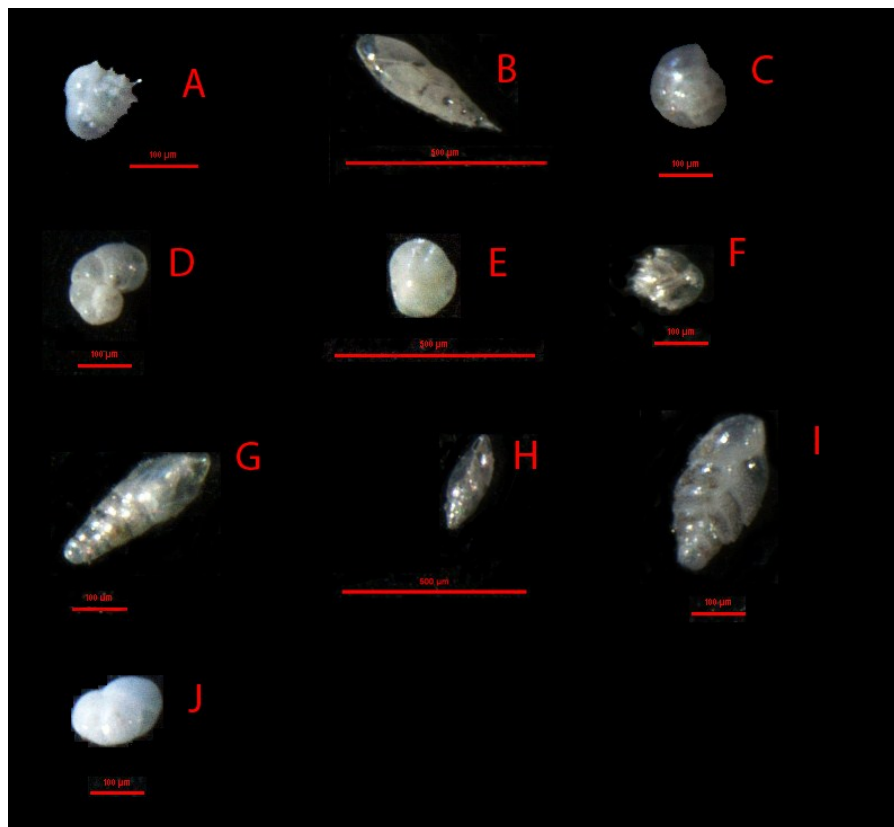


A comparison of size fractions in faunal assemblages of deep-water benthic foraminifera—A case study from the coast of SW-Africa

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Dissertations in Geology at Lund University,
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Department of Geology
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2014

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Foraminifera are abundant in the marine sediment in all of the world's oceans and offer a valuable proxy method to reconstruct water depth, circulation, productivity and deep water aeration. The choice of size fraction used when studying benthic foraminifera in upwelling areas are important. A review of 15 earlier studies where benthic foraminifera has been analysed, has shown that there are different size fractions used and this may in some cases cause problems. The aim of the study will have to decide what method that is most appropriate in each case. Deep water, depleted of oxygen with high fluxes of carbon seem to favor some species. Amongst them *E. exilis*, *C. laevigata* and *Epistominella sp.* Through this study it is shown that *Epistominella sp.* and *C. crassa* are not abundant, or very rarely abundant if sieves of >125 μm is used. The explanation is that foraminifera species tolerant of low oxygen conditions are high in number and small in sizes and will fall out if the sieve is >125. To secure a correct scientific result, and to perceive correct faunal assemblages, the 63-125 μm size fraction together with the larger fraction should always be used in regions characterized by deep water upwelling.

Keywords: Benthic, foraminifera, upwelling, size fraction, faunal assemblages, Marine Geology

Supervisors: Claire McKay and Helena Filipsson

Subject: Quaternary geology

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En jämförelse av storleksfraktioner vid faunasammansättning av bentiska djuphavsforaminiferer—en fallstudie från SW-Afrikas kust

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Sammanfattning: Foraminiferer förekommer i marina sediment i världens hav och utgör en värdefull proxy metod för att rekonstruera vattendjup, strömmar, produktivitet och syrenivån vid djuphavsmassor. Valet av storleksfraktion som används när studier på bentiska djuphavsforaminiferer utförs har visat sig ha betydelse när ekologisk fauna vid uppvällningsregioner studeras. En genomgång av tidigare studier har visat att valet av storleksfraktion skiljer sig åt, och detta kan i vissa fall skapa komplikationer. Syrefattigt djupvatten där mycket organiskt material tillförs havsbotten verkar vara fördelaktigt för vissa arter. Bland dem *E. exilis*, *C. laevigata* och *Epistominella sp.* Genom denna studie har det visat sig att *Epistominella sp.* och *C. crassa* inte är förekommande överhuvudtaget om storleksfraktionen 63-125 µm inte har inkluderats. Förklaringen till detta tolkas vara att foraminiferarterna vid syrefattiga förhållanden ofta är små till storleken och många till antalet. Dessa opportunistiska arter kommer att sällas bort om silen som används vid framtagandet av fraktionerna är större än 125 µm. För att få ett så korrekt vetenskapligt resultat vad gäller ekologisk fauna så bör alltid storleksfraktionen 63-125 µm tillsammans med större fraktioner analyseras.

Nyckelord: Bentiska, foraminiferer, storleksfraktioner, uppvälling, faunasammansättning, maringeologi

Handledare: Claire McKay & Helena Filipsson

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1 Aim

The aim of this study is to understand the importance of size fractions used for faunal assemblage studies based on benthic foraminifera. There has been, and there still is, difference in opinion about the methods that are used when sampling and analyzing foraminifera faunal assemblages. (Schröder et al. 1987) already suggested in a paper from 1987 that the way of handling samples and data should be standardised.

This study is divided in to two parts. A completed literature review aims to shed light on the most common used size fractions and whether there are any difference in size fractions used when paleoecological, paleoceanographic and stable isotope studies are performed.

A quantitative study of a core that originates from the coast of SW-Africa has been performed (Romero 2003). The 63-125 μm fraction has been studied and compared to larger fractions (125-250, 250-500, >500 μm) that has been analyzed earlier.

It is assumed that there will be a change in abundance and faunal assemblages when the 63-125 μm fraction is studied and compared with the larger fractions. The conditions where the core has been collected (See study site and Fig 1) are highly ideal for small oxygen-tolerant and opportunistic species, and it is therefore likely that these species will be more abundant in >63 μm , because they will be washed out from the >125 μm

However, because of the unclearness about the best use of size fractions, this analysis will together with already existing data from the larger size fractions provide direct information if there are differences in abundance and faunal assemblages, in an environment characterized by deep water and intense upwelling, when the 63-125 μm fraction is analyzed for faunal assemblages.

2 Scientific questions and hypothesis

- What is the most common sieve size used, and are there a wide spread of fraction sizes used?
- When counting and identifying species of the 63-125 μm fraction a larger number of foraminifera will be found – that have been washed out when analyzing the larger fractions.
- Different species, associated with oxygen-poor conditions and high organic fluxes to the sea floor will be more abundant. Foraminifera associated with oxygen-poor conditions (upwelling areas) are known to be small and will not be fairly presented when looking at larger fractions because they will be washed out when the samples are prepared.

3 Introduction

There is no doubt about the oceans great importance when it comes to climate and the developing of life on

earth. The thermohaline circulation and the interaction between oceans and some of the most fundamental cycles, like carbon and nitrogen cycle are both clear examples of that. The oceans also function as an archive that is letting us study past geological, biological and ecological activities. The marine sediments are providing us with fossils that can tell us a lot about the past. One of those fossils faunas are foraminifera (Bleil 1996).

Benthic foraminifera are simple one celled organism, protozoans that exist in and on sediments throughout the deep sea environment. They are organisms that form a shell of calcareous material (apatite or calcite) or cemented sediment particles (agglutinated) (Gupta 2002). The organic cement of agglutinated species normally degrades when buried in the deep sea sediment and can therefore be underrepresented in the fossil archives (Gupta 2002). The calcareous species have a high preservation potential and are well preserved in sediments. An exception is at abyssal depth, where the carbonate is dissolved because of under saturation from the bottom waters. The benthic foraminifera are represented in the fossil archives from Cambrian to today (Gupta 2002).

Benthic foraminifera are amongst the most extensively distributed marine organism existing in the oceans. The abundance and diversity of foraminifera are known to be affected by many factors, including the most significantly properties of the oceans such as, temperature and salinity (Sengupta & Machaincastillo 1993).

Benthic foraminifera have been used for a long time to reconstruct deposition depth. Their abundance, diversity and species composition show a distinct trend with depth of water (Berger & Diesterhaass 1988). They are also very valuable as a proxy for reconstructing productivity and deep water aeration (Filipsson et al. 2011). Depth may be an important factor controlling the distribution but also factors like presence of organic matter, deep water masses, influx of terrigenous mud and redeposition are controlling the distribution (Berger & Diesterhaass 1988).

Understanding the ecology of foraminifera is one of the key factors to be able to use them in scientific studies. The fact that foraminifera are small, abundant in the fossil archive since 500 ma years ago and that they are forming a test that often is preserved in the sediment, makes them invaluable as paleoenvironmental proxy. Foraminifera are used in sequence stratigraphy, as biomarkers, to interpret past environments, as indicators for productivity, low oxygen, and seasonal stratification – both in the past and to monitor changes and current conditions.

They are also frequently used in isotopic studies of stable oxygen- and carbon isotopes (Murray 2006).

3.1 Study site

Upwelling regions are associated with nutrient rich, oxygen depleted water and high primary productivity in the surface water, see figure 1. (Kuypers et al. 2005)

As can be seen in Fig. 2, The Oxygen Minimum Zone, (OMZ) characterized by low dissolved oxygen is dependent on global ocean currents, geography and primary production. Old water masses that have not been aerated for a long time is depleted of oxygen. If they are upwelled or situated under areas with high primary production in the surface water, the consumption of organic debris in the water column will deplete the water even more of oxygen. (Gupta 2002)

Upwelling occurs at the Benguela current system (White box in Fig. 1).

