REFEREE #1

REF.1 COMMENT: **Statistical analyses:** While reading the ms I get repeatedly the impression that the authors relate foraminifera abundance or area density to a single environmental parameter (e.g. L276-283, L286-287, L613, these are just some examples). How did they distinguish between the influence of covarying environmental parameters? (and how is that possible by doing a PCA on the environmental parameters?). They have used the PCA to describe the variability in the environmental parameters and plotted the foraminifera data in the PCA space. These plots go some way towards a meaningful statistical analysis, but it is still hard to see (and impossible to quantify) the correlations to which the authors repeatedly refer. It would make more sense to then use the PCA scores and see how these correlate (in a scatter plot) with the abundance or area density. Better still would be to use CCA to take both the environmental and the foraminiferal data into account.

ANSWER: Plankton tow results are usually not related to a *unique* environmental parameter but to co-varying parameters; as mentioned in the above comment there are likely multiple factors affecting their physiology and distribution. We decided to apply the PCA for the statistical analysis of the environmental parameters as we consider it as appropriate and sufficient for the purpose of this study (e.g., Schiebel et al., 2001; Horigome et al., 2014). In order to discuss the foraminiferal results we characterize and distinguish different sea surface water masses and the PCA is a tool for achieving this. The PCA doesn't strictly allow the distinction between the influence of covarying environmental parameters. However, it can produce valuable results to better understand in which water masses/environment the foraminifera were retrieved. We will put emphasis in the revised manuscript on the outcomes of the PCA and as suggested by the referee we provide the scatter plots combining both the PCA scores (for each factor) and the abundances or the density area (see fig R1), although this new figure presents the exact same characteristics presented in figure 3 of the revised manuscript. The two first factors produced by the PCA performed on the environmental parameters account for more than 77% of the total variance of all the parameters taken together. As such, we attributed the 1st factor to the temperature and the food availability (inferred here from the nutrients concentrations and the fluorescence (Fig. 3 of the revised manuscript)). This 1st factor explaining more than 55% of the variance depicts well the general trend observed in the Mediterranean Sea with in general colder and more productive waters in the western basin and warmer and less productive waters in the eastern one (see Fig. 1c of the revised manuscript for the fluorescence). The 2nd factor accounts for about 22 % of the total variance and is attributed to the carbonate system. Once again this reflects the general trend observed within the Mediterranean Sea with in general lower [CO_3^{2-}] waters in the western basin compared to the eastern basin (see Fig. 1d-e of the revised manuscript for the distribution of pH and [CO_3^{2-}]). We added a new table in the revised manuscript presenting the loadings of the environmental parameters in the PCA and additional Pearson correlation coefficients (r) for relationships between the environmental parameters, the PCA factors, the abundances of the selected species and the density area of the selected species (Table 2).

From Fig R1 and Table 2, we can see that in general the total abundances are higher when the factor 1 is >0 and factor 2 <0 (Fig R1 a and g) in other words when the temperature is lower, the food availability id higher and the pH lower such as in the western basin, with the exception of st. 15 and 16-18 (factor 1, fig R1a) and st. 10 and 12 (factor 2, fig R1 g). The same pattern is observed for *T. sacculifer* (without sac) (fig R1 c and i), *G. bulloides* (fig R1 e and k) and to a lesser degree for *G. inflata* (fig R1 b and h) as no significant correlations are found between the abundances of this species and the 2 factors (fig R1 b and h). The opposite trend is observed for *G. ruber* (white), with in general higher abundances observed when the temperature is higher, the food availability is lower and the pH higher such as in the eastern basin (fig R1 d and g) although no significant correlations are observed (Table 2). Finally no significant correlations were found between the abundances of *O. universa* and the 2 factors (fig R1 f and l; Table 2).

When we compare the density area to factor 1 and factor 2 (Fig R2), it shows for *G. ruber* (white) that ρ_A is higher when the temperature are lower, the food availability higher and the pH lower (Fig R2 a and d). The opposite occurs for *G. bulloides* and *O. universa,* for which the ρ_A is higher when the temperature is higher, the food availability lower and the pH higher (fig R2, b and e).

For both *G. bulloides* and *G. ruber* (white) these observations taken together show that the two species have a higher ρ_A when they are less abundant.

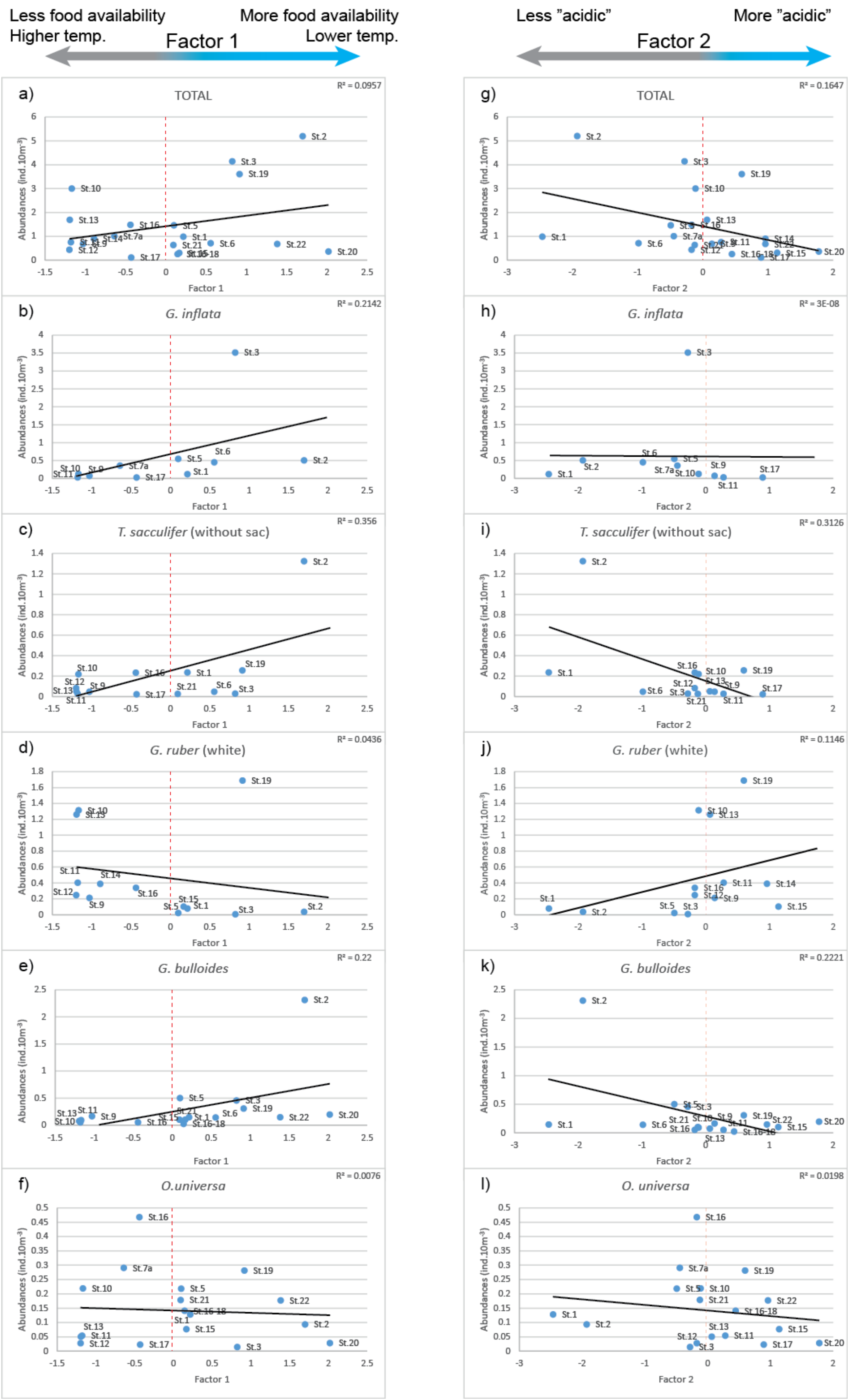


Fig R1: scatter plots between the PCA scores (factor 1 on the left and factor 2 on the right) and the total abundances (a and g), *G. inflata* (b and h), *T sacculifer* (without sac) (c and i), *G. ruber* (white) (d and j), *G. bulloides* (e and k) and *O. universa* (f and l). The red dotted lines show the zero of each factor.

