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Stomach content analysis of *Mugil cephalus* and *Mugil curema* (Mugiliformes: Mugilidae) with emphasis on diatoms in the Tamiahua lagoon, México

Patricia Sánchez Rueda
Departamento de Hidrobiología. Universidad Autónoma Metropolitana-Iztapalapa. Av. Michoacán y La Purísima. Apdo. Postal 55-532, México D.F. 09340. Fax (52) 57-24-47-38; sarp@xanum.uam.mx

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Abstract: A year-long research on the *Mugil cephalus* and *M. curema* diet was conducted. The food content in the cardiac portion of 192 stomachs revealed a great similarity in both species leading to two conclusions: sediments are their basic food and high levels of benthic diatoms are dominant. A total of 130 taxa were found (*Nitzschia*, *Navicula*, *Amphora*, and *Cocconeis* dominated). Other food components were: Foraminifera, Nematoda, Copepoda, Ostracoda, Amphipoda, Pelecypoda, Gastropoda, eggs of invertebrates, and undetermined organic matter.

Key words: Diatoms, stomach content, *Mugil cephalus*, *Mugil curema*, coastal lagoons.

The Mugilidae family lives in tropical and subtropical regions worldwide. They have been traditionally used in extensive aquaculture in the Mediterranean and the Middle East for their adaptation to different trophic levels (Oren 1981). They feed by sucking silt or scraping rock and plant surfaces (Hickling 1970, and Romer and Mclachlan 1986). The *Mugil curema* diet consists basically of diatoms. *Mugil cephalus*, instead, exhibits a gradual diet transition associated with its body development (Albertini-Berhaut 1974)—from zooplanktonic to benthic diatoms. The adults' diet includes macroalgae, diatoms, detritus, and inorganic sediment particles (Odum 1970, Marais 1980).

The presence of micro-phytobenthos in the *M. cephalus* and *M. curema* diets have been extensively discussed in the literature (Odum and Heald 1972, Marais and Erasmus 1977, Marais 1980, Sánchez *et al*. 1997). Our paper analyzes and compares the occurrence of diatoms in the 192 stomachs studied.

MATERIALS AND METHODS

Ninety-six organisms of each species were analyzed. They were collected in the Southern region of the Tamiahua lagoon (21°15'35'' to 21°29'45'' N, and 97°22'00'' to 97°29'10'' W) in Veracruz, Mexico. The content of the cardiac portion was diluted with 20 ml and preserved in formalin at 10%. The Moreno-Ruiz and Carreño technique (1993) was applied to clean up the four aliquots of 2.5 ml taken, which were also mounted on the synthetic resin Sigma (r.i = 1.6). For diatom identification, procedures described by Hasle and Syvertsen (1996) and Moreno *et al*. (1997) were applied.

The quantitative analysis of major taxonomic groups was performed using 40x and 100x magnifying glasses, under an acceptable confidence interval of 90% according to Lund *et al*. (1958). Not less than 300 valves per compound (Kim and Barron 1986) were counted following Keast's standards (1968). Photomicrographs obtained by using an inverted Zeiss microscope (405 ICM) at 500, 787.5, and 1250x magnifications were used to identify diatoms.

Based on the diatom density, the following classification was established: a) dominant = to 50%; b) abundant = from 10 to 50%; c) ocassional = 10%. The Morisita-Horn's index was applied to establish diet similarity.

RESULTS

In both species, diatoms made up 97% of the food intake. The remaining 3% consisted of major taxonomic groups. Foraminifera and Copepoda were found to be important components of the *M. cephalus* diet. Foraminifera and Nematoda were important in *M. curema*'s. Pelecypoda, Gastropoda showed a far lower occurrence in both species.

Among diatoms, 130 taxa were identified. The pennate types dominated—*Nitzschia*, *Navicula*, *Cocconeis*, and *Amphora*. Both species showed a highly similar composition regarding taxonomic group specimens. Taxa found in the stomachs are shown in Tables 1 and 2 and Figs. 1 and 2.