The shelf adjacent to the coast of Namibia is a part of this system, and is characterized by an upwelling zone with high primary production, oxygen depleted water with following anoxic conditions and sulfidic bottom waters. (Bruchert 2003)

Southeasterly trade winds in the region are causing upwelling of cold nutrient rich water that origins from south atlantic central water. (Romero 2010)

Romero (2010) has with studies of diatom assemblages and bulk biogenic components described the intensity of the upwelling at the region trough the last 70 ka. There has been up welling occurring during the whole period but with variety in intensity and cli

mate. Several gravity cores have been collected from RV METEOR cruises. This study uses the sediment core GeoB3606-1 from Cruise 34/1. The core was brought up from a water depth of 1795 meters. It is

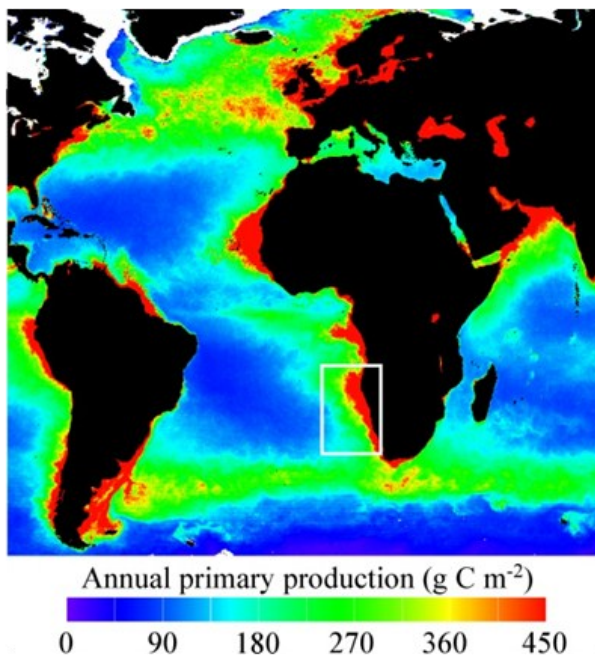


Fig 1. Global map showing the annual primary production. The white box are showing the Benguela current system, within the core GeoB3606-1 has been brought up (Kuypers et al. 2005)

kept at the University Of Bremen, Germany. (Romero 2010 & Bleil 1996)

3.2 Distribution of deep water benthic

foraminifera

Salinity affects the foraminifera through osmosis. Different species have different preferences when it comes to salinity, but the majority of foraminifera thrive at salinity between 32-37 ppm. The salinity range from foraminifera are from 0-70. (Murray 2006)

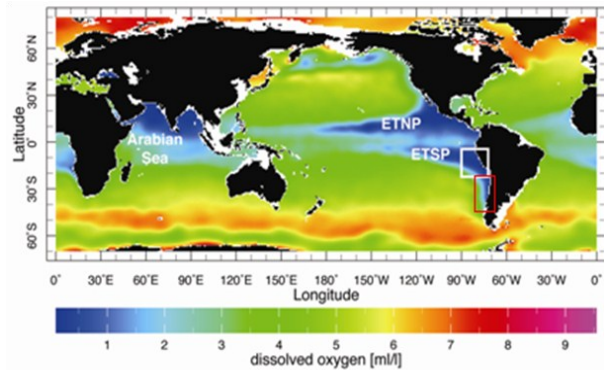


Fig 2. Global map showing the OMZ (oxygen minimum zone) The red square is showing the region where the core used in this study has been sampled. (Max planck institute for marine microbiology 2014)

Temperature is also an important factor controlling the distribution of foraminifera assemblages. Species have their own preferences and the variability amongst them is wide spread. (Murray 2006)

Biotic factors as competition and predation and food supply are also factors that strongly control the distribution of foraminifera.

The samples that have been analyzed in this study origins from an upwelling region. The upwelling zone is associated with low oxygen conditions and high dissolved organic carbon input to the sea floor. These two factors will therefore be more comprehensive in this study.

3.3 Oxygen

Oxygen is a known factor limiting organisms on the earth. It has been shown through earlier studies that some hard shelled foraminifera can survive in anoxia conditions up to two month or in some cases, even longer (Gupta 2002). Oxygen is only important when it is near the lower tolerance level for species. Above that level it is not limiting and can be ignored. (Gupta 2002)

The top surface of the sediment is normally a low oxygen area because organisms in the sediment consumes the oxygen. (Gupta 2002)

Several studies confirm that smaller foraminifera survive low oxygen conditions better than larger species. In many cases smaller foraminifera species are dominated in low oxygen regions. (Santa Barbara basin dominated by *Nonionella stella*) *Epistominella spp* are common as dominant specie of Low oxygen regions. (Gupta 2002)

Deep infaunal species that are tolerant to low oxygen conditions seem to develop large population, and it seems like the organic input is the main controlling factor. (Gooday 2003) A high abundance and dominance and low species richness is common at the low oxygen regions. (Gooday 2003)

3.4 Microhabitat

Benthic foraminifera are believed to a large extent be controlled by depth and the large overlying water masses. Corliss (1985) showed in a study that a number of in faunal benthic foraminifera species are more controlled by the physiochemical conditions within the sediment than earlier believed. This is something that is important to consider when faunal assemblages are looked upon. (Corliss 1985)

Several studies have shown the importance of the microhabitat in sediment affecting the diversity and abundance of foraminifera. Even if oxygen levels and organic input of foraminifera assemblages are well examined, the microhabitat's chemical composition can vary from one place to another. (Gooday 2003)

3.5 Carbon fluxes

It is known that some taxa can take advantage of pulses of organic matter better than others. There are different ecological niches when it comes to benthic foraminifera. There are those who feed on detritus material, those who feed on bacteria that thrive in the detritus and those who feed on bacteria that degrades the organic matter in the sediment mixed zone. (Gupta 2002)

According to (Murray 2006) there is evidence that benthic foraminifera feed in a non-competitive way. The common view is that carbon organic matter is considered to be a single variable when the truth is that C organic matter should be viewed as a complex factor. (Murray 2006)

Some foraminifera live in the phytodetritus, and favors directly from the input. Small species, including *Epistominella* sp are one of those species. *C. crassa* feeds on fresh organic matter from phytoplankton's in the surface water. (Suhr & Pond 2006)

Species that feed directly on the phytodetritus are only representing a small part of the total assemblage. (Murray 2006)

3.5.1 Diatoms

Diatoms are primary producers that in upwelling regions strongly attributes to the organic material reaching the sea floor. The organic chains in diatoms are one of the main feeding sources for deep water benthic foraminifera in upwelling regions. (Romero 2010)

3.6 Species expected to be found

Families *Bolivina*, *Bulimina*, *Fursenkoina*, *Uvigerina*, *Cassidulina*, *Chilostonella*, *Epistominella*, *Lenticulina* and *Nonionella* are all common at organic rich and

oxygen depleted areas and are believed to be found. (Gooday 2003)

4 Literature study

The sieve used when washing the samples has the simple function of removing unwanted inorganic compounds and remain the foraminifera so it is possible to count and identify them. According to Schroder et al (1987) a sieve opening of 20 μm is necessary if all foraminifera tests, including some numbers of unidentified juveniles should be preserved. Here we also need to take in consideration that the analyzing of the samples will be very time consuming and the juvenile foraminifera may be a problem because they are too small to identify.

If a major part of the unwanted inorganic fractions wish to be excluded the sieve needs to be 200 μm . However, in these fraction small foraminifera, both adults and juvenile will be lost. In some cases, the loss of the smaller foraminifera will affect the result of the study. Schröder et al (1987) therefore suggests that the 63 μm fraction is used, as a lower limit for the finest fraction, in scientific studies including benthic foraminifera because it will provide a better range of indicator species and produces larger assemblages.

Also (Sengupta & Machaincastillo 1993) are observant on the fact that laboratory procedures are not standardized in foraminifera ecology. Therefore should data concerning dominance and abundance be viewed with some caution, and if possible look at which size fractions that have been studied. (Sengupta & Machaincastillo 1993)

In the cases where different size fractions are used in low oxygen regions, the studies can not really tell if smaller species have an advantage over larger species in oxygen depleted region, because the result will simply be different depending on the chosen size fraction. However, larger species are not well documented in low oxygen regions (dyoxic, microxic, anoxic) conditions. (Gupta 2002)

In a study reviewed in (Gupta 2002) the conclusion regarding foraminifera and low oxygen conditions was that survival of foraminifera in anoxic environments was different in two separate size fractions. They therefore suggest that when sampling from low oxygen areas small size fractions are used when analyzing.

Abundance of foraminifera is in some oxygen depleted regions very high. Because of low predation pressure and opportunistic species that can use the high amount of dissolved organic material. (Gupta 2002)

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5 Method

3.1 Literature study

In this project previous studies have been reviewed. The direction has been to look at studies that somehow are related to the work with benthic foraminifera and where the same methods have been used.

In the data base Web of Knowledge three different search terms were made with the aim of going through different studies to see what size fractions that are normally used in studies with benthic foraminifera.

1-4a: Search terms: Benthic foraminifera – Title, paleoceanography – topic (Highest cited)

1-5b: Search terms: Benthic foraminifera – Title, paleoecology – topic (Highest cited)

1-5c: Search terms: Benthic foraminifera isotopes* - Title (Newest to oldest)

The hits from each search were then systematically worked through from top to bottom. The search terms helped to pick out relevant studies where benthic foraminifera are used. The results were put in to a table and are presented in the results below, see (table 2)

3.2 Laboratory analysis

Prepared samples from 10 cm³ of the core Geob3606-1 within the fraction 63-125 µm has been analyzed according to species and number of species within the samples. Foraminifera have been counted and identified in the fraction 63–125 µm. Earlier, McKay (in prep.) 125-250 µm, 250-500 µm and >500 µm.

The samples were picked out with regards to peaks and troughs in the other fractions that were analyzed.

The samples were prepared for microscope by evenly distribute them over a microfossil tray containing 45 squares. In some cases, when the samples contained much material, the sample was divided by using a sediment splitter. Some samples were even split twice.

The foraminifera were then identified and counted up to a total of >300. After counting up to 300, for method see (Murray 2006), individuals the foraminifera were multiplied up to an average value for the whole sample. This was done with help of the squares of the tray 45 for one tray 90 for two trays etc.

A total of 15 samples was analyzed. The data were put in to excel. The data were compared to earlier unpublished data done by McKay. A comparison between Individual occurrence and relative abundance in percentage in the different size fractions were made. In the McKay (In prep.) work, the samples representing the same depth as written below were picked out for the study.

The fifteen samples and their depth are shown in table 1.

Table 1. The fifteen analyzed samples in depths, meter.

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Depth (Meter)	4.23	4.78	5.08	5.23	5.48	8.18	8.33	8.53	8.58	8.63	8.78	8.98	9.03	9.33	9.58

Data from both individual species assemblages and abundance data were also put in to the program Tilia and excel to get illustrative charts.

Diatom data from Romero (2010) was used to plot against foraminifera abundance and total foraminifera concentration.

4 Results

4.1 Literature study

In five of the examined earlier studies, see (Table 2), >63 µm fraction is used. In two studies 4a and 5b in (table 1) they are using a mix of three different size fractions. Three uses the >150 µm fraction and 2 the >125 µm fraction. In one they use >200 µm fraction and in one >250 µm fraction.

4.2 Paleoecological analysis of foraminifera of the 63-125 µm fraction

4.2.1 Abundant foraminifera in the 63-125 µm fraction

Photos of all abundant species in the 63-125 µm fraction (Fig 4)

Fig. 3 shows relative percentage of all abundant foraminifera in the 63-125 µm fraction. It also show the total concentration of foraminifera per sample and the diatom concentration. The diatom concentration has been analyzed in (Romero 2010)

4.2.2 Comparison of benthic foraminifera assemblages between different size fractions

The graphs (Fig. 6-13) are representing individual abundance of species from fractions 63-125, 125-250, 250-500 and >500 µm fractions.