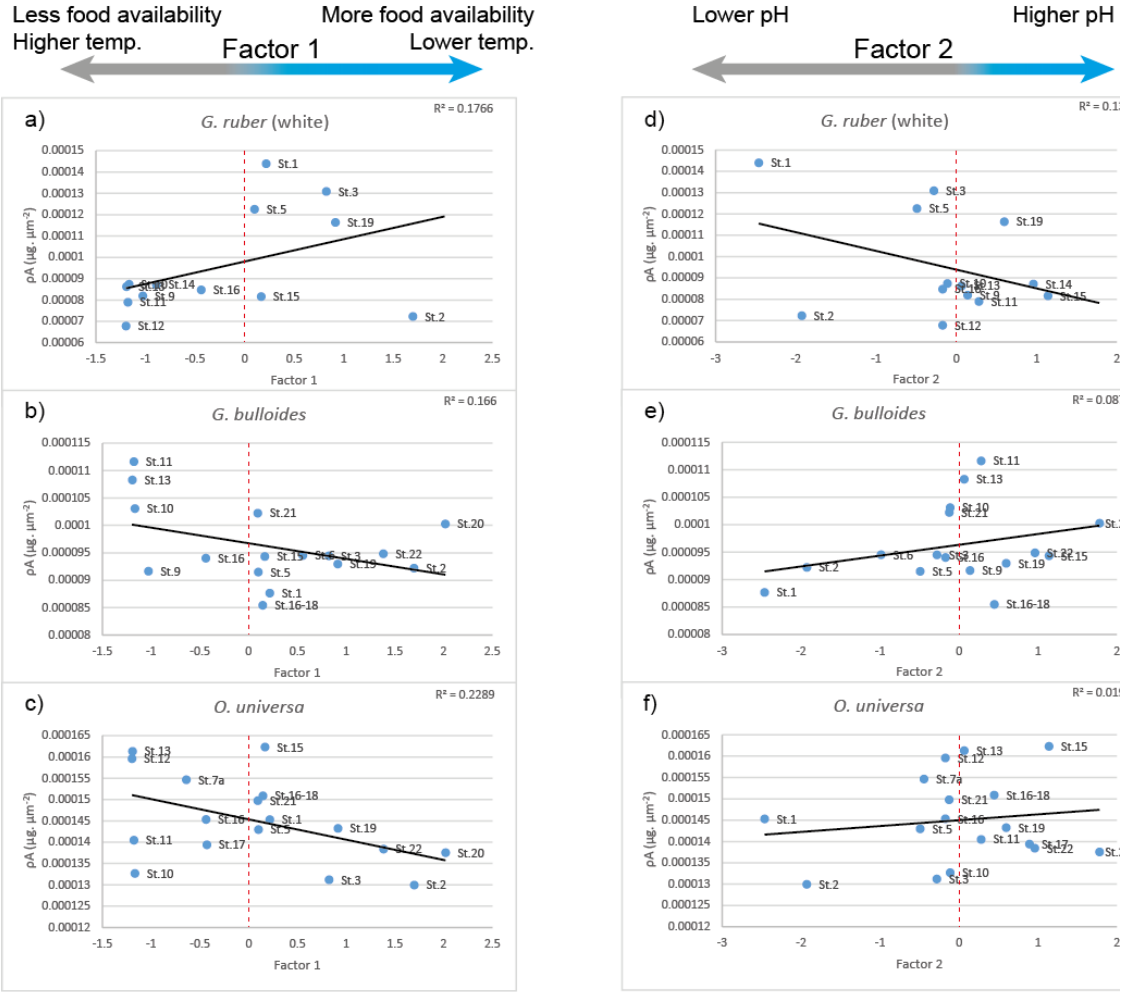
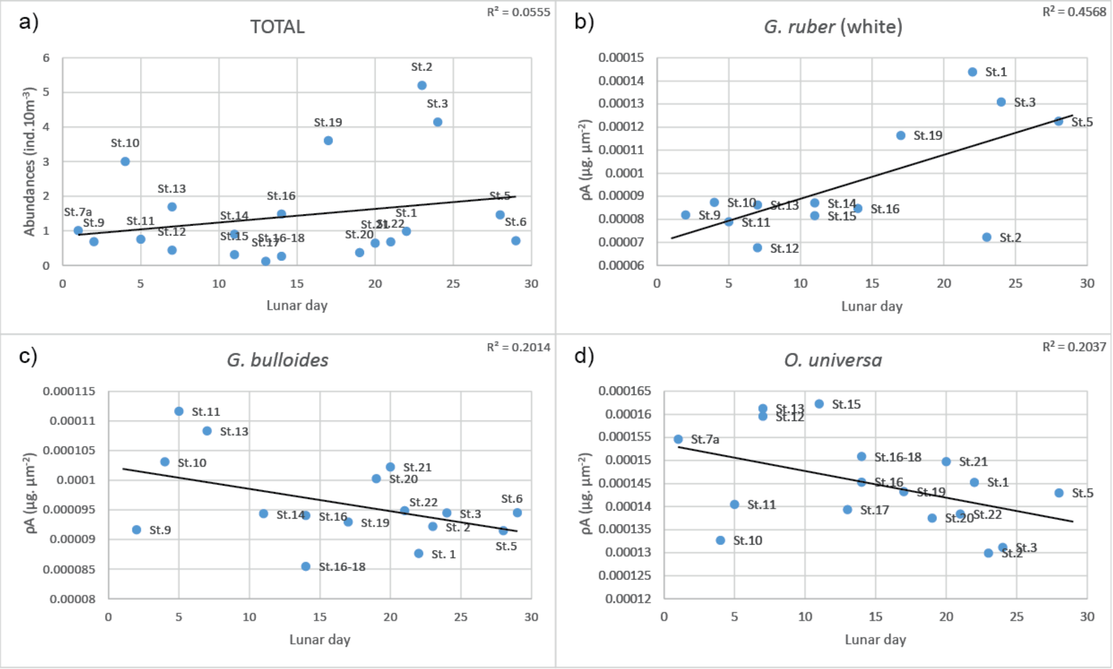


Fig R2: scatter plots between the PCA scores (factor 1 on the left and factor 2 on the right) and the density area of *G. ruber* (white) (a and d), *G. bulloides* (b and e) and *O. universa* (c and f). The red dotted lines show the zero of each factor.

REF.1 COMMENT: **Lunar cycles:**
In response to my previous comment, the authors write:
We are aware that lunar cycle can influence the distribution of foraminifera. However, in our study the lunar day influence on the total absolute abundances (REV Fig. 2) was negligible.
First of all, it is unclear to me how that is evident from Fig. 2 (map of sample locations with chlorophyll-a concentration as background), so please explain. Also, I think this should be part of the manuscript, even a negative result is important and show that lunar paced abundance variability was at least considered as a possible mechanism. Moreover, was the influence of a lunar cycle on area density checked? It seems to me that this parameter would be extremely sensitive to the ontogenetic stage of the organism.

ANSWER: We clarify this point by providing the following plots. We cannot exclude that there is a possible influence of the lunar cycle on the foraminiferal distribution, however our results showed that other factors are probably more important and drive the observed changes. The figure related to this in the previous revised manuscript is REP Fig. 2 and not Figure 2 of the manuscript. We show below the figure, adding the density area plots in it:



REF.1 COMMENT: **Area to long axis relationship:**
In response to my previous comment, the authors write: "Size and mass of foraminifers relationship does not start at the origin. The proloculus of planktic foraminifera measures between 15-30 m in average, and has a certain calcite mass, which has so far not been determined (see Hemleben et al., 1989). We will use the power fit in the three species treated in Fig. S4 of the original manuscript for consistency reasons."

