable to firstly screen any positive result. Five mussel size-classes (1, 2, 3, 4 and 5 cm) were chosen and samples (n=20) collected at 25 cm below the surface from the sides of the fish cage floats in Iskele-Urla. Mussel stomachs were dissected and separated immediately before being fixed with buffered formalin (4%). All specimens but those from February and July were examined using an Olympus cwhk10x-t/18l microscope (400x). Planktonic species were identified according to Rampi and Bernhard (1978), Sournia (1986), Larsen and Moestrup (1989), Hasle and Syvertsen (1996), Steidinger and Tangen (1996), and Tomas (1997) while occurrence reported as presence (+) and absence as (-) in the Table 1.

Statistical analyses were performed using Primer 5.0 software package program. The plankton species similarities between the mussel size classes, based on their stomach samples, were examined using hierarchical classification and multi-dimensional scaling (MDS). Hierarchical clustering and MDS

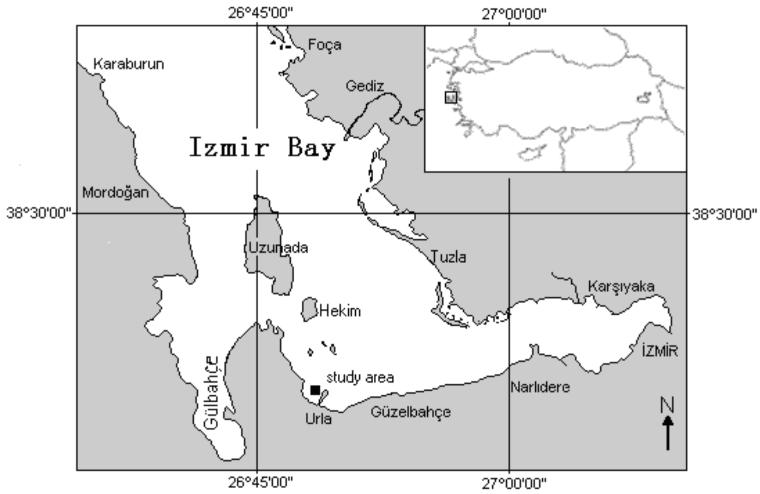

Figure 1. The map of mussel sampling area.

were based on Bray-Curtis similarities of the abundance data. The goodness of fit for the data points in the MDS was measured by the stress coefficient, where stress tends to zero when data are perfectly represented. Stress values <0.2 give a potentially useful 2-dimensional picture, stress <0.1 corresponds to a good ordination and stress <0.05 gives an excellent representation. Correlation between species separated them into two groups (similar and dissimilar) at the 60% level (Clarke and Gorley, 2001).

Results and Discussion

Microalgae play a critical role in marine biological ecosystems, being major organic producers of biomass from their photosynthetic activity. Moreover, it is well recognized that microscopic algae are crucial food for crustacean larvae as well as for filter-feeding bivalve shellfish of commercial interest (e.g. *Crassostrea gigas*, *Mytilus edulis*, *Tapes decussatus*) (Bayne *et al*., 1987). Mussels of the genus *Aulacomya*, *Mytilus* and *Perna* are widely distributed in temperate and/or subtropical regions, and considered as main consumers of seston, including particulate material such as phytoplankton, detritus and silt in coastal waters (Gardner, 2002**)**. While proliferation of planktonic algae (up to millions of cells per ml) can be beneficial to aquaculture, negative effects have also been reported due to punctual toxicity and eutrophic, dystrophic conditions, causing major environmental and human impacts, as well as economic losses (Carvalho Pinto-Silva *et al*., 2003). Although no seawater monitoring was carried out in our study, data provide preliminary information on seawater planktonic community at the near vicinity of mussel location. Microscopic observations of species from the mussel stomach are presented in Table 1. A total of 39 species were identified, including 11 species of Bacillariophyceae, 16 species of Dinophyceae, 1 species of Oxyphyceae, 1 species of Euglenophyceae for phytoplankton; 1 species of Cladocera, 1 species of Granuloloreticulosa, 5 species of Tintinidae for the zooplankton.