The graphs are representing species that are in some way different in abundance or total individual species abundance in the 63-125 µm fraction compared to the 125-250, 250-500 and >500 µm fractions. Graphs and raw data for all species from all size fractions are attached in appendix 1.

In the 15 samples used in this study the total number

Table 2. Fifteen reviewed studies. Title and field of research is included in every box 1-4a, 1-6b, 1-5c was found with different search methods. (See methods) The size fraction used is plotted in the box to the right.

1a. A low extinction rate of intermediate-water benthic foraminifera at the Cretaceous/Tertiary boundary. (Kaiho 1992) Field: paleontology/paleoecology/paleoceanography	>63 μm
2a. Paleocene to Neogene deep-sea paleoceanography in the eastern Indian Ocean: benthic foraminifera from ODP Sites 747, 757 and 758. (Nomura 1995) Field: Paleontology/paleoceanography	>63 or >149 μm
3a. Late Quaternary benthic foraminifera and deep-water paleoceanography in the South China Sea. (Jian & Wang 1997) Field: paleontology/paleoceanography	>150 μm
4a. Relevance of specimen size in distribution studies of deep-sea benthic foraminifera. (Gupta et al. 1987) Field: Paleoceanography	63+125+250 μm
1b. Paleocirculation of the Deep North Atlantic: 150,000-Year Record of benthic Foraminifera and Oxygen-18. (Streeter & Shackleton 1979) Field: Paleoceanography	>150 μm
2b. The distribution of benthic foraminifera in the Adriatic sea. (Jorissen 1987) Field: Paleontology/paleoecology	>150 μm
3b. Natural dissolution of modern shallow water benthic foraminifera: taphonomic effects on the paleoecological record. (Murray & Alve 1999) Field: Paleoecology	>63 μm
4b. Benthic foraminifera as indicators of changing Mediterranean-Atlantic water exchange in the late Miocene. (Seidenkrantz et al. 2000) Field: Paleoecology	>125 μm
5b. Deep-water changes: the near-synchronous disappearance of a group of benthic foraminifera from the Late Miocene Mediterranean. (Kouwenhoven et al. 1999) Field: Paleoecology	63+125+595 μm
6b. Sea-level history, 45,000 to 30,000 yr B.P., inferred from benthic foraminifera, Gulf St. Vincent, South Australia. (Cann et al. 1988) Field: paleoceanography	>63 μm
1c. Improved oxygen isotope temperature calibrations for cosmopolitan benthic foraminifera. (Marchitto et al. 2014) Field: Oxygen isotope study	>250 μm
2c. Sub-arctic Holocene climatic and oceanographic variability in Stjernesund, northern Norway: evidence from benthic foraminifera and stable isotopes. (Joseph et al. 2013) Field: Holocene climate/isotope	>125 μm

Table 2 continued. Fifteen reviewed studies. Title and field of research is included in every box 1-4a, 1-6b, 1-5c was found with different search methods. (See methods) In the left column number, title and field of study. In the right column, the used size fraction.

3c. Variation in stable carbon and oxygen isotopes of individual benthic foraminifera: tracers for quantifying the magnitude of isotopic disequilibrium. (Ishimura et al. 2012)	>63 μm
Field: carbon and oxygen isotopes	
4c. Benthic foraminifera and their stable isotope composition in sediment cores from lake qarun, Egypt: changes in water salinity during the past 500 years. (Abu-Zied et al. 2011)	>63 μm
Field: Stable isotopes	
5c. Boron isotopes and B/Ca in benthic foraminifera: Proxies for the deep ocean carbonate system. (Rae et al. 2011)	>200 μm
Field: Boron isotopes	

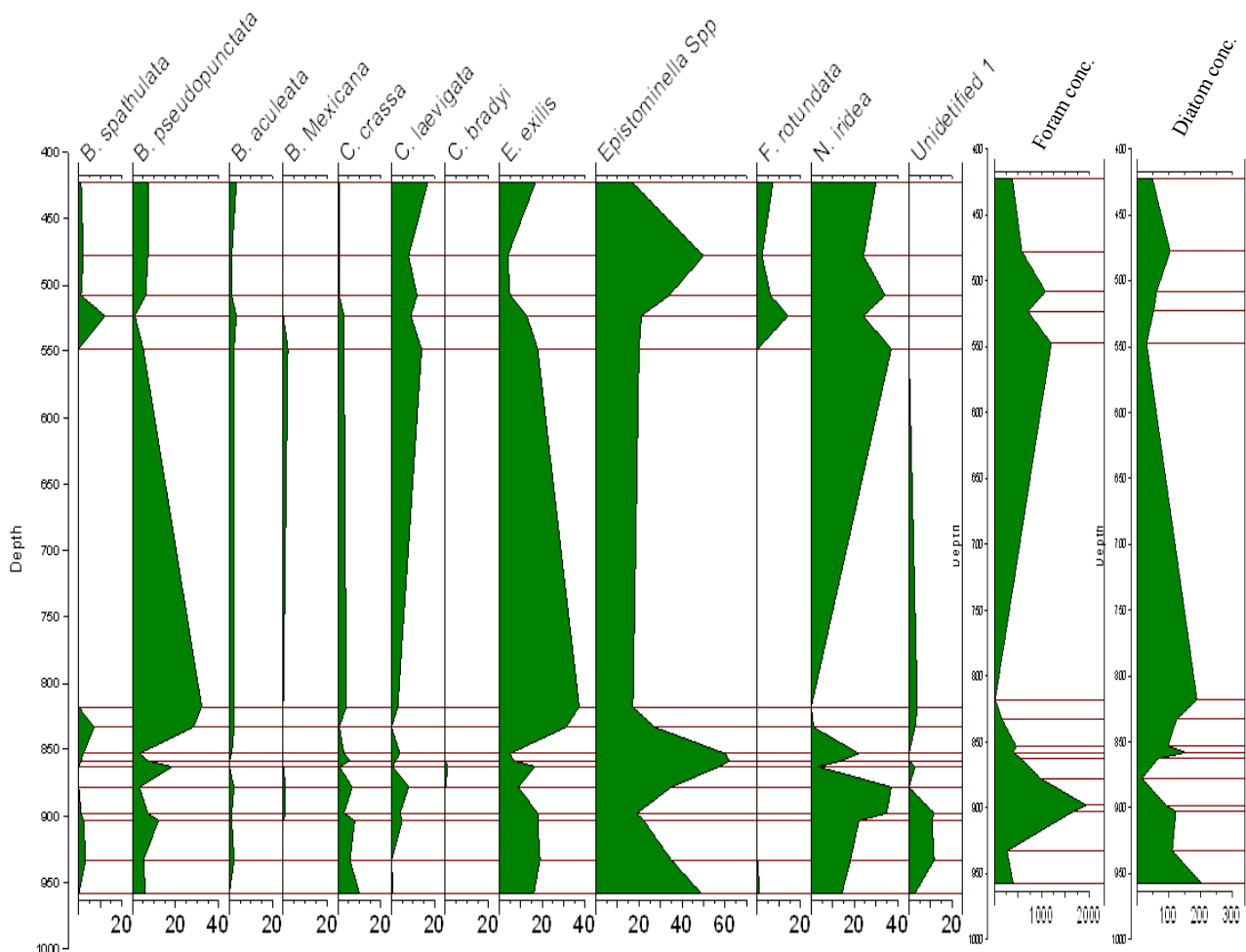


Fig 3. Abundance in percentage. All of the species abundant in 63-125 fraction. Total foraminifera concentration and diatom concentration.

of species found was 11. 8 of those species are shown in graphs in Fig. 6-13.

Overall are the 63-125 μm fractions showing simi-

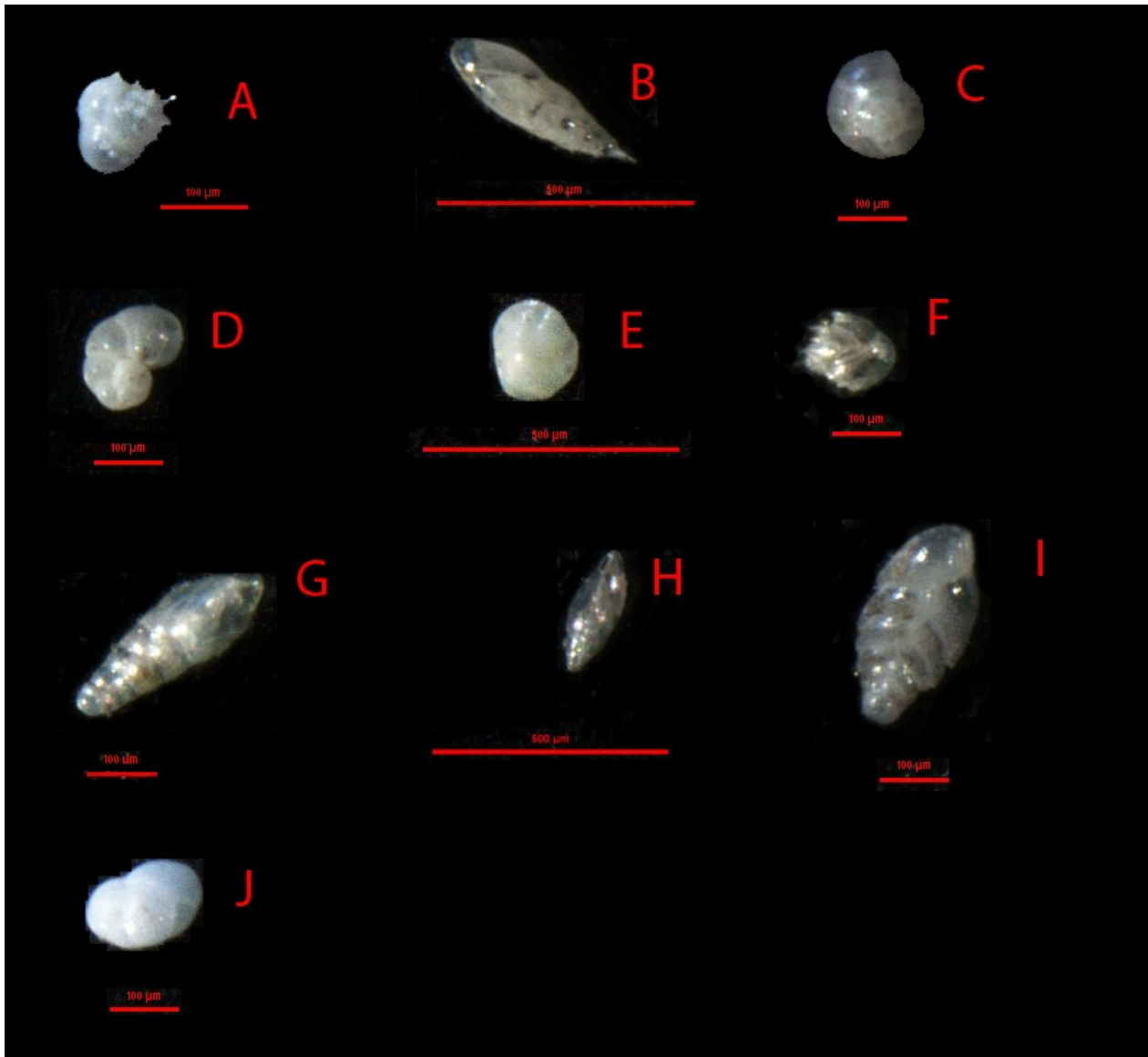


Fig 4. Abundant species in the 63-125 μm size fraction studied. **A:** *B. aculeata*, **B:** *E. exilis*, **C:** *Epistominella sp.*, **D:** *N. iridea*, **E:** *C. laevigata*, **F:** *B. mexicana*, **G:** *B. pseudopunctata*, **H:** *F. rotundata*, **I:** *B. spathulata*, **J:** *C. crassa*.