I'm happy to see that the species are treated consistently, but disagree with assertion that the curves – which are apparently interpreted as growth curves - should not go through origin. That is physically impossible.
As to the interpretation that these relationships reflect growth patterns, it seems that the relationships reflect regional differences in size, rather than ontogeny (Fig. S2). Do the authors think that they sampled shells at different ontogenetic stages at different locations (synchronized reproduction?)? It would be good if they commented on this. Also, were juvenile O. universa (without the spherical chamber) recognized/found?

ANSWER: We agree about the fact that a growth curves should not go through origin since it is physically impossible. This indeed is not the case in the figure presented (Fig. S2). Above and below the regression line, the relation between the area and long axis would be certainly different, with a different slope of the line. In any case, the data points for Fig. S2 (also Fig. S4) are the result of image analysis by incident light microscope of foraminifera, and the graph just reflects the results obtained and the pattern that follow the data (a power regression in this case).

The data points together with the regression line show the general increasing size of the studied foraminifera. This suggests different foraminiferal ontogenetic stages such that smaller/younger ones and older/bigger ones are the end members. As we probably picked individuals in a wide range of ontogenetic stages, we can see a curve of growth. This is what we mean by “growth pattern” in the manuscript.

We did not found any juvenile *O. universa* by recognizing by incident light microscope. We were aware of the shape that juvenile *O. universa* has, previous to its terminal chamber formation, when we identified the different species distribution (i.e. Vilks and Walker, 1974).

Minor comments:

REF.1 COMMENT: L16: it would be good to mention here the reason why are density was investigated.
ANSWER: Changed in the revised manuscript as follows: “The main aim was to characterize the species distribution and test the hypothesis of covariance between foraminiferal area density (ρ_A) and seawater carbonate chemistry in a biogeochemical gradient including ultraoligotrophic conditions.”

REF. 1 COMMENT: L49: perhaps delete ‘source’ and mention the influence of temperature on seasonal abundance variability (Jonkers and Kučera, 2015; Zaric et al., 2005).
ANSWER: Changed in the revised manuscript as follows: “The absolute abundance of foraminifera is also affected by a predictable and distinct seasonal cycle for each species driven by the food content and temperature of the water mass (Hemleben, 1989; Bé and Tolderlund, 1971; Jonkers and Kučera, 2015; Žarić et al., 2005; for Mediterranean examples see: Pujol…”.

REF. 1 COMMENT: L67-69: I don’t quite understand this sentence about the different temperature and salinity ranges for water masses (and doubt that Be and Tolderlund is the right citation for that); please clarify.
ANSWER: To clarify better we substitute the sentence: “There are specific temperature and salinity ranges for each water mass,” by “Each water mass has a characteristic range of temperature and salinity (Brown et al., 2001)”.
We deleted the sentence: “as Bé and Tolderlund (1971) stated for the Atlantic,”

Biogeochemical parameters are used for differentiate Mediterranean water such as Mediterranean Intermediate Water (MIW), Modified Atlantic Water (MAW),…; (see Rohling et al., 2015).

REF. 1 COMMENT: L81: is it Gulf of Lion or of Lions?
ANSWER: Both terminologies are accepted, but the original term is “Lion”. Note that in French, Spanish and Italian is written in singular (Lion, León, Leone). The name comes originally from the animal name. This part of the Mediterranean is historically known by the sailors to be a dangerous area; in consequence they named it as the mammal.

REF. 1 COMMENT: L83: the terms distribution and daily fluxes are confusing to me, sediment traps do not provide daily fluxes, but integrate the flux over a certain time interval. Perhaps leaving distribution and daily out is better.
ANSWER: We change ‘fluxes’ with ‘export production’. Authors of the cited papers

express daily flux as organisms·m^{-2}·day^{-1}. The daily export production was estimated considering that the sediment trap sampling period per cup was of 10-11 days (See their methodology sections plus Fig. 5 of Bárcena et al., 2004, and Fig. 4 of Hernández-Almeida et al., 2011). "Distribution" refers to the species relative abundance, which varies considerably between seasons.

REF. 1 COMMENT: L85-87: this sentence is also unclear to me. Sediment traps provide information about the export flux of shells, not an abundance that is directly comparable to measurements from plankton nets. And if there is a correlation (or relationship?) between flux and nutrient supply (why nutrients? Forams don't rely on nutrients) and water column conditions, then how does this work (which direction)?
ANSWER: Rigual-Hernández et al. (2012) analyzed the foraminiferal assemblage in sediment trap samples with sampling period of 14 days to one month (see their methodology section for further details). They calculated the relative abundance of foraminifera species in the total foraminiferal assemblages (see Table 1 in Rigual-Hernández et al. (2012)).
We changed that sentence in the revised manuscript to avoid any confusion as follows: "The 12-year sediment trap foraminiferal export production record in the Gulf of Lion (October 1993 – January 2006) shows a strong seasonal pattern, with more than 80% of the annual export production recorded from winter to spring related to higher food supply and mixing state of the upper water column (Rigual-Hernández et al., 2012)."

REF. 1 COMMENT: L106-108: it would be good if the authors explicitly stated what SNW or area density can be used for, i.e. say that it may tell something about calcification intensity.
ANSWER: Changed in the revised manuscript as follows: "In addition, very few size-normalized weight (SNW) and area density (ρ_A) studies to infer the calcification intensity of water column foraminifera are available in the literature…"

REF. 1 COMMENT: L112: add a space between spring and 2013. There are more cases where the space is missing between words (I guess because of the many changes in the document), please double check.
ANSWER: Changed in the revised manuscript. Thanks, true, sometimes the text justification hide this problem to our eyes too.

REF. 1 COMMENT: L138: is there really a longitudinal increase in insolation?
ANSWER: We don't understand this comment on the longitudinal increase in insolation. We did not mention any longitudinal increase in insolation; the main text is: "Natural connection with the ocean is through the narrow Strait of Gibraltar, where nutrient-rich Atlantic surface waters enter the Mediterranean and experience an eastward increase of temperature and salinity (Fig. 1) driven by insolation and evaporation, having a negative hydrological balance (evaporation exceeding precipitation)."

REF. 1 COMMENT: L146: add 's' after become.
ANSWER: Changed in the revised manuscript.

REF. 1 COMMENT: L165-167: please reword this sentence.
ANSWER: Changed in the revised manuscript as follows: "Twenty samples were

collected with BONGO nets (mesh size 150 µm and 40 cm diameter, for further details see Posgay, 1980). Those nets sampled primarily 200 m depth, but also caught foraminifera during the net descent and ascent to the surface, which both involve negligible towing and capturing time compared to the sampling at 200 m depth (Table 1)."

REF. 1 COMMENT: L175: replace PO4 and NO3 with PO43- and NO3- throughout the manuscript.
ANSWER: We consider that is not needed to change as it is just an acronym to name it.

REF. 1 COMMENT: L186-187: Can you please reword this sentence, it is unclear to me what has been done.
ANSWER: We appreciate the referee comment here, and changed the sentence in the revised manuscript as follows: "When necessary, samples were split into aliquots of 1/4 and 1/6."

REF. 1 COMMENT: L190: I guess the last statement about the exclusion of tests with attached organic matter only applies to the size/weight analyses, or not? If not, then please explain the reason why.
ANSWER: Yes. Changed in the revised manuscript as follows:
L189-190: "Foraminifera smaller than 150 µm and/or with tests partially broken, making them unrecognizable or unmeasurable, were discarded."

L 202-203: "For the area density (ρ_A) study, we selected three main species: *G. ruber*, *G. bulloides* and *O. universa*. All specimens without partially broken tests and/or with organic matter attached of these three species were photographed…"

REF. 1 COMMENT: L191: consider changing 'under optical microscopy.' to 'using optical microscopy.'
ANSWER: Changed in the revised manuscript by: "using incident light microscopy".

REF. 1 COMMENT: L218: I think the figure order needs to be updated, Fig. 7 should not appear before Fig. 3.
ANSWER: Figure order changed by order of appearance, in the text and the figure section of the manuscript: Fig. 7 turned to Fig. 3, Fig. 3 to Fig. 4, Fig. 4 to Fig. 5, Fig. 5 to Fig. 6, and Fig. 6 to Fig. 7.