The quantitative analysis of diatoms revealed a wide content fluctuation in both species (Fig. 3). *Mugil cephalus* presented its peak value in August (12.2 x 10^6 cells/20 ml) and January (11.4 x 10^6 cells/20 ml) when the rainy season actually takes place. Minimum density was observed in September (1.7 x 10^6 cells/20 ml). As for *M. curema*, its peak value occurred in June during the dry season (9.2 x 10^6 cells/20 ml), and the minimum density occurred in September and January (4.7 x 10^3 cells/20 ml and 1.9 x 10^5 cells/20 ml).

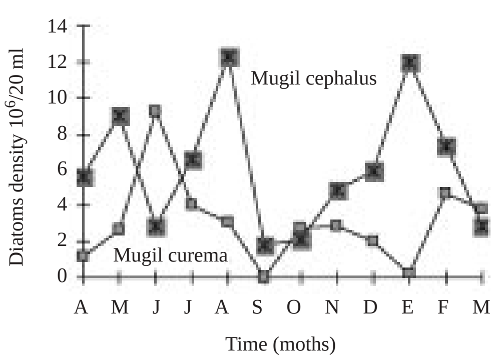

Fig. 3. Quantitative analysis of the diatoms in *Mugil cephalus* y *M. curema* in Tamiahua lagoon.

Mugil cephalus food intake showed an 11.5% of the dominant diatoms (*Nitzschia frustulum*, *Grammatophora marina*, *Tryblionella apiculata*, *Navicula abunda*, *Actinoptychus senarius*, *Amphora ovalis* var. *pediculus*, *Cyclotella caspia*, *Diploneis bombus*, *Nitzschia dissipata*, and *Psammodictyon panduriforme* var. *minor*), 43% of the abundant types (*Neodelphineis pelagica*, *Gyrosigma* sp. 1, *Navicula pavillardii*, *Nitzschia laevis*, *N. denticula*, *Rhopalodia gibberula* var. *producta*, *Tabularia* sp. 2, and *Thalassiosira eccentrica*), and a 44.5% of the occasional type.

The *M. curema* food intake included a 12.0% of the dominant diatoms (*Nitzschia frustulum*, *Entomoneis alata*, *D. bombus*, *N. abunda*, *A. senarius*, *C. caspia*, *Navicula cryptocephala*, *Opephora marina*, *Thalassiosira subtilis*, and *T. apiculata*) and a 37.0% of the abundant types (*Cylindrotheca closterium*, *G. marina*, *N. laevis*, *N. longissima*, *P. panduriforme* var. *minor*, *Synedra cristallina*, and *Tryblionella punctata* were highly important). The Morisita-Horn's index value of 0.90 indicated a highly similar number of diatoms within the sediments consumed by both species.

DISCUSSION

The Mugilidae found in the Tamiahua lagoon share a similar stomach content. Márquez (1994) interprets the presence of living Foraminifera near estuaries and associated areas as a good indicator of the organic productivity of a region. Since both species feed on Foraminifera, this can be interpreted as evidence of the higher organic productivity in the Southern region of the Tamiahua lagoon.

Sánchez *et al*. (1997) pointed that *M. cephalus* and *M. curema* regularly return to the continental shore for feeding—mainly looking for sandy and muddy areas. This statement finds further support in the assertion of Méndez *et al*. (1986)—this kind of sediment contributes to the presence of benthic life. Their dietary similarity and the Morisita-Horn's index value (0.90) strongly suggest that Mugilidae share the same trophic level. However, they make a different use of the shared space in different time periods. The strong superiority of a few diatom species shows the wide fluctuations in the studied microalgae community structure, a fact already mentioned by Moreno-Ruiz *et al*. (1994) when discussing the instability in the ecosystem of the Tamiahua lagoon.