lar trends with the larger 125-250 μm fraction. Species *C. crassa*, *N. iridea* and *Epistominella sp.* show in the graphs, see (Fig. 6, 7 and 8) that they are more abundant in the 63-125 μm fractions than in the other fraction. *B. pseudopunctata* (Fig. 9) shows a little less abundance in the 63-125 μm fractions when compared to 125-250 μm . *B. Mexicana* is more abundant at certain depth (Fig. 10)

C. laevigata (Fig. 8) is showing the same pattern of abundance as in the larger fraction (125-250 μm) but it is less abundant in 63-125 μm fraction. The same goes for *E. exilis*, (Fig. 13) which is the most abundant species in the 125-250 μm , 250-500 μm and >500 μm fraction together.

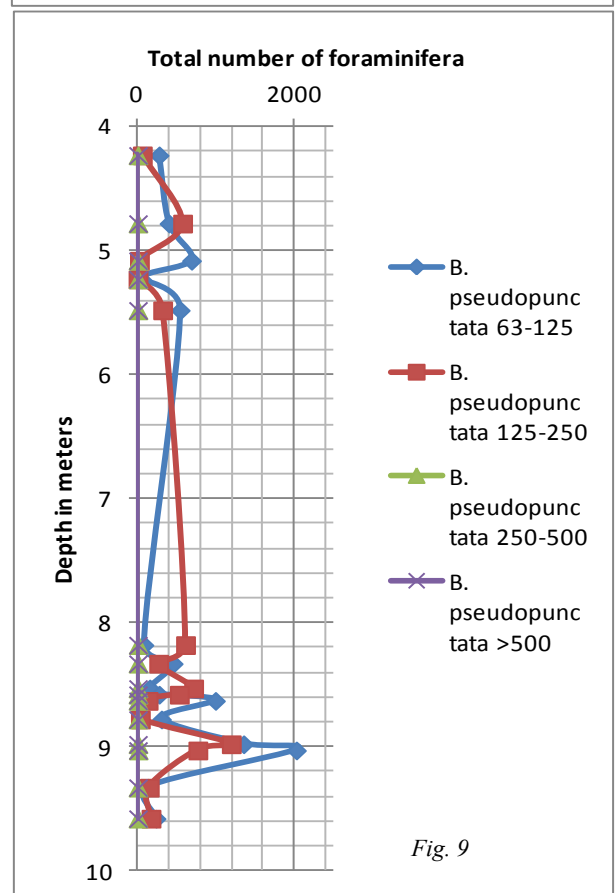
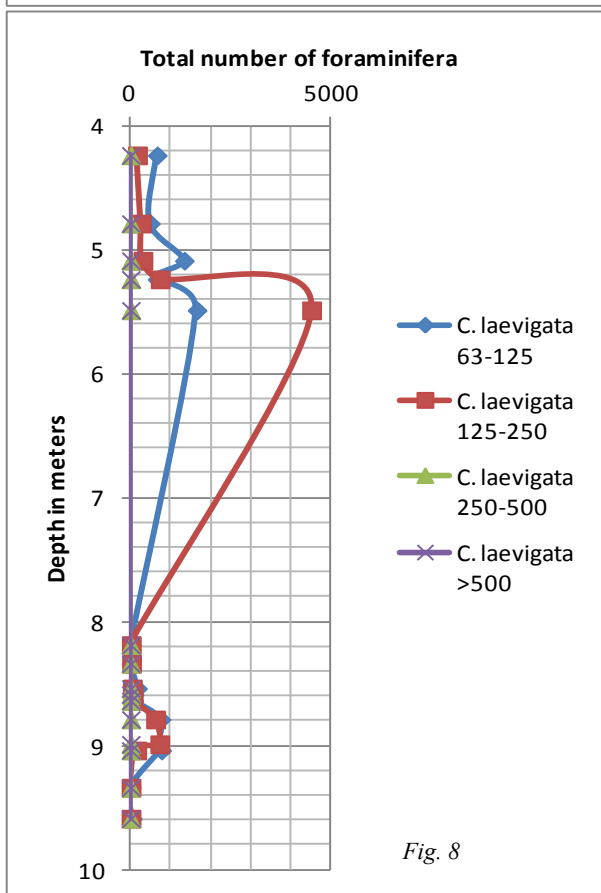
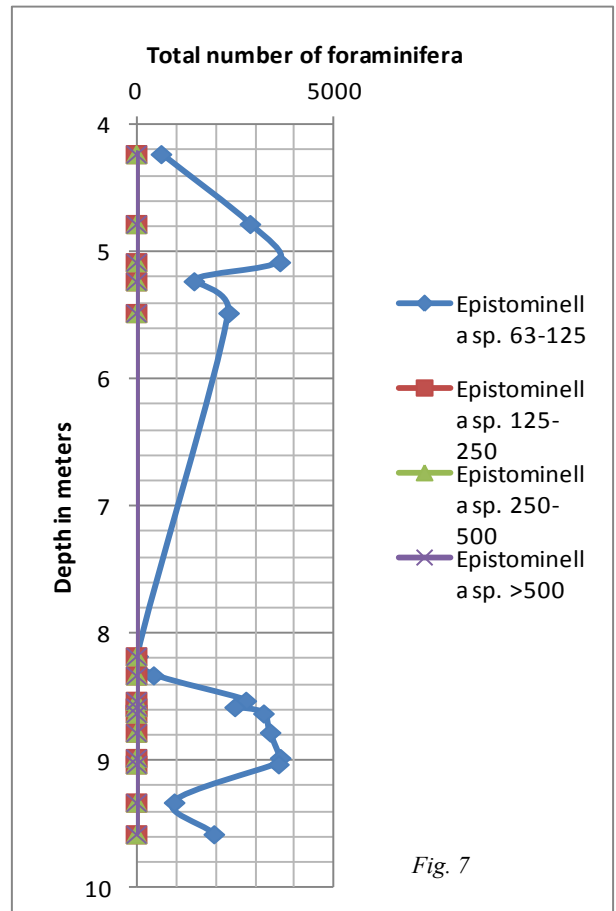
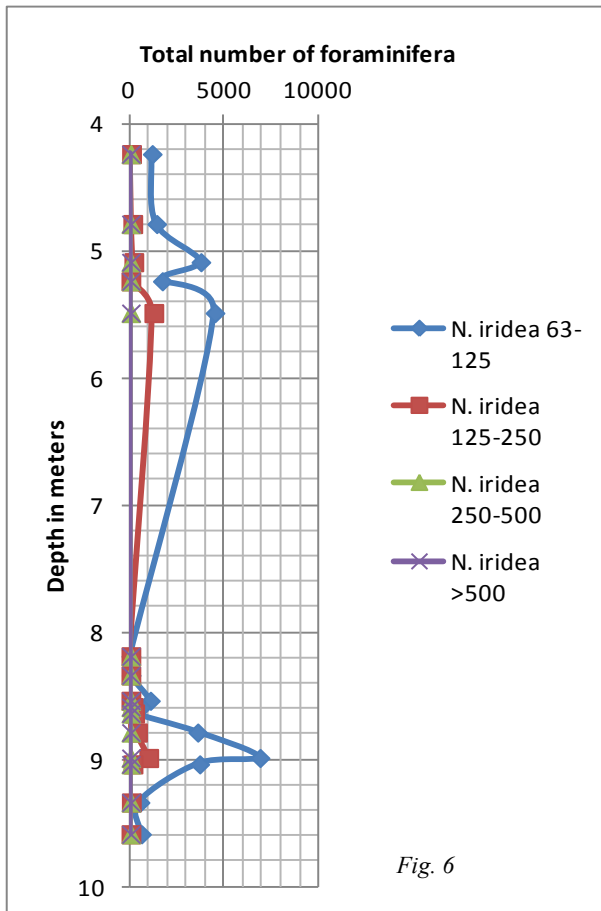
Some of the species found in 63-125 fraction were not

found in the 250-500 μm and >500 μm . Amongst them family *Epitominella sp* and species *C. crassa*. (Fig. 7 and 11)

4.2.3 Comparison of abundance in percentage between >63 μm and >125 μm fraction

The graphs (Fig. 14-24) are showing abundance in percentage. The blue line is abundance in >125 μm . (125-250 μm +250-500 μm +>500 μm) The red line is the abundance in percentage in >63 μm . (63-125 μm +125-250 μm +250-500 μm +>500 μm)

C. crassa and *Epistominella sp.* (Fig. 15 and 16) are more abundant in all of the 15 depth when the 63-125 μm fraction is included in the calculation. *N. Iridea* (Fig. 14) is more abundant in almost all of the samples when 63-125 μm fractions are included. *F. rotundata* (Fig. 22) is more abundant in the samples representing the depth: 4.23, 4.78, 5.08, 5.23 and 9.58. But at the other depth it is the same.