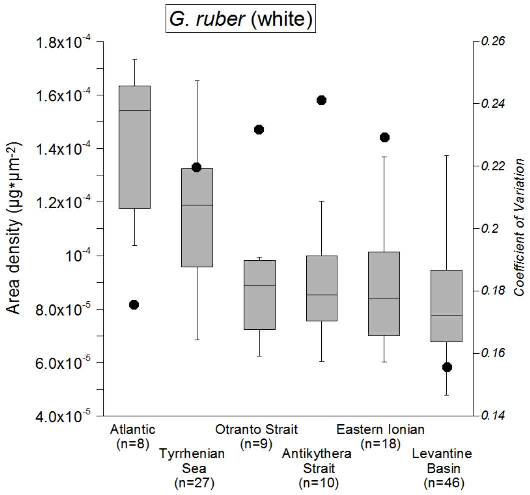
REF. 1 COMMENT: L248: space after 'Overall,'.
ANSWER: Changed in the revised manuscript.

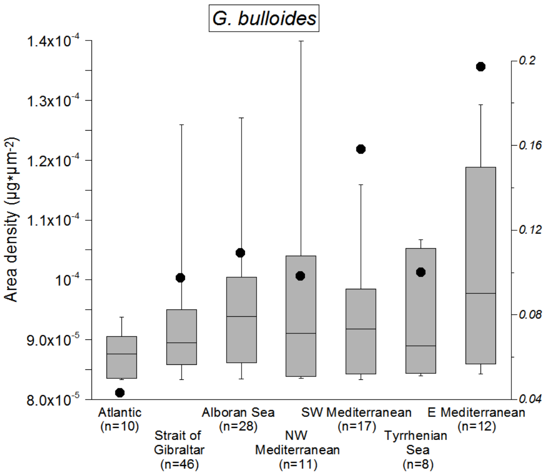
REF. 1 COMMENT: L277: is food availability estimated/inferred from the fluorescence, make this explicit because food availability is not directly in the PCA? Perhaps this is unneeded, but it is important to realise that foraminifera rely on food, not on nutrients. But again, why do a PCA and then discuss individual environmental

parameters and not use the scores?
ANSWER: Yes, food availability is inferred from the CTD fluorescence values (Fig. 1d; Fig. 3) and the nutrient concentration (nitrate and phosphate; Fig. 3). For the PCA scores please to the first comment of this review.

REF. 1 COMMENT: L286-287: it would be helpful if the authors indicate the station number(s) in the text. Also, please explain how this correlation is evident from this plot.
ANSWER: Sentence modified in the revised manuscript as follows: "With the exception of the Tyrrhenian Sea (St. 19), *G. ruber* (white) abundance is related with warmer and saltier waters, and lower pH (St. 9, 10, 11, 12, 13, 14, 16; Fig. 3d)."

REF. 1 COMMENT: L334: to what degree is the large IQR due to the low n?
ANSWER: We plotted the Coefficient of Variation (CV) in Fig. 7 of the revised manuscript. We found no relation between the CV and higher or lower sample size, or with IQR length. We can say that the dispersion of the data is not an artefact of the sample size.





REF. 1 COMMENT: L374-375: this statement should be part of the results.
ANSWER: We agree with the referee. The sentence now is relocated in L250, between the sentence: "The highest percentages are found at the Strait of Sicily and the Northern Ionian Sea (St. 7a, 16-18; Fig. 5; Fig. S1; Appendix A)." and the

sentence: “However, due to the extremely low standing stocks the above observations are mere snapshots, and may not be generalized.”

REF. 1 COMMENT: L398: reword. Sediment traps provide shell flux.

ANSWER: The data of Rigual-Hernández et al. (2012) also provide relative abundances. See the answer to referee’s REF. 1 COMMENT about L85-87 for further details.

REF. 1 COMMENT: L401: not Mediterranean studies (even though all the authors were from countries bordering the Med). Rigual-Hernandez analysed the >150 micron fraction, not the 63-150.
ANSWER: True. Changed in the revised manuscript as follows: “…a possibility potentially supported by Pujol and Vergraud-Grazzini (1995): 120 µm mesh size.” Deleted the Rigual-Hernández et al. (2012) reference, also deleted in L415: “and Rigual-Hernández et al. (2012)”.

REF. 1 COMMENT: L408: the comparison with R-H is appropriate. This study is not from the Alboran Sea as is suggested here. Better compare to the other sediment trap studies from the Alboran Sea.
ANSWER: Sentence in L408-409 deleted in the revised manuscript.

REF. 1 COMMENT: L410-411: I still think one cannot and should not extrapolate a few observations spread over several decades to suggest a trend. Moreover, ‘in the Mediterranean’ (L410) should be replaced with ‘this study’ and the ‘trend of changing conditions’ is a very vague description of what is happening to temperature and salinity and water mass mixing. If the authors insist on leaving this speculative statement in the ms they should at least analyse this properly (i.e. take the counted number of shell into account, calculate a rarefaction curve etc) and explain what and how the Med is changing and suggest a mechanism how this can affect species diversity.
ANSWER: We replace it “in the Mediterranean” replaced by “in this study”.
We do not extrapolate a few observations spread over several decades to suggest a trend. However, it is well known that the Mediterranean is one of the most impacted seas in the world and climate change interacts synergistically with many other disturbances. We consider that our results highlight the need of further work addressing the impact of climate change on plankton diversity in areas particularly vulnerable to rapid environmental change. The Mediterranean Sea is changing rapidly under anthropogenic climate change forcing (e.g. see Giorgi 2006; IPCC 2007, 2013); Yáñez et al., 2010; Hassoun et al., 2015a; Hassoun et al., 2015b, Cossarini, 2015) being among the ocean regions warming fastest. Warming, increased stratification and acidification footprints on the biota can be detected (e.g. Marbá et al., 2015, Meier et al., 2014). Mediterranean biodiversity is undergoing rapid alteration under the combined pressure of climate change and human impact, but detailed studies and biodiversity monitoring are still scarce (Bianchi and Morri, 2000).

We would like to highlight that although our absolute abundance results are obtained by sampling in a relatively high productivity annual period (i.e. see Rigual-Hernández et al., 2012; Barcena et al., 2014) they are the lowest ever recorded in the literature, even lower than recent studies in other oligotrophic areas (i.e.: Auras-Schudnagies et al., 1989; Schmuker and Schiebel, 2002). This surely deserve attention and future studies to clarify the impacts of climate change and human activities on the Mediterranean marine plankton biodiversity.

REF. 1 COMMENT: L413: I somehow missed where it is discussed how 'the ecology and distribution of planktic foraminifera' could change due to these changing conditions. Please explain and provide evidence that the ecology is really changing (and what is meant with that).
ANSWER: In our study, we just provide a suggestion (note the word "could" in that sentence) since our data are based on a single oceanographic expedition. We added a new reference to provide evidence of recent measurable changes in planktonic foraminiferal distributions in another oceanographic region (off southern California: see Field et al. (2006)).

REF. 1 COMMENT: L430: add a reference.
ANSWER: The second and third sentences of that paragraph share reference with the fourth sentence: Bé and Tolderlund, 1971. We considered it enough to provide it once and not repeat it twice in such a short text space.

REF. 1 COMMENT: L433-434: reword 'characterized by its wide temperature range'.
ANSWER: Modified in the revised manuscript as follows: "The spinose and symbiont-barren species *G. bulloides* tolerates a wide temperature range and is typical of subpolar and transitional regions as well as upwelling areas, it is also found in subtropical and tropical waters at lower abundances (Thunell, 1978; Bé and Tolderlund, 1971)."

REF. 1 COMMENT: L440-442: the comparison with Cifelli doesn't make sense here: L437-440 compare the Atlantic with the western Med, Cifelli compares western and eastern Med. The sentence is also very long and complicated, please reword.
ANSWER: We appreciate the referee comment here, and we are clarifying this point and change the sentence: "In our study and the one by Cifelli (1974), *G. ruber* (white) occurs with higher abundances in the eastern compared to the western Mediterranean Basin, being the most abundant species in the Levantine Basin and the South Ionian Sea. Also like Cifelli (1974), in our study, *G. ruber* (white) from the Atlantic station is found with slightly higher relative abundances than in the western Mediterranean Basin. Temperature-related factors may be the main cause, i.e.: warmer Atlantic waters (16.1 ºC) compared to the western Mediterranean (14.3 ºC in the SW, 14.0 ºC in the NW; Fig. 1a)."