The observed diet, described by ingested species, of black mussel in Urla-Iskele was mainly composed of dinoflagellates and diatoms. Our results agree with similar studies on bivalve stomach contents (Ciocco and Gayoso, 2002). Most food items observed in stomach contents were found of planktonic origin. Koray (1987) and Kocataş *et al*. (1988) reported that Urla had the highest planktonic species richness, while the community structure in Inner Bay and Urla was similar in terms of qualitative distributions of diatoms, dinoflagellates and tintinids.

According to Metin and Cirik (1999) results of phytoplankton populations in Izmir Bay, diatoms are dominant in May, November, January and June, while dinoflagellates are dominant in June, December and April. In this study, the seasonal variability of ingested phytoplankton was characterized by a large diatom diversity occurring in the fall, reaching 8 species in October whereas the lowest diversity was reported in spring and early summer (Figure 2). Diatoms showed three peaks in May, September and November and none in June. Among the Bacillariophyceae, *Licmophora abbreviata* and *Navicula* sp. were the most commonly observed species over the year. Koray (2001) listed 14 species of *Coscinodiscus* in phytoplankton of Turkish seas.

In contrast, dinoflagellate species were in greater diversity than diatoms in mussel stomach contents with a peak reported in October (Figure 2). Dinoflagellates were dominant in stomach samples compared to diatoms and other species during all months except October. Over the experimental year, the most common of species Dinophyceae was *Prorocentrum micans*, being systematically observed in each stomach sample whatever the size classes of mussels. Although rarely seen in September and October, *Dinophysis tripos* was observed regularly over the experimental year except in June. Moreover *Alexandrium* spp. and *Diplopsalis lenticula* were the other Dinophyceae represented, while *Peridinium trochoideum* was rarely reported.

While most species of *Protoperidinium* are heterotrophic, usually feeding on diatoms, *Protoperidinium depressum* was dominant from June to October. Although the potential of *Protoperidinium* cysts as marine eukaryotic productivity indicators is evident, dinocysts and other organic matter are degraded by bottom and poor water oxygen (Reichart and Brinkhuis, 2003). Phytoplankton cysts were not observed in stomach content of mussels in the present study.

Oxyphysis oxytoxoides and *Euglena* sp., of Oxyphyceae and Euglenophyceae respectively, were observed only in May and August.

Zooplankton species in stomach contents were observed in higher number in summer and autumn months compared to winter and spring (Figure 2). Copepods were the main representative zooplanktonic species. Bivalve larvae in the mussels' stomach were found year round except in January, March and August. *Evadne* sp., Cladocera, was reported only in the summer and fall. Besides those, several rare species such as Tintinidae and Granuloreticulosa were also reported in the mussel stomach content.

By comparing the food variability in the stomach contents of the five size classes of mussels, similar food items were generally observed (Table 1). Similarities between stomach contents of mussel size classes were examined using cluster analysis. Stress coefficient for all groups was found zero that showed the goodness of fit for the data points in the MDS. Plankton species variability in the stomach contents of all of the mussel size classes was similar (greater than 60%) during the year except in August and

Table 1. Organisms identified in stomach contents of mussel of different size, *Mytilus galloprovincialis*

	August 97					September 97					October 97					November 97					December 97				
	Mussel size(cm)																								
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
PHYTOPLANKTON																									
Bacillariophyceae																									
Coscinodiscus sp.	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	+	-	-
Guinardia flaccida	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Gyrosigma sp.	-	-	-	-	+	-	-	+	+	+	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-
Licmophora abbreviata	-	-	-	-	-	+	-	-	-	-	+	-	-	+	+	-	+	+	+	-	-	-	+	-	-
Navicula sp.	-	-	+	-	+	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-	+	-	+	+	-
Nitzschia closterium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Nitzschia pungens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Nitszchia sp.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	+	-	-	-	-	-	-
Pleurosigma normanii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhabdonema adriaticum	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Striatella unipunctata	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dinophyceae																									
Dinophysis acuta	-	-	+	-	+	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
D. tripos	+	-	+	+	-	-	+	-	-	-	-	-	-	-	-	+	+	+	+	-	+	+	+	-	+
D. fortii	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	-
D. ovum	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	-
Diplopsalis lenticula	-	-	-	-	-	-	+	+	+	+	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-
Diplopeltopsis minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Gonyaulax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Prorocentrum micans	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	+
P. scutellum	-	-	-	-	+	+	-	-	-	-	+	-	+	-	+	-	+	+	-	-	-	-	-	+	-
P. triestinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Protoperidinium depressum	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. conicum	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. oceanicum	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-
P. stenii		-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-
P. trichoideum	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-
P. sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Oxyphyceae																									
Oxyphysis oxytoxoides	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euglenophyceae																									
Euglena sp	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ZOOPLANKTON																									
Ciliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-
Undella sp.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-
Salpingella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Granuloreticulosa																									
Tretomphalus bulloides	-	+	-	-	-	-	-	-	-	-	+	-	+	-	+	+	-	-	-	-	-	-	+	-	-
Cladocera																									
Evadne sp	-	-	-	+	-	-	+	-	+	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Copepod	-	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	-	-	-	-	-	-		-
Appendicularia																								-	
Oikopleura sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-		-
Bivalve larvae	-	-	-	-	-	+		+	+	+	-	-	-	+	-	+	+	+	+	+	-	+	+	+	+
Gastropod larvae	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zooplankton strew	-	-	+	-	-	-	+	+	+	+	+	+	+	-	-	+	-	+	+	+	+	+	-	+	-