Odum (1970) establishes that *M. cephalus* features a long enough intestine to assimilate the elements of a diet based on diatoms and detritus. In the Tamiahua lagoon, *M. cephalus* and *M. curema* feed on huge amounts of both detritus and sediments and might also benefit from the microfauna and meiofauna along with other nutrients. Mugilidae are the principal food consumers of this ecosystem and play an important ecological role within it by releasing energy at higher trophic levels. Abarca-Arenas and Valero-Pacheco (1991) maintain that detritus constitute the basic food resource in the Tamiahua lagoon, which could explain why Mugilidae are one of the main scale fisheries of the region.

Diatom density was higher in the *M. cephalus* stomachs. This could be interpreted as their superior ability to select fine particles and filter sediments. *Mugil cephalus* features a protractile mouth, small teeth, and a highly specialized pharynx and digestive system. The monthly changes in diatom density might be due to seasonal variation. A strong reduction of diatoms in the stomach content of both mullets occurs when the "nortes" (northern winds) blow in November, December, and January. This reduction is due to the narrow association between microfauna, meiofauna, and the fine sediments easily subjected to disturbance during that particular season.

The predominance of pennate diatoms with rafe (*Nitzschia*, *Navicula* and *Diploneis*) in the stomach content of mullets suggests the ingestion of soft silt-like sediments. Those algae are found on sand particles and are a part of the dominant epipelic flora (Round *et al*. 1990). In this respect, it is important to stress that the southern part of the Tamiahua lagoon is characterized by the presence of poorly sorted silts sometimes blended with fine sands or different types of clay (Márquez 1994). All this partially explains why both species ingest a wide range of sediments ranging from fine sands of 125 µm to medium silt of 15 µm (Sánchez *et al*. 1997). On the one hand, these sediments directly reflect part of the lagoon substrate stability; on the other hand, they indirectly show the development of the associated benthic fauna. Although the ecology of epipelic algae is hard to study because of its close association with the disturbed sediments, the distribution of microalgae seems to depend more on the lagoon bottom properties than any other parameter.

The energetic importance of certain types of diatoms (*Anaulus birostratus*, *Chaetoceros*, *Coscinodiscus*, *Nitzschia paradoxa*, *Skeletonema costatum*, *Phaeodactylum tricornutum*, and *Thalassiosira weissflogii*) has been studied with relation to the *Liza richardsoni* (Romer and McLachlan 1986) as well as their application in aquaculture (Groth-Nard and Robert 1993). These researchers argue that diatoms show a high caloric value due to their content in carbohydrates, lipids, and proteins. Postulating a diet rich in diatoms, it is possible to assume that their ingestion provides the mullets of the Tamiahua lagoon with an important source of calories. The ingestion of lipids, carbohydrates, and proteins is assured by the consumption of large amounts of diatoms (*Nitzschia*, *Chaetoceros*, *Coscinodiscus*, *Thalassiosira* genera and *Skeletonema costatum*).

The dietary habits of Mugilidae are based on detritus, and both species depend on this trophic level within the food chain. The results confirm the conclusions drawn by Abarca-Arenas and Valero-Pacheco (1991) who claim that the food chain in the Tamiahua lagoon is a short one, which explains why the Mugilidae family is one of the largest fin fisheries of the lagoon.

TABLE 1

Some diatoms in the stomach content of M. cephalus *and* M. curema *from the Tamiahua coastal lagoon (Fig. 1)*