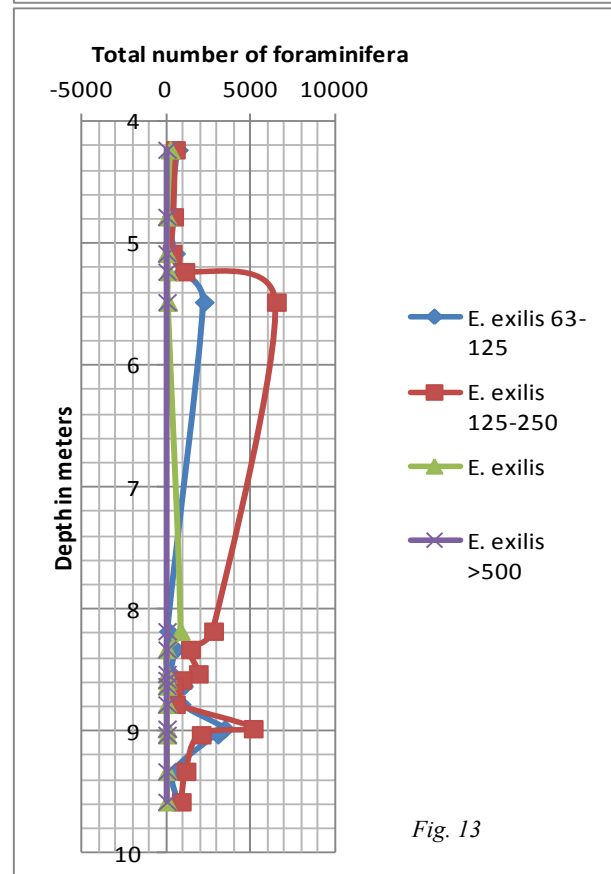
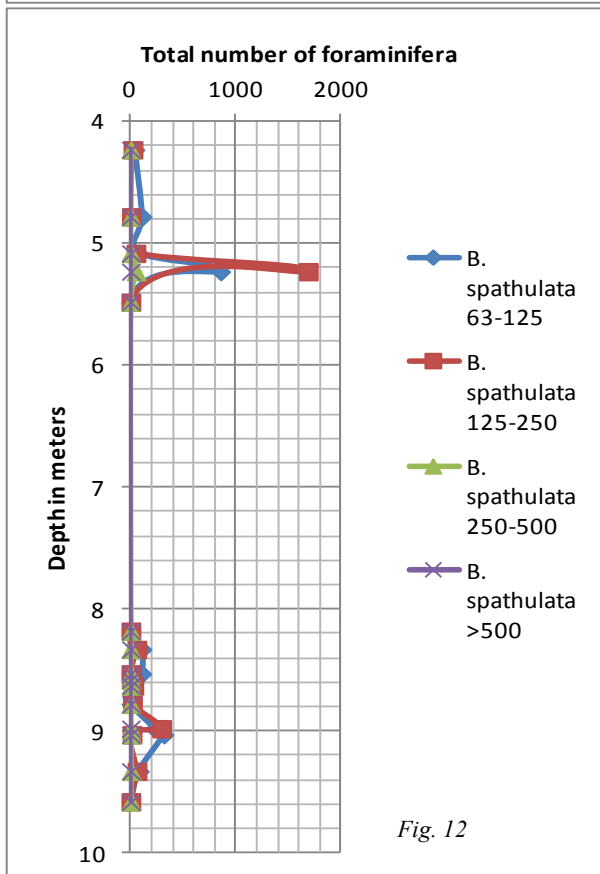
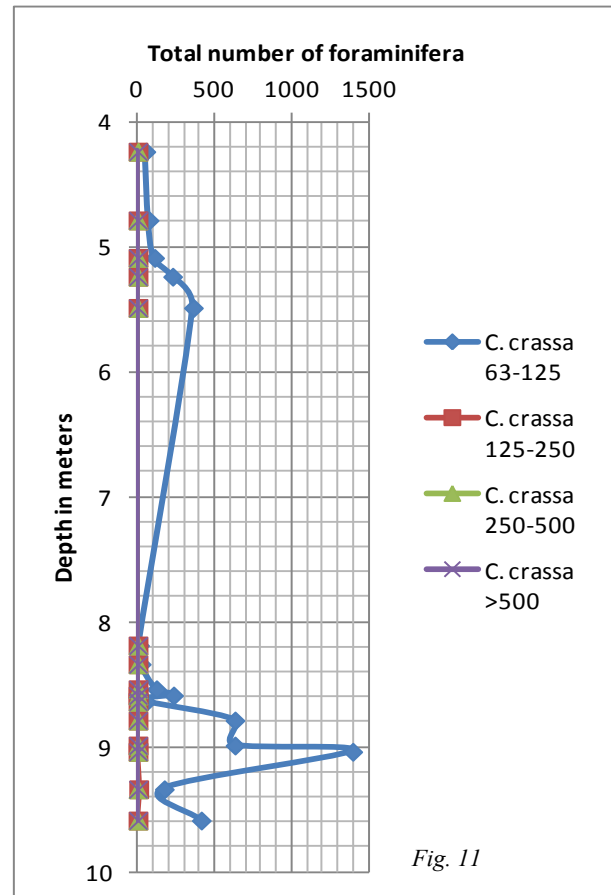
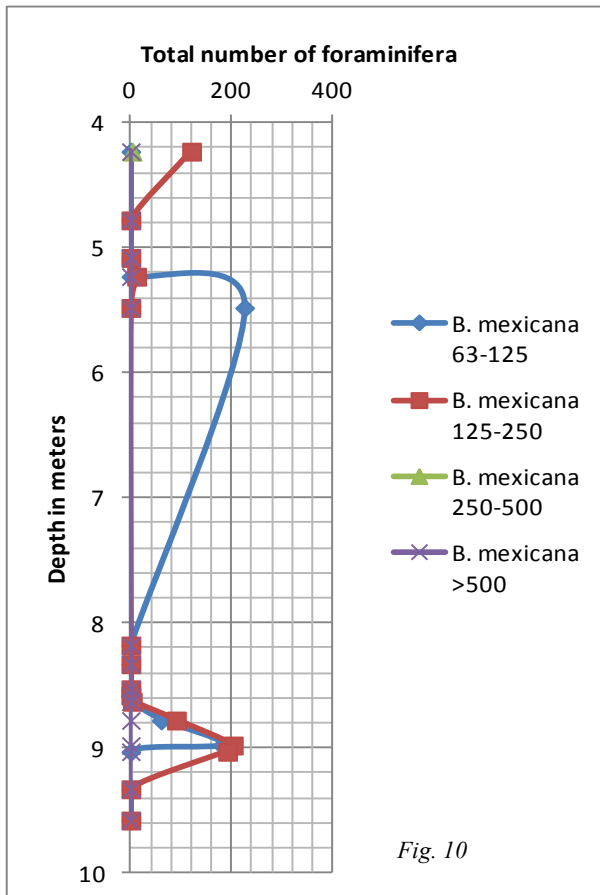
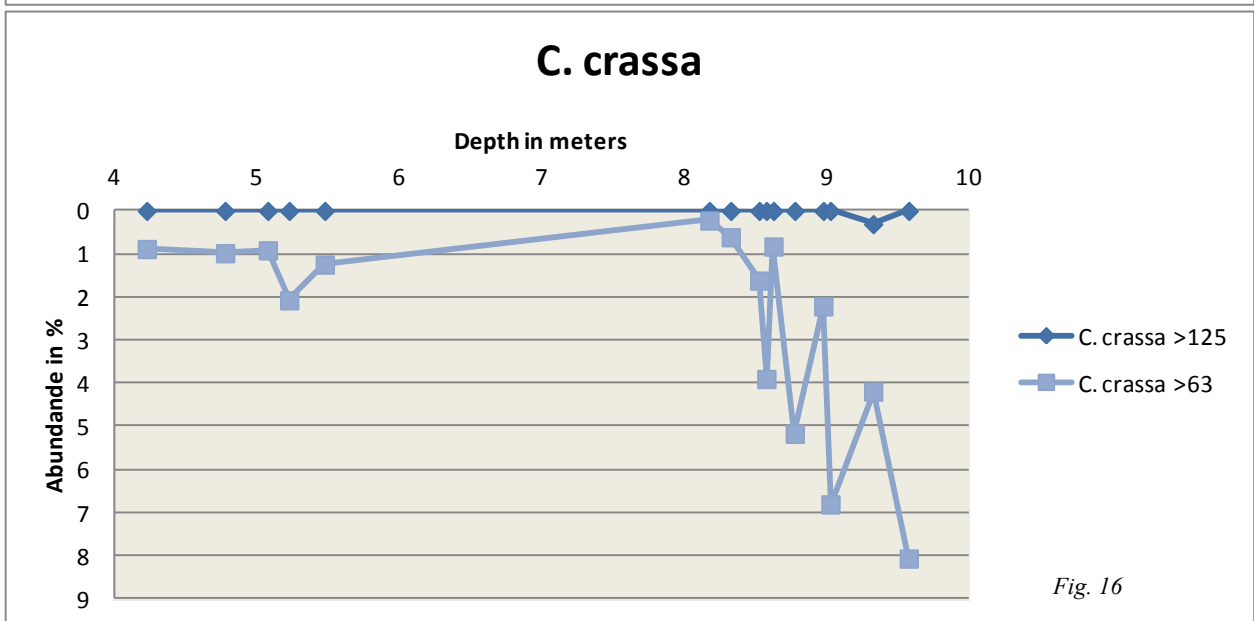
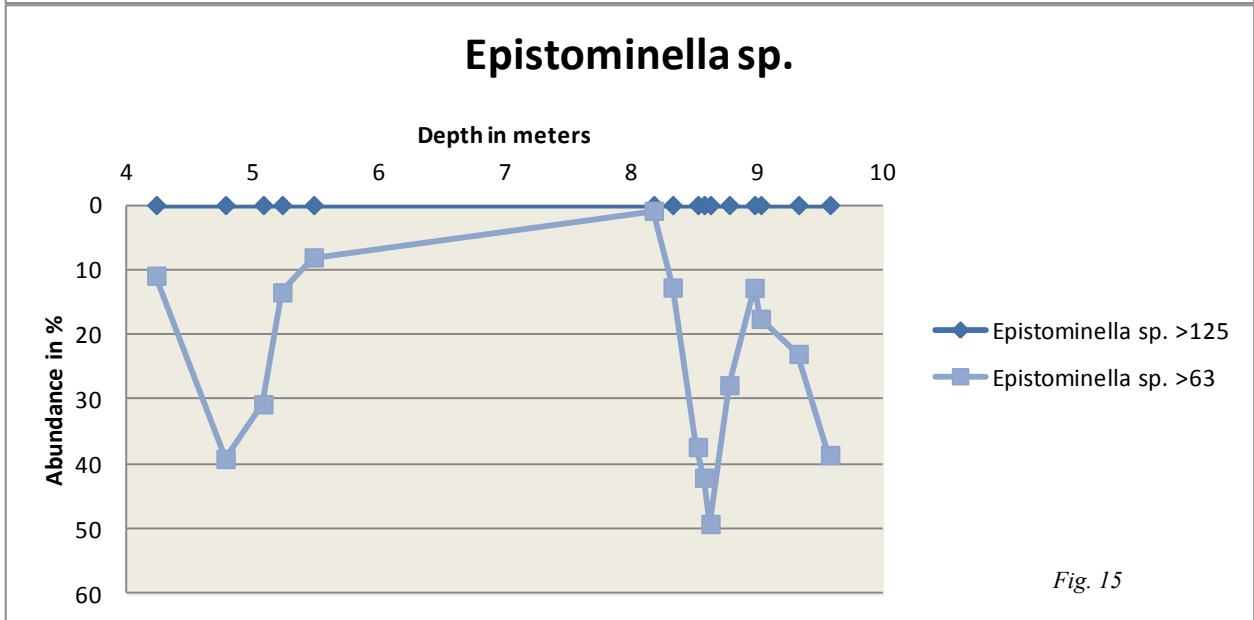
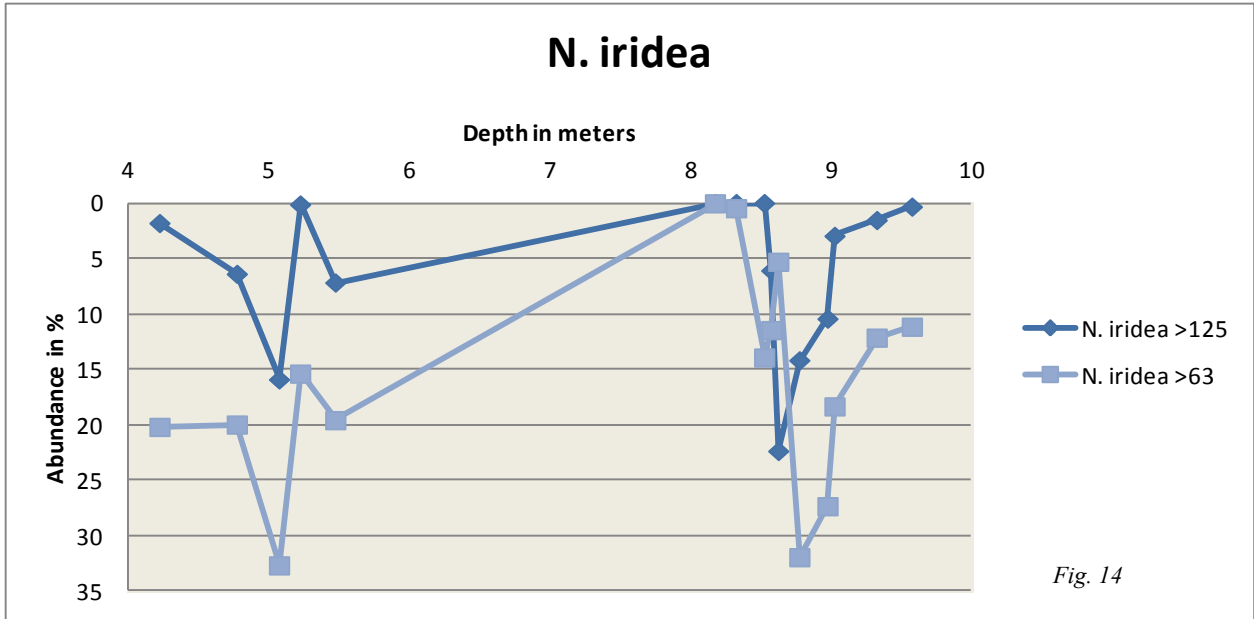