October. Results showed that approximately 100 % and 70% of the dissimilarities were accounted for 2 cm and 4 cm size classes of mussel's stomach contents in August and October (Figure 3). These differences may be coincidental filtration. For example *Undella* sp., and *T. bulloides* were observed only in the 2 cm size class stomach. This size class may have a limited probability to select them due to the reduced availability of this plankton in the water column in August. Therefore stomach contents discrepancies might be related to low occurrence of plankton species on a monthly basis. Addressing the issue would further require water samples and quantitative plankton assessments.

Size range of the food items can be considered using data from a literature review (Table 2). The plankton particle size ranged mainly from 20 to 700 µm, while the smallest and largest particles were *Prorocentrum triestinum* and *Evadne* sp., respectively. The dinoflagellate *Prorocentrum micans*

Table 1. (continued)

	January 98					March 98					April 98					May 98					June 98				
	Mussel size(cm)																								
Species	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
PHYTOPLANKTON																									
Bacillariophyceae																									
Coscinodiscus sp.	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guinardia flaccida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gyrosigma sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Licmophora abbreviata	+	+	-	-	+	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	-	-	-	-	-
Navicula sp.	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	-	-	-
Nitzschia closterium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitzschia pungens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitszchia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleurosigma normanii	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Rhabdonema adriaticum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Striatella unipunctata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dinophyceae																									
Dinophysis acuta	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	+	+	-	-	-	-	-
D. tripos	+	+	-	+	+	+	+	+	+	+	-	-	+	+	-	+	-	-	-	-	-	-	-	-	-
D. fortii	+	-	-	+	-	-	-	+	-	-	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-
D. ovum	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Diplopsalis lenticula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diplopeltopsis minor	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	+	-	+	+	+	-	-	-	-	-
Gonyaulax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gymnodinium sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Prorocentrum micans	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	+	+	+	+
P. scutellum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
P. triestinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
Protoperidinium depressum	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. oceanicum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
P. stenii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+	-
P. trichoideum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
P. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyphyceae																									
Oxyphysis oxytoxoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-
Euglenophyceae																									
Euglena sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-
ZOOPLANKTON																									
Ciliata	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Undella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Helicostomella edentata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eutintinus latus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Favella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Granuloreticulosa																									
Tretomphalus bulloides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-
Cladocera																									
Evadne sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Copepod	+	+	+	+	-	-	-	+	-	-	+	-	+	-	+	+	-	+	+	+	+	+	+	+	-
Bivalve larvae	-	-	-	-	+	-	-	-	-	-	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+
Zooplankton strew	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	+	+	+	-	-	-	-	-

was the most common species in all sizes of mussels' stomach (size ranged from 50 to 100µm length). Moreover, the largest organisms were zooplanktonic species such as copepods, *Evadne* spp., *Helicostomella* spp., and *Tretomphalus bulloides*. According to the size range of food items, we might consider that no particle selectivity occurred among mussel size classes. Moreover, the largest food particle was observed in the smallest mussel size class (1 cm) (Table 1).