REF. 1 COMMENT: L449: please add station numbers.
ANSWER: Changed in the revised manuscript as follows: "*G. ruber* (white) remains scarce (St. 9, 14, 15) or absent (St. 16-18) in the Ionian Sea stations (Fig. 4), increasing its abundance towards the Tyrrhenian Sea. On the other hand, in the Ionian Sea it exhibits relative abundance around 40 to more than 60% in the surface sediments (Thunell, 1978), and decreases towards the Tyrrhenian Sea."

REF. 1 COMMENT: L454: reword 'as due to….'
ANSWER: That sentence is now deleted in the revised manuscript.

REF. 1 COMMENT: L455-456: May is not the month when G. ruber fluxes are highest in the Gulf of Lions or the Alboran Sea (it's perhaps the month when total shell fluxes are highest).
ANSWER: Sentence deleted in the revised manuscript: "This may not be the typical spring situation, as due to surface sediment evidence, the Ionian Sea sediments are enriched in G. ruber tests (Thunell, 1978) and May is the most productive season in terms of foraminiferal tests (Rigual-Hernández, 2012; Bárcena et al., 2004; Hernández-Almeida et al., 2011)."

REF. 1 COMMENT: L483-485: add reference and what is the rational behind the link between seasonal and spatial distribution?

ANSWER: Last sentence of that paragraph is a summary/conclusion of the whole paragraph of *G. inflata*. We consider it unnecessary for a reference here as the reader would have the references after each sentence of that paragraph and our study results.
"Seasonal distribution" is the change of foraminiferal assemblage or a concrete species during periods of time (seasons). "Spatial distribution" is the change in geographical locations of foraminiferal assemblages or a concrete species. The seasonal distribution is linked with the spatial distribution when every season or concrete period of time the foraminiferal assemblage move from one place to another, or it expands or diminishes its presence from determinate locations.

REF. 1 COMMENT: L495-496: I don't understand this sentence. How does it match and why is bulloides mentioned?
ANSWER: In spring, our study, together with Pujol and Vergraud-Grazzini (1995) and van Raden et al., 2011) identified G. inflata as the main species of the assemblage (the highest relative abundance, %) and G. bulloides the second main species (the second highest relative abundance), with a clear difference (in %) from the third main species and the others. The mention of *G. bulloides* here is useful to understand the behavior of these two species regarding temperature in a food-abundant scenario. This is clarified later on L511-L516: "In April (Pujol and Vergnaud-Grazzini, 1995; van Raden et al., 2011) and May (this study), *G. bulloides* is found to be the second most abundant species, surpassed by *G. inflata*, in the westernmost Alboran Sea. High temperature anomalies could provoke an inverse situation, thanks to more suitable environmental conditions for *G. bulloides*, which profits from successful reproduction than *G. inflata*, which instead stays further from its optimum temperature (Bárcena et al., 2004). One month later it is found to be the dominant species replacing *G. inflata*, which is still dominant in the eastern Alboran Sea (Cifelli, 1974)."

REF. 1 COMMENT: L501-502: reword, it cannot be 'In accordance with Cifelli' and 'whereas in our study'.
ANSWER: Changed in the revised manuscript as follows: "Following Cifelli (1974), *G. bulloides …*"

REF. 1 COMMENT: L506: replace 'all the transect' with 'the whole transect'.
ANSWER: Changed in the revised manuscript.

REF. 1 COMMENT: L509: what characteristic of bulloides correlates with

fluorescence peaks (its abundance, relative abundance) and if it really correlates, then show the scatter plot.
ANSWER: Its absolute abundance (see Fig. 3e). To avoid any confusion we rephrased the sentence as follows: "Consequently, higher standing stocks of *G. bulloides* are related with higher fluorescence values (i.e., Morthyn and Charles, 2003; Fig. 1; Fig. 3e)." See also the answer to comment 1 about statistical analysis.

REF. 1 COMMENT: L513: faster reproduction, how would that work? I know that Barcena et al say this, but struggle to grasp it. Where is the evidence? Reproductive success may be higher, population growth too, but faster reproduction?
ANSWER: We appreciate the point of view raised by the referee here. According to Schiebel and Hemleben (2005) both species (*G. bulloides* and *G. inflata*) rely on a synodic lunar cycle, but *G. bulloides* could have a better fertilization success and higher growth and survival of the offspring compared with *G. inflata*. Despite no study proving this concretely, we infer this by looking at the behavior (in abundance terms) of the adult specimens: concretely, *G. inflata* would have a better fertilization and offspring legacy in the westernmost Alboran Sea with colder temperatures compared with *G. bulloides*, as we found *G. inflata* less abundant in the warmer June than *G. bulloides*, when before (colder April and May) it was the opposite. We retain that only as a possibility as we do not have enough evidence from our study, or those of Pujol and Vergraud-Grazzini (1995) and van Raden et al. (2011) which consist of "snapshots in time" samples.
We modify the sentence as follows: "High temperature anomalies could provoke an inverse situation, thanks to more suitable environmental conditions for *G. bulloides*, which profits from successful reproduction than *G. inflata*, which instead stays further from its optimum temperature (Bárcena et al., 2004)."

REF. 1 COMMENT: L517: replace 'higher' with 'larger'.
ANSWER: Changed in the revised manuscript.

REF. 1 COMMENT: L524: water 'column' stratification.
ANSWER: Added in the revised manuscript.

REF. 1 COMMENT: L525: 'being more present': there seems to be a word missing.
ANSWER: Changed in the revised manuscript by "is more abundant".

REF. 1 COMMENT: L537: foraminiferal prey? Or fluorescence/chl a?
ANSWER: Fluorescence acts as a proxy for Chlorophyll-*a* concentration. Fluorescence is related with phytoplankton presence, which is a food source, and Chlorophyll-*a* high values very often relate with high presence of foraminifera, and viceversa (i.e. Fairbanks et al., 1982; Mortyn and Charles, 2003). Other zooplankton and other foraminiferal prey concentrations are generally linked with the phytoplankton concentration. Because of that, we consider an area of low Chlorophyll-*a* and fluorescence values, an area with less foraminiferal prey.

REF. 1 COMMENT: L541: planktonic foraminifera rely on food, not on nutrient, availability.
ANSWER: Changed in the revised manuscript as follows: "To conclude, the distribution of *G. bulloides* seems to be limited by food availability, caused by stratification and consequent nutrient depletion of the surface water column, and

increased sea surface temperatures."

REF. 1 COMMENT: L544: reword '… was found ubiquitous…'
ANSWER: We consider not rewording that sentence. See the details of that decision in the referee REF. 1 COMMENT about L547 below.

REF. 1 COMMENT: L547: there is an abundance peak of O. universa at station 16, so I don't understand this sentence.
ANSWER: *O. universa* is present at 19 of the 22 stations sampled, where it is present, the highest absolute abundance value is 0.468 ind·10 m^{-3} (St. 16) and the lowest is 0.014 ind·10 m^{-3} (St. 3), making a difference of 0.454 ind·10 m^{-3}; also the SD of all the absolute abundance values where *O. universa* is present makes: 0.123.
If you compare the highest and lowest values and the SD of the other main species you find higher values:
G. ruber (white) [*highest - lowest; SD*]: 1.681; 0.567
T. sacculifer (without sac): 1.3; 0.35
G. bulloides: 2.288; 0.552
G. inflata: 3.491; 1.053
For that reason we consider *O. universa* ubiquitous and its small difference in abundance detected in St. 16 is not considered a peak, taking into account the low number of species per towing (57 individuals in station 16, but others like station 16-18 consist of only 11 individuals) and the aliquots treatment that represent 52.33% of the sample, making more variable the results in stations with low numbers of individuals.