Fig. 6-13. Chosen species abundant in the 63-125 μ m fraction plotted against the larger fractions 125-250, 250-500 and >500. The values are equal to total number in foraminifera.



C. laevigata

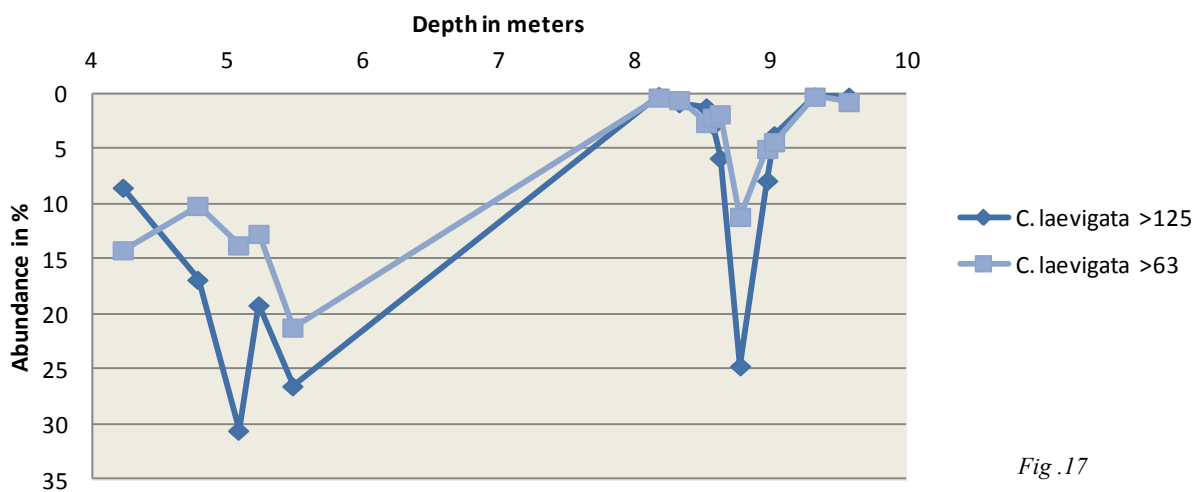


Fig. 17

E. exilis

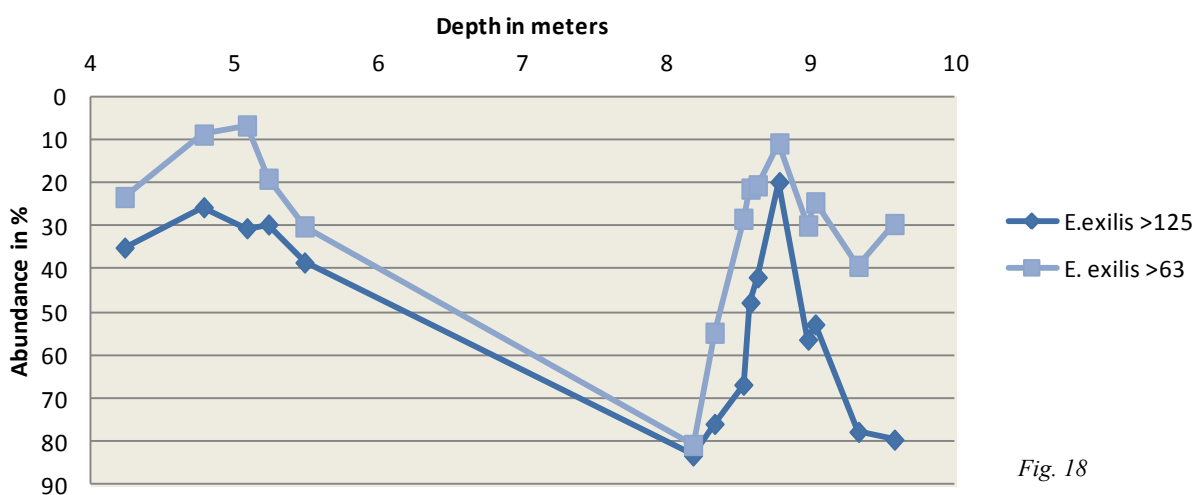


Fig. 18

B. aculeata

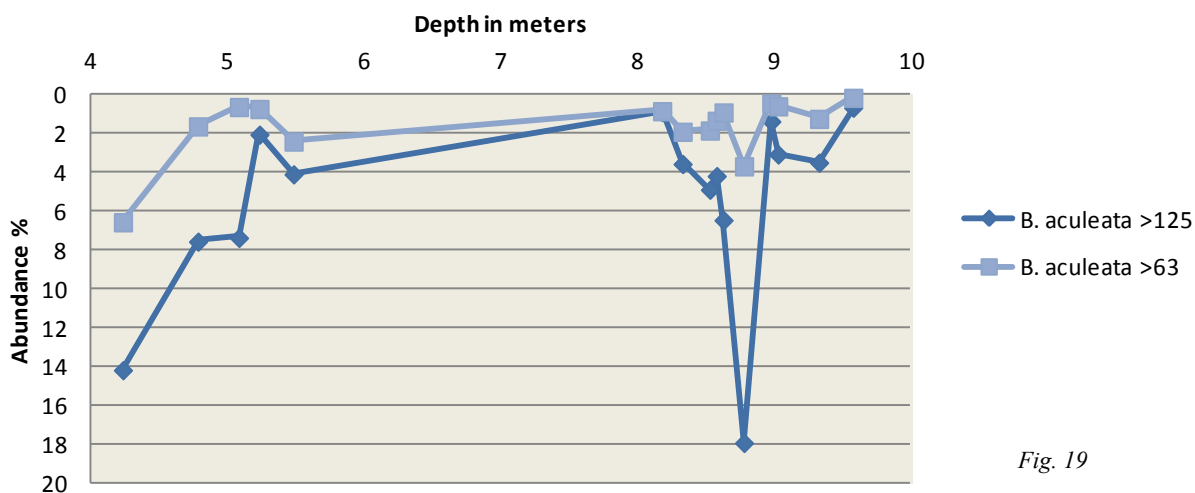


Fig. 19

B. bradyi

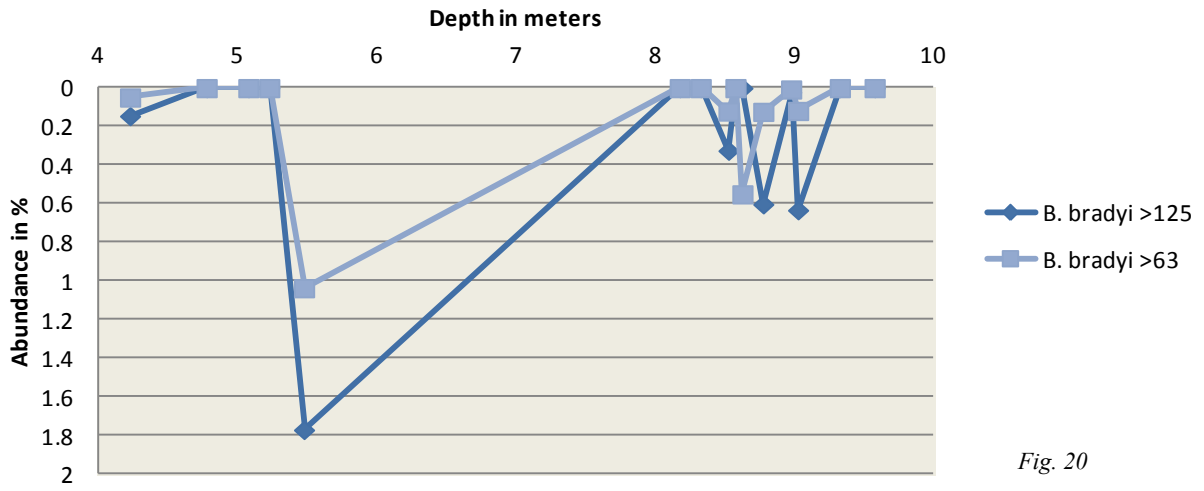


Fig. 20

B. pseudopunctata

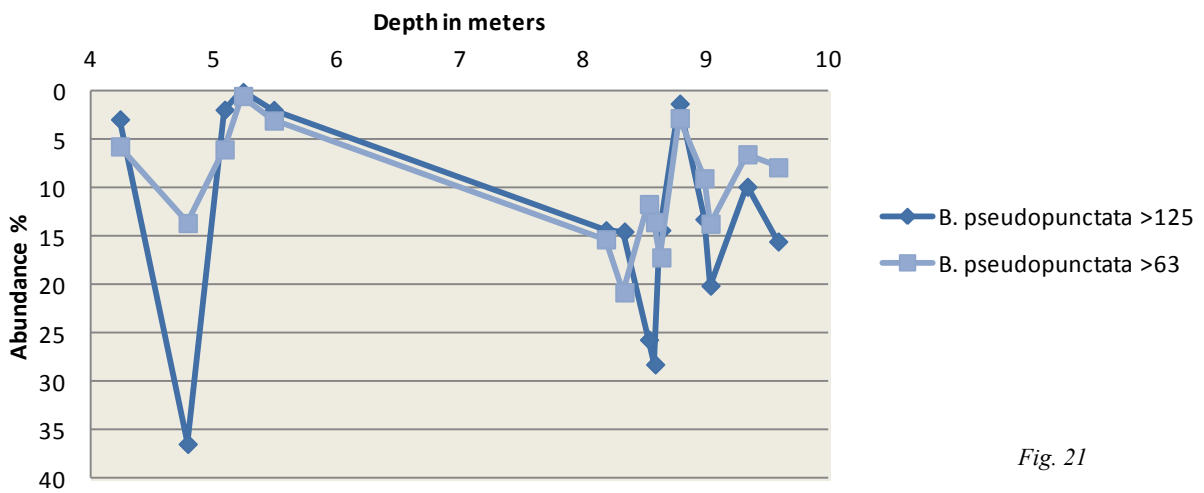


Fig. 21

F. rotundata

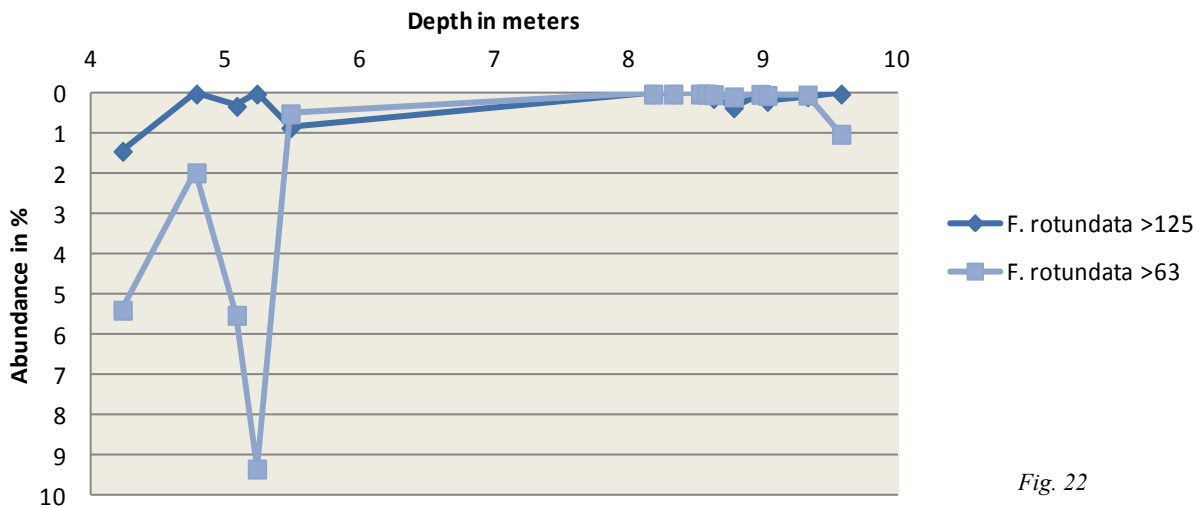


Fig. 22

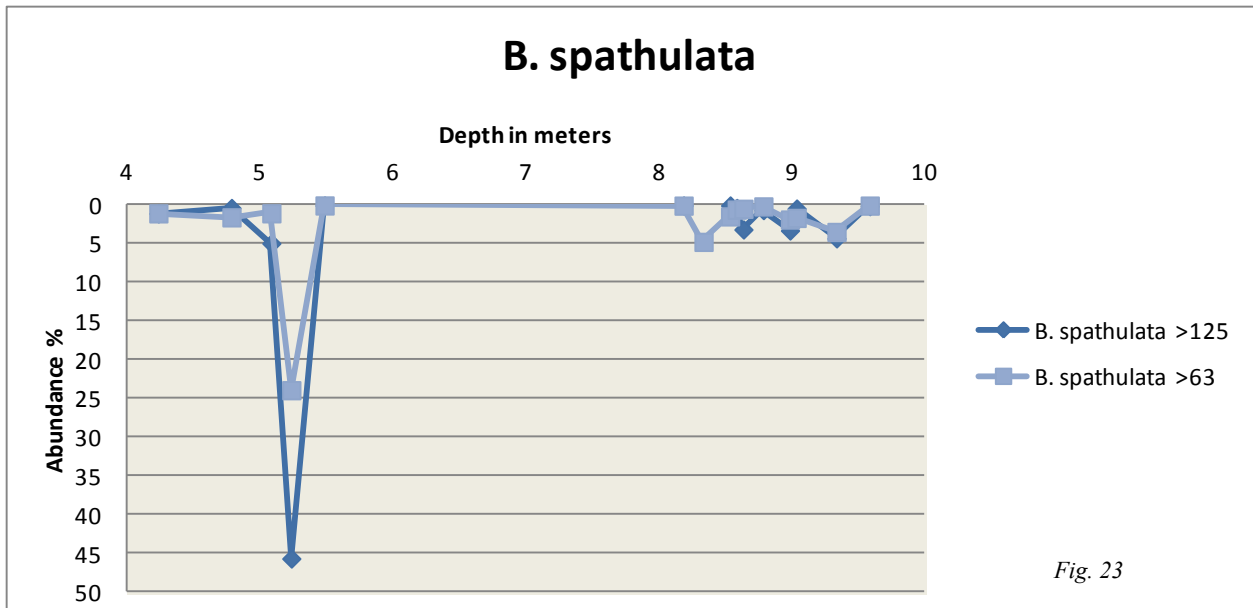


Fig. 23

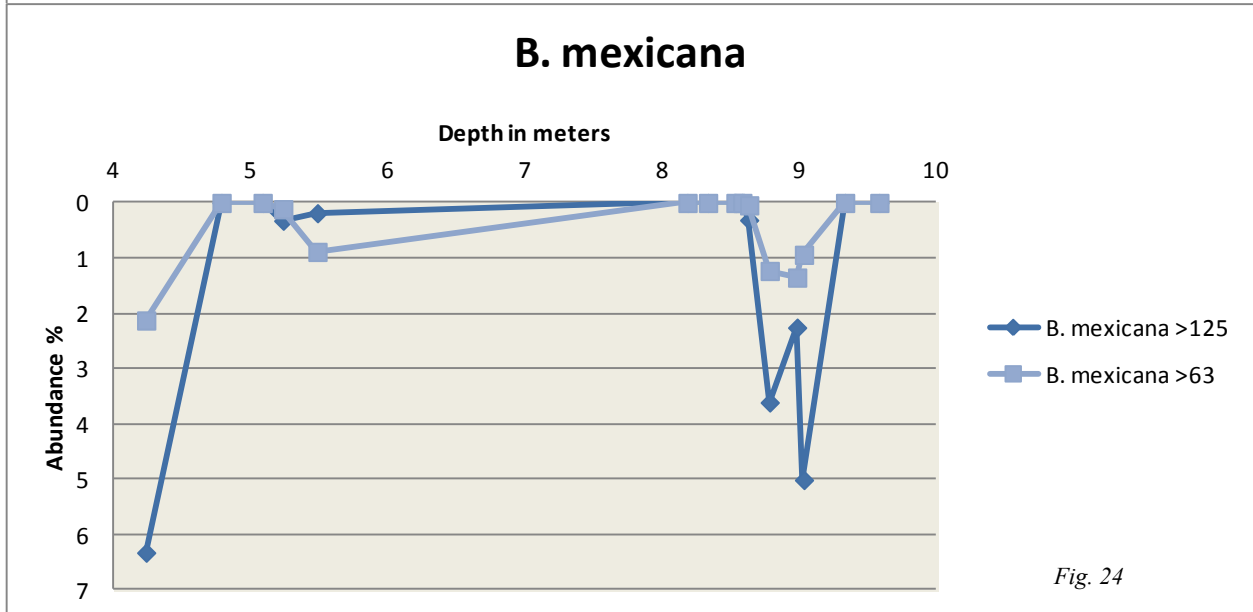


Fig. 24

Fig. 14-24. Abundance in percentage. The dark blue line is representing >125 μm (125-250 μm , 250-500 μm , >500 μm) The light blue is representing the >63 μm (63-125 μm , 125-250 μm , 250-500 μm , >500 μm fraction). Plotted against each other.

C. laevigata, *E. exilis* and *B. aculeata* (Fig. 17, 18 and 19) are all less abundant when the 63-125 μm fraction is included.

C. bradyi (Fig. 20) is less abundant in all of the fractions including 63-125 μm except at 8.63 m. *B. spathula* (Fig. 23) is less abundant at 5.08 m, 5.23 m, 8.63 m, 8.98 m, 9.33 m. (Much less abundant at 5.23 rest is pretty much alike)

B. mexicana (Fig. 24) is less abundant at 8.78 m, 8.98 m and 9.03 m.

5 Discussion

The literature study shows that different size fractions are used when research is performed with benthic foraminifera.

The approach in the literature study that was performed was to get a perception of the different sieve sizes that are used. In general the aim of studies with benthic foraminifera is affecting the size fraction used. When paleoceanographic studies and in particular when benthic foraminifera are used in isotopic studies, the sieve size is less important, and therefore a larger fraction is often chosen. But, when the faunal assemblages are important in the study, it is obvious that if the finer fraction is being ignored, the abundance and faunal assemblage will not be presented in a correct way.