a *Achnanthes curvirostrum,* length 29.3 µm
b *A. minutissima var. cryptocephala,* length 12.5 µm
c *A. minutissima var. gracillima,* length 49.5 µm
d *Actinoptychus senarius,* 41.4 µm in diameter.
e *Amphora angusta,* length 38.2 µm
f *A. richardiana,* length 41.4 µm
g *A. turgida,* length 15 µm
h *Bleakeleya micans,* length 58.6 µm
i *Chaetoceros seiracanthus,* resting spore apical axis 16.5 µm
j *Cocconeis californica,* length 18.5 µm
k *C. dirupta var. dirupta,* length 10.5 µm
l *C. dirupta var. flexella,* length 16.5 µm
m *C. placentula var. euglypta,* length 16.5 µm
n *C. scutellum,* length ca. 20.4 µm
o *Coscinodiscus radiatus,* 31 µm in diameter.
p *Cyclotella caspia,* 7.6 µm in diameter.
q *Cylindrotheca closterium,* length 52 µm
r *Delphineis surirella,* length 13.5 µm
s *Dimeregramma minor,* length 16.5 µm
t *Diploneis bombus,* length 43 µm
u *D. decipiens,* length 21 µm
v *D. weissflogii,* length 31.2 µm
w *Eunotogramma laeve,* length 10.5 µm
x *Fallacia subforcipata,* length 16 µm
y *Grammatophora marina,* length 30 µm
z *Gyrosigma balticum,* length 377 µm
aa *Gyrosigma fasciola,* length 79.6 µm
bb *Hemiaulus sinensis,* apical axis 7.5 µm
cc *Licmophora gracilis,* length 70 µm
dd *Lyrella lyra var. subtypica,* length 71 µm
ee *Navicula abunda,* length ca. 25 µm
ff *N. cryptocephala,* length 21 µm
gg *N. pavillardii,* length 59.2 µm
hh *N. platyventris,* length 13 µm
ii *N. scopulorum,* length ca. 147 µm
jj *N. takoradiensis,* length 55.4 µm