Although plankton abundance is critical for mussel growth, the type of plankton is also important. For example, phytoplankton species that produce toxins can affect marketing of shellfish when bivalves accumulate the toxins while feeding. Obviously this requires early and active detection since usually no systematic indicator correlated to those specific events would disclose the risk and prompt the managers to react. Therefore, high level of phytoplankton is required to optimize growth and yield, whereas no harmful algal species should occur which would induce marketing delays. However,

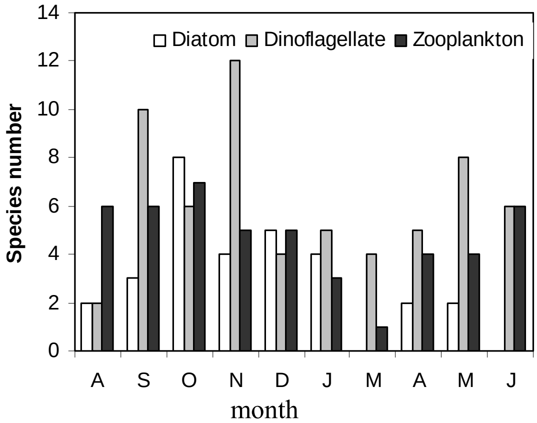

Figure 2. Mean peak periods of diatom, dinoflagellate and zooplankton species.