When the diatom concentration is plotted against the abundance in the 63-125 μm fraction there is a high correlation between high diatom concentration

and species *Epistominella sp.*, *N. iridea*, *E. exilis* and *B. Pseudopunctata*, (Fig. 3).

It is shown in the results that the abundance and faunal assemblage is affected when a fraction of 63-125 μm is analyzed and plotted versus the larger fractions. The species that are found in higher number are all small sized, e.g. *Epistominella sp.*, *C. crassa* and *N. iridea*. (Fig. 6, 7, 11)

This is explained by two reasons. This region is located at an upwelling zone where the primary production, organic input to the sea floor and oxygen depleted water are characterizing the environmental conditions. The species that can take advantage of the high organic input to the sea floor and tolerate the low oxygen conditions will thrive. *Epistominella sp.* is a good example of a family with small species that can feed from the detritus and because of its small size is very tolerate against low oxygen conditions. This family is significantly unrepresented in the larger fraction and show an opportunistic life cycle in the deep sea. *E. Exilis* grows larger than *Epistominella sp.* and is abundant in all fractions between 63-500 μm . In this case this might be because of the spiral-like shape of *E. Exilis* and *B. Pseudopunctata* (Fig. 4) and why they are abundant in the both the finer fractions and the larger ones. They are simply thin and long and will therefore slide through the finer sieve sizes. Another explanation might be that their size will be directly dependant on the amount of oxygen, and they will grow large only if the oxygen level will allow them.