REF. 1 COMMENT: L552: 'quite ubiquitous' is very vague.
ANSWER: Regarding Cifelli (1974), *G. trilobus* (*T. sacculifer* (without sac)) is only absent at one station sampled and its relative abundance SD inside the Mediterranean (starting at Cifelli's station 49) is 5.52 %. "quite ubiquitous" is changed in the revised manuscript by the term "wide distribution".

REF. 1 COMMENT: L639: misnumbered? Fig. S4a.
ANSWER: No, Fig. S3a indicates the weight-long axis relation of *G. ruber* (white), which is the subject discussed in that paragraph. Fig. S4a compares the weight-area relation of the same species.

REF. 1 COMMENT: L640: suitable conditions?
ANSWER: Changed in the revised manuscript.

REF. 1 COMMENT: L652: 'effect of limited alimentation on calcification'. What is meant exactly? And I assume this only holds for bulloides?
ANSWER: We appreciate referee's comment here, as it was a confusing sentence. Now it is deleted in the revised manuscript.

REF. 1 COMMENT: L654-655: reword.
ANSWER: Added "is" between "carbonate chemistry" and "only partially affecting" in the revised manuscript.

REF. 1 COMMENT: L660: the samples were collected in May 2013
ANSWER: To avoid any confusion we add the word "collected" in the sentence as it

follows: "…across the Mediterranean, collected in May 2013."

REF. 1 COMMENT: L663: that looks more like the average and standard deviation than like a range.
ANSWER: Changed in the revised manuscript as follows: "Average standing stocks in the upper 200 m of the water column are 1.42±1.43 ind.·10 m^{-3}"

REF. 1 COMMENT: L674: 'rather balanced' – what does that mean?
ANSWER: "Rather balanced" inside this manuscript means with similar absolute abundance values everywhere, without considerable peaks. See the answer of referee's REF. 1 COMMENT about L547 for further details. We delete "rather" in the revised manuscript to avoid confusion.

REF. 1 COMMENT: L679: 'trophic conditions and food availability' – what is the difference? And how is that clear from the analyses?
ANSWER: "tropic conditions" is deleted in the revised manuscript. The answer to that question can be found in the first referee comment of that report (Statistical analysis), specifically in Fig. R2.

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REFEREE # 2

1. General comments

In the section below, I give detailed comments (including line numbers) about very specific issues. However, in this section I already want to summarise some major points that are more relevant for the entire manuscript than at any specific place.

REF. 2 COMMENT: **1.** The work does still not normalize its data for the consistent differences in sampling employed by the other studies, with which comparisons of assemblages are anticipated. Cifelli (1974) sampled the upper 250m water depth, while Pujol and Vergnaud-Grazzini sampled the upper 350 m. This study uses mainly the association at 200m and partly an integrated column of the upper 200 m. Furthermore, mesh sizes have been different between most studies. In addition, the authors now state that their net had a diameter of only 40 cm (0.12m2 opening), in contrast to the 0.5m2 common with most plankton nets (e.g. Pujol and Vergnaud Grazzini 1995). While absolute abundances are certainly normalized for filtered water volume, this much smaller net opening means that the authors have much larger errors in their assemblage data than the compared studies, because of the much lower volume of filtered sea water. All this has already been criticised in my first review, but the authors did not change anything, although I for instance suggested already there to use equations provided by Berger (1969) to normalize all studies concerning mesh sizes. The authors try to argue that Cifelli (1974), who actually used a comparable mesh size, argue in favour of their interpretation of changing abundances due to changing environments. However, they totally ignore that Cifelli (1974) used another depth range in their studies, so certainly they found other abundances. In my opinion, the authors cannot succesfully show, that the assemblage differences they observe between studies with employing such different sampling techniques are not an artefact of the data, but a real trend.

ANSWER: The referee is clearly correct on the differences among the study approaches over the years. For this reason, we do our best to incorporate any attempts at normalization to plankton tow approaches, including that of Berger (1969) on the issue of mesh sizes. We have already incorporated new text on this in the previous revision, and we admittedly do not add new information on this issue here in this 2nd round. We do our best to compare results across studies as well as possible, always keeping in mind and stating very clearly the caveats to doing this more directly and satisfyingly. That said, given the admitted issues in direct comparison, instead of drawing firm and quantitative conclusions we make observations and derive sensible suggestions that result from them. The Editor and other reviewers did seem to appreciate more our efforts this way, including clear acknowledgment of limitation.

The Berger (1969) approach to normalizing for mesh sizes does so for major ocean basins, as opposed to smaller seas like the Mediterranean. Whether or not this technique would be suitable therefore is somewhat questionable for this Mediterranean plankton tow study.

REF. 2 COMMENT: **2.** The systematics are still not consistent. Why is quadrilobatus designated as belonging to the genus Globigerinoides? From André et al. (2013), which the authors cite themselves, it is very clear that the species genetically belongs to the trilobus–sacculifer plexus (at least as long as recent specimens are concerned). It makes absolutely no sense to not only treat it as a separate species from Trilobatus sacculifer, but even put it into another genus. It should instead be correctly categorized as another morphotype of T. sacculifer.

ANSWER: We agree with the referee's major comment and in accordance with André et al. (2013) plus Spezzaferri et al. (2015) we changed *Globigerinoides quadrilobatus* to *Trilobatus quadrilobatus* in the entire manuscript. New text is added on the methodology section inside the paragraph of L191-200 as follows: "*Trilobatus sacculifer* morphotype *quadrilobatus* was inferred from Spezzaferri et al. (2015) after André et al. (2013); this morphotype is referred as *T. quadrilobatus* in this study and is treated separately from *T. sacculifer* (without sac)."

REF. 2 COMMENT: **3.** The statistical analyses is still a huge problem. The authors state they applied a principal components analysis (PCA), which by the way is data visualization and no proper statistics (because it lacks any possibility to infer significance), and thus a step back from the faulty approach the authors applied in the first iteration of this paper. However, PCA does not include explanatory variables such as environmental parameters. So it is first not clear to me what have been done, i.e. what are Factors 1 and
2 in Fig. 7? Have samples (as it seems) been ordinated by environment, and then somehow overlain by assemblages? Or is it indeed a redundancy analysis that have been applied, and if so, constrained for which environmental parameters? Furthermore, since PCA is using euclidean distances for ordination, it is very unsuitable for abundance data, and other methods like principal coordinates analysis are much more suitable for comparing assemblages (Hammer and Harper, 2006; Legendre and Legendre, 2012). The authors also still do not use proper techniques to interpret their findings in relation to the hefty multicollinearity in their data. I suggested some techniques in my first review (e.g. GLM, GAM). The authors may also use any of the techniques applied by the Thunell-work group, who also do an excellent job in that (e.g. Marshall et al., 2013; Osborne et al., 2016). As it is now, however, the authors only visually interpret trends in the PCA by eye, which is no proper and robust method when reliable interpretations should be reached.

ANSWER: In the previous version of the manuscript as in this revised version, the PCA was conducted on the 9 environmental parameters considered (i.e., temperature, salinity, fluorescence, [PO4], [NO3], [O2], pH, pCO2 and [CO_3^{2-}]; figure 3 of the revised manuscript). *De facto*, the explanatory variables were included in this analysis. To avoid any confusion we made it clearer in the revised manuscript. The matrix used to perform the PCA was organized as follows: the lines correspond to the stations and the columns to the environmental parameters. As a result the two first factors of the PCA account for more than 77% of the total variance of all the environmental parameters taken together and we attributed the 1st factor to the temperature and the food availability (inferred here from nutrients concentrations and fluorescence), while we attributed the 2nd factor to the carbonate system. The 1st factor explains more than 55% of the variance and depicts well the general trend observed in the Mediterranean Sea with in general colder and more productive waters in the western basin and warmer and less productive waters in the eastern one (see Fig. 1c of the revised manuscript for the fluorescence). The 2nd factor accounts for about 22 % of the total variance. Once again this reflects the general trend observed within the Mediterranean Sea with in general lower pH/[CO_3^{2-}] in the western basin compared to the eastern basin (see Fig. 1d-e of the revised manuscript for the distribution of pH and [CO_3^{2-}]). We added a new table in the revised manuscript presenting the loadings of the environmental parameters in the PCA and additional Pearson correlation coefficients (r) for relationships between the environmental parameters, the PCA factors, the abundances of the selected species and the density area of the selected species (Table 2).