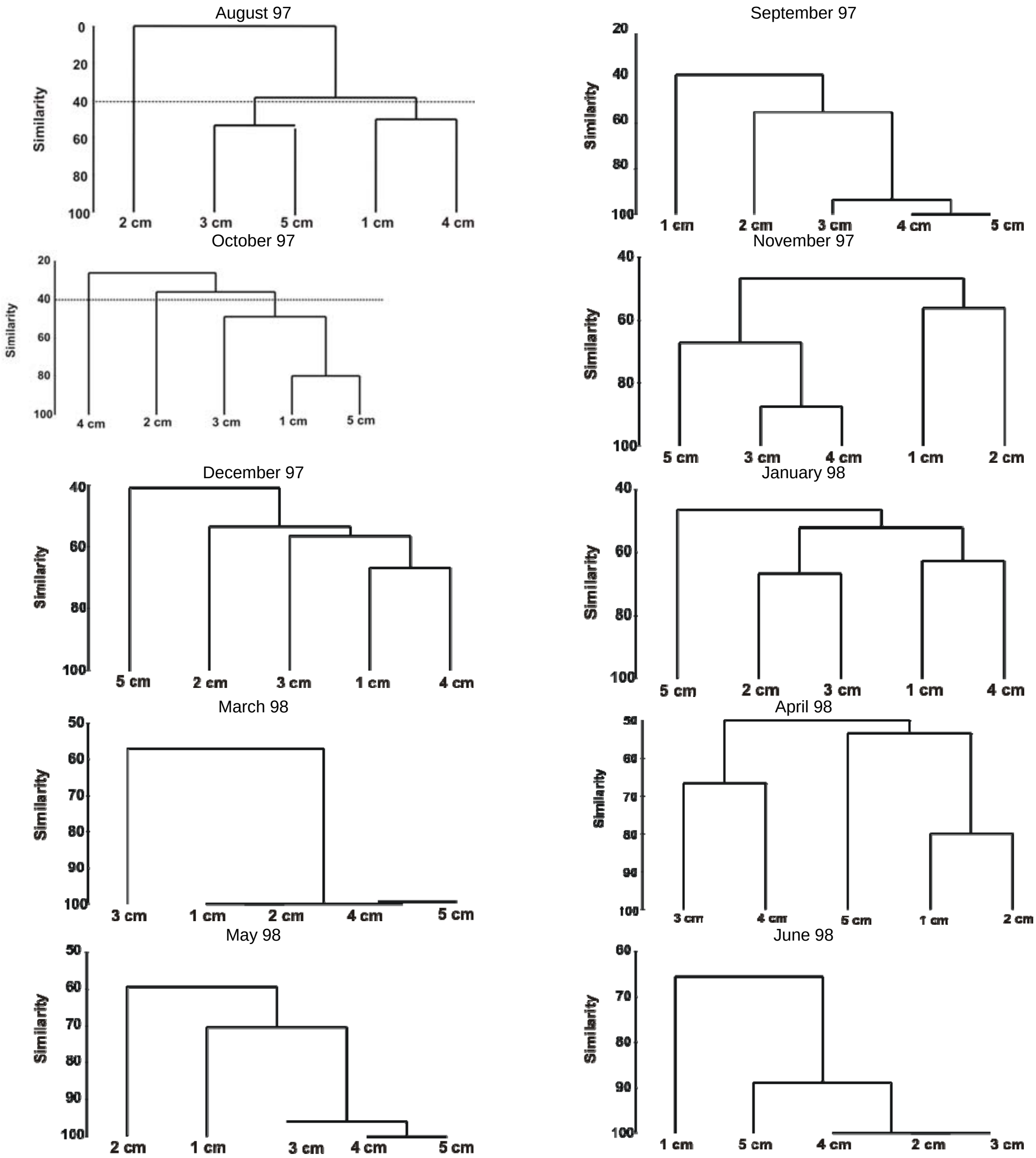

Figure 3. Hierarchical cluster analysis showing affinities of the stomach contents of mussel size classes.

Table 2. A literature review of size range for planktonic species observed during the study

Species	Size	Author
Coscinodiscus	Up to a few hundred µm	Newell and Newell, 1963
	31-500 µm	Tomas, 1997
Guinardia flaccida	40-90 µm	Newell and Newell, 1963
	25–90 µm	Hasle and Syvertsen, 1996.
Gyrosigma	60-180 µm	Tanaka, 1984
Navicula sp.	18-53 µm	Turpin *et al*., 2001
Nitzschia closterium	30-150 µm	Rampi and Bernhard, 1978
Nitzschia pungens	80-140 µm	
Striatella unipunctata	80 µm	Stidolph, 1980
Dinophysis acuta	80 µm–large	Tomas, 1997
(toxic)	54-94 µm	Steidinger and Tangen 1996
Dinophysis fortii	60 µm –medium size	Tomas, 1997
(Toxic)	56-83 µm	
Dinophysis tripos	100 µm –large cell	Tomas, 1997
(Toxic)	90-125 µm	Larsen and Moestrup, 1989
Dinophysis ovum	34-46 µm	Caroppo *et al*., 2001
Diplopsalis lenticula	Length 23-48 µm	Larsen and Moestrup, 1989
	25-60 µm	Sournia, 1986
Prorocentrum micans	48 µm–medium	Tomas, 1997
(Non-toxic, may cause oxygen depletion at	50-100 µm	Sournia, 1986
high cell concentration)	35-70 µm	Larsen and Moestrup, 1989
Prorocentrum scutellum	42 µm–small to medium	Tomas, 1997
Prorocentrum triestinum	20 µm-small	Tomas, 1997
(Non-toxic; caused fishkills by oxygen depletion)	18-22 µm	Dodge, 1982
Protoperidinium depressum	155 µm–large	Tomas, 1997
	116-200 µm	Dodge, 1982
Protoperidinium oceanicum	185 µm – large cell	Tomas, 1997
	112-118 µm	
Protoperidinium steinii	L. 39-60 µm, w. 22-44 µm	Hansen and Larsen, 1992
	78-84 µm	
Scrippsiella	<50 µm	Tomas, 1997
Scrippsiella trochoidea	L. 23-37 µm, W.19-30 µm	Lewis, 1991
Oxyphysis oxytoxoides	60-70 µm	Sournia, 1986
Undella hyalina	221-270 µm	Koray and Ozel, 1983
Helicostomella	150-500 µm	Jörgensen, 1924
Eutintinnus latus	317.5 µm	Koray and Ozel, 1983
Favella sp.	90-282 µm	Koray and Ozel, 1983
Salpingella	100-320 µm	Koray and Ozel, 1983
Evadne	400-700 µm	Özel, 1998
Tretomphalus bulloides	560 µm	Özel, 1998

toxic dinoflagellate such as *Alexandrium tamarense*, although not reported in our study, can effect directly and negatively energy budgets of bivalves (Li *et al*., 2002). Actually, shellfish physiological processes (e.g., filtration rate, byssus production, oxygen consumption) can be directly affected when the animals feed on the toxic algae (Gainey and Shumway, 1988). Several toxic phytoplankton species have been already reported in Turkish seas (Koray, 1984, 1988, 2001; Koray *et al*., 1992). These authors reported that the blooms of *Alexandrium tamarensis*, *A. minutum*, *Peridinium steinii* and *Prorocentrum micans* were observed in spring and autumn resulting sporadically in local red-tides (water discolouration) in the polluted areas of Inner Bay. *Noctiluca scintillans* has formed red tides very frequently in those bay waters, although *Prorocentrum micans*, *P. trietinum*, *Ceratium* sp., *Nitzschia* sp., *Pseudo-nitzschia spp.*, *Thallassiosira* sp., *Eutreptiella* sp., and *Mesodinium rubrum* are additional potential causative organisms of seawater discoloration (Koray *et al*., 1992). Metin and Cirik (1999) reported that *P. micans*, a non toxic species, is the common species both in inner and middle part of Izmir Bay.