Highly abundance of *E. exilis* and *Epistominella sp.* (Fig. 3) where high diatom abundance is appearing. Both these species can take advantage of the organic fluxes that are reaching the sea floor, and that is why there are peaks of the species where there are high concentrations of diatoms. *C. crassa* is feeding on fresh input of organic matter from the surface water. The species is not very abundant if compared to *Epistominella sp.*, and *E. exilis*. But, the abundance of it is much higher if the 63-125 μm is analyzed. When studying the results from the relative percentage in abundance between the >125 fractions the >63 fractions it is easy notable that there are differences. The family *Epistominella sp.* and the specie *C. crassa* are both more abundant in all of the comparable sample depth. *N. iredea* is more abundant in almost all. *C. laevigata* and *E. exilis* are showing the opposite trend which means that they are all less abundant at all of the sample depth when the 63-125 μm fraction is included. This means that we have a result that is different in both ways, some species are more abundant and some are less abundant. Because of the highly abundance of *Epistominella sp.* and *C. crassa* in the size fraction 63-125 μm the result in relative abundance for some species, like *E. exilis* will be less abundant. The small low oxygen tolerate species that are opportunistic will not be represented if the finer fractions are not used. The abundance of the dominant species in the fractions without the 63-125 μm fraction is risking not only to show less species abundance and lower

foraminifera individual richness but also to give misleading information when it comes to ecology and ocean conditions like productivity, organic fluxes and oxygen levels.

Even if oxygen level and high organic fluxes to the sea floor most likely are the main factors controlling the distribution and faunal assemblage at this region, one should not disregard the importance of microhabitats affecting the foraminifera. It has been showed that the chemical conditions can differ a lot in sediment within the same region, and the explanation of high abundance of opportunistic species at sites can in some cases be explained by microhabitats. However, any interpretations or conclusions regarding the effect of microhabitat influencing can not be made from or within this study.

When the planning for this thesis was done, 20 samples were decided to be analyzed. Because of the limited time of this project and the time consuming lab work 15 samples were analyzed. To get a overall more trustworthy result, all the samples from the core that are analyzed for the larger fractions should also be analyzed within the 63-125 μm fraction. By doing that it would be possible not only to distinguish the large scale trends like carbon fluxes and ecological features, but also to see minor fluctuations and patterns and secure them with a stronger scientific support.

6 Conclusion

When studying foraminifera from upwelling areas like the ones in this study, the 63-125 μm fraction should definitely be included in the analysis. Without looking at the finer fraction, the faunal assemblages and total number of foraminifera can and will change the total number and relative abundance because species like *Epistominella sp.*, *C. crassa* and *N. iridea* that are small sized will be washed out if >125 fraction is used. But if the study is more orientated towards paleoceanography or isotope studies, it may not make a difference if the 63-125 μm fraction is ignored in the study because the ecological assemblage of species are not as important in those cases.

Of course the aim of the study and the use of the data should decide and assess which size fraction that is best used in each case. If the study is focusing on the faunal assemblages it needs to be accurate and present all species. If the aim of work with foraminifera is more comprehensive and large-scale studies the courser fractions can give enough information. The comparison between studies is also problematic when different size fractions are used and also favors for a lower sieve size so that studies easily can be compared.

C. crassa and *Epistominella sp.* are more abundant if the 63-125 μm than in size fractions >125 μm . High diatom concentration correlates with species that favor high organic input *Epistominella sp.* and *E. exilis*. *C. crassa* is more abundant in the 63-125 μm fraction than in >125. These species will be underrepresented

and important indicator species of organic carbon fluxes will not be included unless this fraction is analyzed.

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8 References

- Abu-Zied, R. H., Keatings, K., Flower, R. J. & Leng, M. J., 2011: Benthic foraminifera and their stable isotope composition in sediment cores from Lake Qarun, Egypt: changes in water salinity during the past similar to 500 years. *Journal of Paleolimnology* 45, 167-182.
- Berger, W. H. & Diesterhaass, L., 1988: PALEOPRODUCTIVITY - THE BENTHIC PLANKTONIC RATIO IN FORAMINIFERA AS A PRODUCTIVITY INDEX. *Marine Geology* 81, 15-25.
- Cann, J. H., Belperio, A. P., Gostin, V. A. & Murraywallace, C. V., 1988: SEA-LEVEL HISTORY, 45,000 TO 30,000 YR BP, INFERRED FROM BENTHIC FORAMINIFERA, GULF ST VINCENT, SOUTH-AUSTRALIA. *Quaternary Research* 29, 153-175.
- Corliss, B. H., 1985: MICROHABITATS OF BENTHIC FORAMINIFERA WITHIN DEEP-SEA SEDIMENTS. *Nature* 314, 435-438.
- Filipsson, H. L., Romero, O. E., Stuut, J. B. W. & Donner, B., 2011: Relationships between primary productivity and bottom-water oxygenation off northwest Africa during the last deglaciation. *Journal of Quaternary Science* 26, 448-456.
- Gooday, A. J. 2003: Benthic foraminifera (protista) as tools in deep-water palaeoceanography: Environmental influences on faunal characteristics. In A. J. Southwards, P. A. Tyler, C. M. Young & L. A. Fuiman (eds.): *Advances in Marine Biology*, Vol 46, 1-90. Academic Press Ltd-Elsevier Science Ltd.
- Gupta, B. K. S., 2002: *Modern Foraminifera*. Kluwer Academic Publishers.
- Gupta, B. K. S., Shin, I. C. & Wendler, S. T., 1987: RELEVANCE OF SPECIMEN SIZE IN DISTRIBUTION STUDIES OF DEEP-SEA BENTHIC FORAMINIFERA. *Palaios* 2, 332-338.
- Ishimura, T., Tsunogai, U., Hasegawa, S., Nakagawa, F., Oi, T., Kitazato, H., Suga, H. & Toyofuku, T., 2012: Variation in stable carbon and oxygen isotopes of individual benthic foraminifera: tracers for quantifying the magnitude of isotopic disequilibrium. *Biogeosciences* 9, 4353-4367.
- Jian, Z. M. & Wang, L. J., 1997: Late Quaternary benthic foraminifera and deep-water paleoceanography in the South China Sea. *Marine Micropaleontology* 32, 127-154.
- Jorissen, F. J., 1987: THE DISTRIBUTION OF BENTHIC FORAMINIFERA IN THE ADRIATIC SEA. *Marine Micropaleontology* 12, 21-48.
- Joseph, N., Lopez Correa, M., Schonfeld, J., Ruggerberg, A. & Freiwald, A., 2013: Sub-arctic Holocene climatic and oceanographic variability in Stjernsund, northern Norway: evidence from benthic foraminifera and stable isotopes. *Boreas* 42, 511-531.
- Kaiho, K., 1992: A LOW EXTINCTION RATE OF INTERMEDIATE-WATER BENTHIC FORAMINIFERA AT THE CRETACEOUS TERTIARY BOUNDARY. *Marine Micropaleontology* 18, 229-259.
- Kouwenhoven, T. J., Seidenkrantz, M. S. & Van Der Zwaan, G. J., 1999: Deep-water changes: the near-synchronous disappearance of a group of benthic foraminifera from the Late Miocene Mediterranean. *Palaeogeography Palaeoclimatology Palaeoecology* 152, 259-281.
- Kuypers, M. M. M., Lavik, G., Woebken, D., Schmid, M., Fuchs, B. M., Amann, R., Jorgensen, B. B. & Jetten, M. S. M., 2005: Massive nitrogen loss from the Benguela upwelling system through anaerobic ammonium oxidation. *Proceedings of the National Academy of Sciences of the United States of America* 102, 6478-6483.
- Marchitto, T. M., Curry, W. B., Lynch-Stieglitz, J., Bryan, S. P., Cobb, K. M. & Lund, D. C., 2014: Improved oxygen isotope temperature calibrations for cosmopolitan benthic foraminifera. *Geochimica Et Cosmochimica Acta* 130, 1-11.
- Max-Planck-Institute for marine microbiology, 02.03.2009.
Url:https://www.mpi-bremen.de/en/The_Marine_Nitrogen_Cycle_-_Revisited.html
Visited: 22.05.2014
- Murray, J., 2006: *Ecology and Applications of benthic foraminifera*. Cambridge university press.
- Murray, J. W. & Alve, E., 1999: Natural dissolution of modern shallow water benthic foraminifera: taphonomic effects on the palaeoecological record. *Palaeogeography Palaeoclimatology Palaeoecology* 146, 195-209.
- Nomura, R., 1995: Paleogene to neogene deep-sea paleoceanography in the eastern Indian ocean: Benthic foraminifera from ODP sites 747, 757 and 758. *Micropaleontology* 41, 251-290.
- Rae, J. W. B., Foster, G. L., Schmidt, D. N. & Elliott, T., 2011: Boron isotopes and B/Ca in benthic foraminifera: Proxies for the deep ocean carbonate system. *Earth and Planetary Science Letters* 302, 403-413.
- Romero, O. E., 2010: Changes in style and intensity of production in the Southeastern Atlantic over the last 70,000 yr. *Marine Micropaleontology* 74, 15-28.
- Schroder, C. J., Scott, D. B. & Medioli, F. S., 1987:

CAN SMALLER BENTHIC FORAMINIFERA BE IGNORED IN PALEOENVIRONMENTAL ANALYSES. *Journal of Foraminiferal Research* 17, 101-105.

Seidenkrantz, M. S., Kouwenhoven, T. J., Jorissen, F. J., Shackleton, N. J. & Van Der Zwaan, G. J., 2000: Benthic foraminifera as indicators of changing Mediterranean-Atlantic water exchange in the late Miocene. *Marine Geology* 163, 387-407.

Sengupta, B. K. & Machaincastillo, M. L., 1993: BENTHIC FORAMINIFERA IN OXYGEN-POOR HABITATS. *Marine Micropaleontology* 20, 183-201.

Streeter, S. S. & Shackleton, N. J., 1979: PALEOCIRCULATION OF DEEP NORTH-ATLANTIC - 150,000-YEAR RECORD OF BENTHIC FORAMINIFERA AND O-18. *Science* 203, 168-171.

Suhr, S. B. & Pond, D. W., 2006: Antarctic benthic foraminifera facilitate rapid cycling of phytoplankton-derived organic carbon. *Deep-Sea Research Part II-Topical Studies in Oceanography* 53, 895-902



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