In figure 3 of the revised manuscript, as in the previous version, the scores of the environmental parameters are plotted according to the red axis and are depicted by the red vectors. On the same figure we plotted as well the stations scores (black axis) and for each station the total abundances (Figure 3a of the revised manuscript), the abundances of 5 selected species (Figure 3 b-f of the revised manuscript) and the density area of 3 selected species (Figure 3g-i of the revised manuscript) were overlaid using coloured circles (red for the eastern basin and blue for the western basin, the diameter of the circles being proportional to the abundances and the density area). Although the PCA approach does not strictly allow the distinction between the influence of covarying environmental parameters, the results presented in the figure 3 of the revised manuscript allows to visualize and understand in which conditions the lower/higher abundances and density area of the selected species were observed.

Below we provide the scatter plots combining both the PCA scores (for each factor) and the abundances or the density area (respectively fig R1 and R2).

From fig R1 and table 2, we can see that in general the total abundances are higher when the factor 1 is >0 and factor 2 <0 (fig R1 a and g) in other words when the temperature is lower, the food availability id higher and the pH lower such as in the western basin, with the exception of st. 15 and 16-18 (factor 1, fig R1a) and st. 10 and 12 (factor 2, fig R1 g). The same pattern is observed for *T. sacculifer* (without sac) (fig R1 c and i), *G. bulloides* (fig R1 e and k) and to a lesser degree for *G. inflata* (fig R1 b and h) as no significant correlations are found between the abundances of this species and the 2 factors (fig R1 b and h). The opposite trend is observed for *G. ruber* (white), with in general higher abundances observed when the temperature is higher, the food availability is lower and the pH higher such as in the eastern basin (fig R1 d and g) although no significant correlations are observed (Table 2). Finally no significant correlations were found between the abundances of *O. universa* and the 2 factors (fig R1 f and l; Table 2).

When we compare the density area to factor 1 and factor 2 (fig R2), it shows for *G. ruber* (white) that ρ_A is higher when the temperatures are lower, the food availability higher and the pH lower (fig R2 a and d). The opposite occurs for *G. bulloides* and *O. universa* where the ρ_A is higher when the temperature is higher, the food availability lower and the pH higher (fig R2, b and e).

For both *G. bulloides* and *G. ruber* (white) these observations taken together show that the two species have a higher ρ_A when they are less abundant.

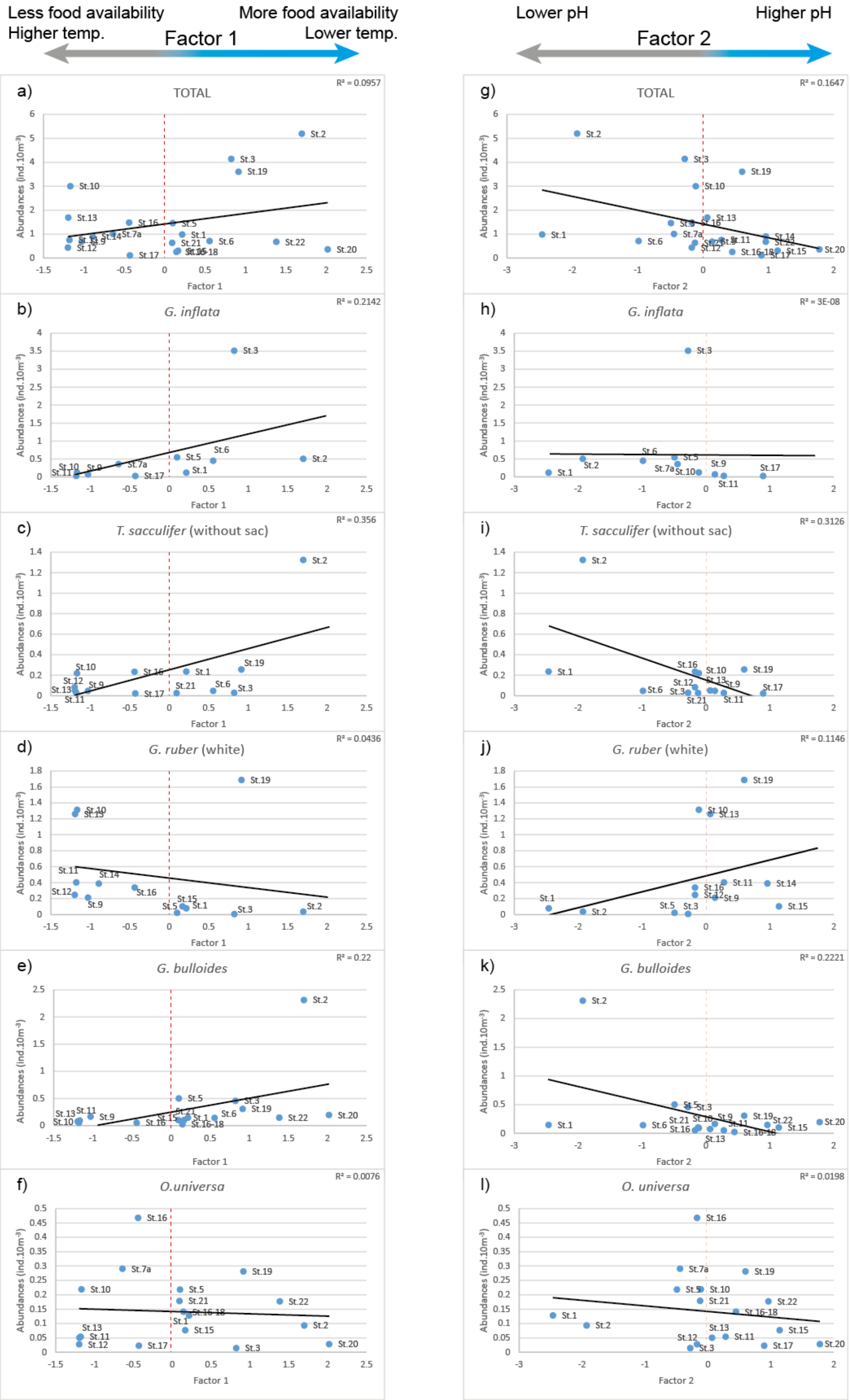


Fig R1: scatter plots between the PCA scores (factor 1 on the left and factor 2 on the right) and the total abundances (a and g), *G. inflata* (b and h), *T sacculifer* (without sac) (c and i), *G. ruber* (white) (d and j), *G. bulloides* (e and k) and *O. universa* (f and l). The red dotted lines show the zero line of each factor.