Our study reported several potential toxic species in mussels' stomach including *D. acuta, D. tripos, D. fortii, Pseudo-nitzschia* spp. and *Alexandrium* spp., therefore likely representing a potential problem if mussel culture were to be developed in those areas. By way of example, *D. acuta, D. tripos, D. fortii* were detected over a period of 6 to 9 months in stomach contents of mussels. Although only observed in November, *D. tripos* was the more abundant species among the *Dinophysis* species. *Alexandrium minutum* was not observed during our experimental time. Although those species have been described to be toxic at the worldwide level, no public health induced problem has been detected up to now in products from Turkish waters. This may be due to limited cell density or toxin abundance below the toxicity threshold, or to no direct relationship with mussel consumption. However, a systematic tracking of harmful algal blooms (HABs) associated with toxicity tests and measurements have not been specifically undertaken until now in Turkish waters. While mussel production is an emerging production in these waters, no concomitant and systematic seawater as well as shellfish monitoring has been undertaken until now to control the rearing areas and to certify shellfish quality. In contrast, the mussel *Mytilus californianus* is used as a sentinel species for monitoring PSP and domoic acid in areas of Canada harvested for shellfish (Whyte *et al*., 1995). In France, a national monitoring network (REPHY) has been operating since 1984 to avoid any public health problem related to phycotoxins (Belin and Berthomé, 1991; Goulletquer and Héral, 1997). Moreover, it should be emphasized that while mussel can be considered as a suitable bioindicator when tested for toxin content, monitoring other commercial species is recommended since toxin bioaccumulation is species-specific, and that differences could be up to 100-fold (Bricelj and Shumway, 1998; Dragacci and Belin, 2001; Gailhard *et al*., 2002). In several European countries, toxic or non-toxic blooms of species like *Alexandrium tamarense, A. minutum, Gymnodinium breve* and *Gyrodinium aureolum* have been reported or occur regularly, prompting the State managers to develop systematic phytoplanktonic monitoring surveys in order to prevent public health problems (Dragacci and Belin, 2001).

Conclusion

Our results represent the first attempt to characterize the annual feeding cycle and variability of the phytoplankton species in the stomach content of black mussel. They also provide the first qualitative assessment of feeding items of black mussel in Izmir Bay (Aegean Sea) as well as general information on plankton community in Urla-Iskele (middle part of Izmir Bay). Plankton species variability in the stomach contents of all of the mussel size classes was similar during the year except in august and october. Potentially harmful species from a public health perspective have been reported while mussels are being well recognized as bioaccumulators of phycotoxins. Therefore, we must conclude that mussel harvesting must be carried out more carefully because of the toxic phytoplankton occurrence at certain intervals. Harmful algal blooms (HABs) may impose a serious threat to aquatic lives and human health (Li *et al*., 2002). Mussel harvesters and local people collect mussels for consumption in Izmir Bay on a regular basis. Therefore, toxic phytoplankton species represents a risk factor both as a threat to public health and aquaculture development in Izmir Bay.

Therefore, preventive measures should be taken and enforced to protect human health, such as prohibition of bivalve harvesting when harmful phytoplankton occur at such a level that toxins are accumulated in shellfish resulting in unsafe levels for human consumption. The occurrence of those toxic species prompts us to recommend further studies including a comprehensive phytoplankton monitoring program to assess potential public health threats, then to further develop a sampling process when toxic phytoplankton are present. Monitoring programmes testing shellfish tissues and screening harvesting areas are likely the most efficient approach to prevent side-effects from potential DSP, PSP, ASP outbreaks. Diatoms and dinoflagellates, as well as their toxicity, toxin contents and occurrence periods should be further determined. Outputs from the monitoring will be critical to improving our knowledge on harmful events (both on toxic effects on humans and mass mortalities on living resources, and facilitate risk analysis), and further decision-making by the State managers for fisheries and aquaculture management schemes.

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