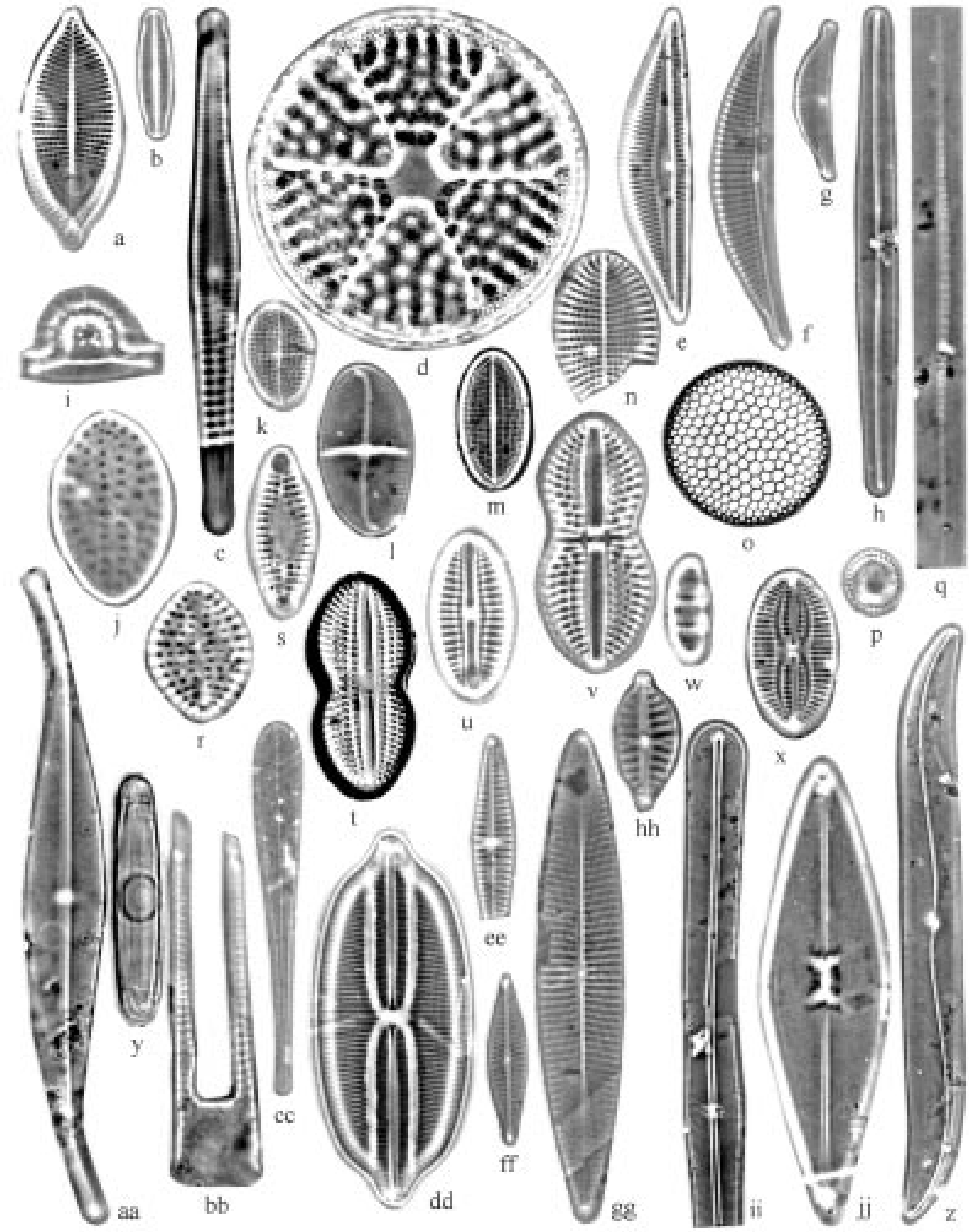

Fig. 1. Some diatoms in the stomach content of *M. cephalus* and *M. curema* from the Tamiahua coastal lagoon (Table 1).

TABLE 2

Some diatoms in the stomach content of M. cephalus *and* M. curema *from the Tamiahua coastal lagoon (Fig. 2)*

a *N. yarrensis var. americana,* length 72 µm
b *Neodelphineis pelagica,* length 26 µm
c *Nitzschia denticula,* length 17.5 µm
d *N. diluviana,* length 26.8 µm
e *N. dissipata,* length 15.5 µm
f *N. frustulum,* length 30 µm
g *N. granulata,* length 25 µm
h *N. laevis,* length 16.5 µm
i *N. sigma,* length 87 µm
j *N. socialis,* length 110 µm
k *N. spathulata var. hyalina,* length 36 µm
l *N. vidovichii,* length ca. 130 µm
m *Nitzschia sp. 1,* length 64 µm
n *Opephora pacifica,* length 13.5 µm
o *Paralia sulcata,* 27 µm in diameter.
p *Petrodictyon gemma,* length 145 µm
q *Petroneis granulata,* length 47.8 µm
r *Podosira moniliformis,* 14.7 µm in diameter.
s *Psammodictyon panduriforme var. minor,* length 39 µm
t *Rhabdonema adriaticum,* length 64 µm
u *Rhaphoneis amphiceros,* length ca. 24 µm
v *Rhizosolenia setigera,* length ca. 48.5 µm
w *Rhopalodia gibberula var. producta,* length 35 µm
x *R. operculata var. operculata,* length 43 µm
y *Skeletonema costatum,* pervalvar axis 23.5 µm
z *Stauroneis amphioxys,* length 49.7 µm
aa *Surirella fastuosa var. recedens,* length 43 µm
bb *Tabularia sp. 1,* length 53.5 µm
cc *Thalassionema nitzschioides var. capitulata,* length 37.6 µm
dd *Thalassionema nitzschioides var. nitzschioides,* length 22 µm
ee *Thalassiosira eccentrica,* 19 µm in diameter.
ff *T. liceae,* 14.5 µm in diameter.
gg *Tryblionella apiculata,* length 28 µm
hh *Tryblionella punctata,* length 20 µm

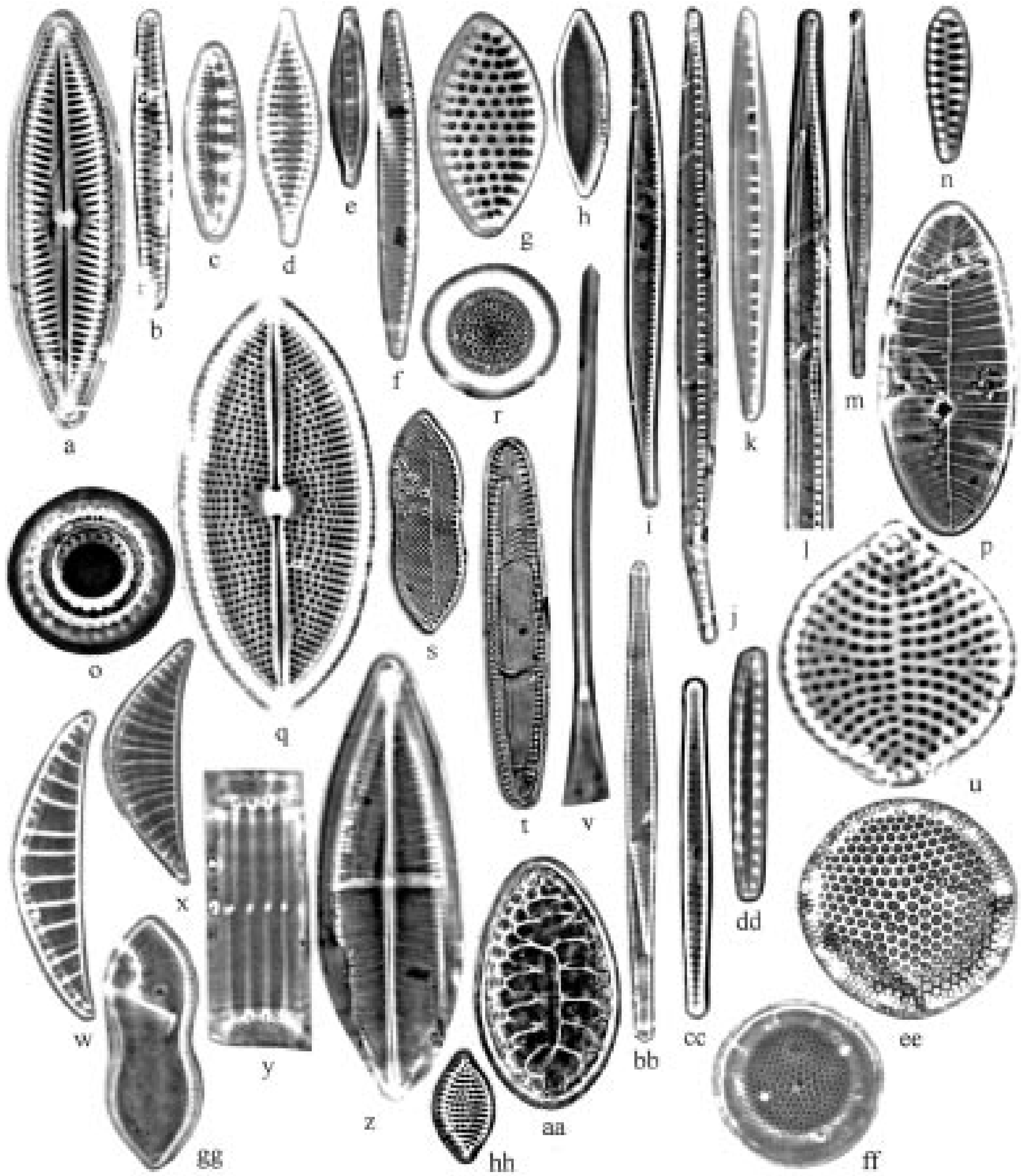

Fig. 2. Some diatoms in the stomach content of *M. cephalus* and *M. curema* from the Tamiahua coastal lagoon (Table 2).

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