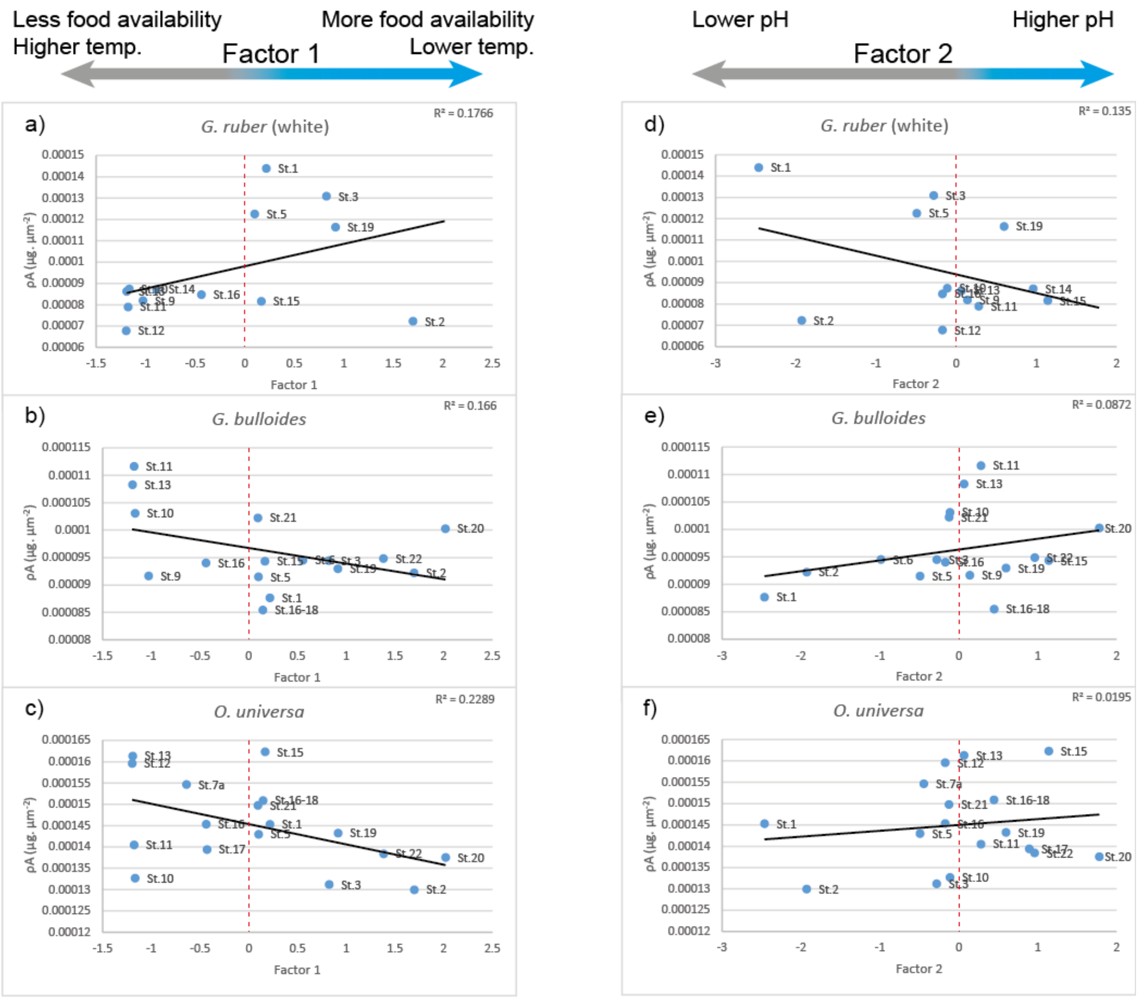


Fig R2: scatter plots between the PCA scores (factor 1 on the left and factor 2 on the right) and the density area of *G. ruber* (white) (a and d), *G. bulloides* (b and e) and *O. universa* (c and f). The red dotted lines show the zero line of each factor.

2 Detailed comments

REF. 2 COMMENT: Line 50, ‘Pujol and Vergraud-Grazzini, 1995’: This work is consistently misspelled. It should be Pujol and Vergnaud Grazzini, 1995!
ANSWER: Corrected in the revised manuscript by: “Pujol and Vergnaud-Grazzini, 1995”. We changed the wrong “r” by the “n”, but we maintain the hyphen, as it is cited with it also in Bárcena et al. (2004) or in Hernández-Almeida et al. (2011), for example.

REF. 2 COMMENT: Line 52, ‘bottom sediments’: Should be ‘surface sediments’.
ANSWER: We disagree, as here we mean studies that cover longer time spans or study the more distant past than the ones working with surface sediments.

REF. 2 COMMENT: Line 63, ‘prominent differenced’: Should be ‘prominently different’.
ANSWER: Changed in the revised manuscript deleting the adjective and leaving it as “different”.

REF. 2 COMMENT: Line 65, ‘retrieved in different sites’: Should be ‘retrieved from different sites’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 69, ‘hydrographis’: Should be ‘hydrographic’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 79, ‘study being carried out’: Should be ‘study have been carried out’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Lines 97f, ‘For further studies that relate foraminiferal calcification with environmental parameters see Weinkauf et al. (2016); Table 7.’: You should also cite Marshall et al. (2013) in this regard.
ANSWER: Marshall et al. (2013) is referred to within Table 7 of Weinkauf et al. (2016) together with other living plankton studies. For that reason, we do not consider to cite it here.

REF. 2 COMMENT: Lines 106f, ‘In addition, few size-normalized weight (SNW) and area density (_A) studies from water column foraminifera are available in the literature’: Area density is a form of size-normalized weight.
ANSWER: We appreciate the comment of the referee. We consider that nothing has to be changed regarding those lines in the revised manuscript.

REF. 2 COMMENT: Line 112, ‘spring2013’: Should be ‘spring 2013’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Lines 120–122, ‘In addition, empty tests are passive particles that ocean currents may displace horizontally, but that displacement is negligible due to their quick settling velocities (Caromel et al., 2014).’: This is not always correct, and it might be good to show that drift distances in the Mediterranean are actually very low (van Sebille et al., 2015).
ANSWER: van Sebille et al. (2015) was considered in the first version of the manuscript with that sentence: “In addition, empty tests are passive particles that ocean currents may displace. On the other hand, average drift distances of foraminiferal tests are estimated to be less than 10 km in the Mediterranean (van Sebille et al., 2015)…”. We reconsidered that reference after Referee #1 REF. 2 COMMENT about the topic: van Sebille et al. (2015) world scale results only represent six grid cells in the Mediterranean area on its Figure 5, making the results less reliable on that area. Despite Caromel et al. (2014) statement, we do not have a reliable proof that displacement is negligible in our study site, we delete also that sentence in L120-122. We consider Vergnaud-Grazzini et al. (1986) as proof enough for the location reliability of Thunell (1978) results.

REF. 2 COMMENT: Line 146, ‘become’: Should be ‘becomes’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 166. ‘primarily 200m depth’: Should be ‘primarily from 200m depth’.
ANSWER: The whole sentence is modified on the revised manuscript to clarify better

the sampling procedure as follows: “Twenty samples were collected with BONGO nets (mesh size 150 µm and 40 cm diameter, for further details see Posgay, 1980). Those nets sampled primarily 200 m depth, but also caught foraminifera during the net descent and ascent to the surface, which both involve negligible towing and capturing time compared to the sampling at 200 m depth (Table 1).”

REF. 2 COMMENT: Line 179, ‘MODIS Aqua L2 satellite’: Should be ‘MODIS Aqua L2 satellite data’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Lines 186f, ‘Samples were studied from the collecting bottles and the bottom collector, the latter representing 52.33% of the total sample were treated in aliquots of 1/2, 1/4, 1/6, until 1/8.’: I do not understand this sentence.
ANSWER: We appreciate the referee comment here, we changed the sentence in the revised manuscript as follows: “When necessary, samples were split into aliquots of 1/4 and 1/6.”

REF. 2 COMMENT: Line 188, ‘≥350–500 µm’: Should be ‘350–500 µm’.
ANSWER: We agree. Changed in the revised manuscript.

REF. 2 COMMENT: Line 199, ‘Globigerinella siphonifera/G. calida/G. radians plexus’: Should be ‘The Globigerinella siphonifera/G. calida/G. radians plexus’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 204f, ‘the individuals were weighed together by triplicate with a Mettler Toledo XS3DU microbalance’: Which means the authors were actually applying the mean area density approach as described in Weinkauf et al. (2013) instead of the more advanced area density approach as described by Marshall et al. (2013).
ANSWER: As we applied the mean weight only when more than one individual was available to weight we consider not to change the name of the approach (area density: ρ_A) to mean area density (MAD). But we include Weinkauf et al. (2013) as one of the references for our approach in the revised manuscript.

REF. 2 COMMENT: Lines 216, ‘The PCA was performed on the environmental parameters:’: So how to understand this? The samples were ordinated by environmental parameters? What then are the scores of the black axes, passively projected assemblage scores? Or is this indeed a redundancy analysis instead of PCA? Compare also general comments why PCA is unsuitable anyways.
ANSWER: See our reply of comment 3.

REF. 2 COMMENT: Line 218, ‘(Fig. 7)’: What happened to Figs 3–6, which should be cited in the text before Fig. 7?
ANSWER: Figure order changed by order of appearance, in the text and the figure section of the manuscript: Fig. 7 turned to Fig. 3, Fig. 3 to Fig. 4, Fig. 4 to Fig. 5, Fig. 5 to Fig. 6, and Fig. 6 to Fig. 7.

REF. 2 COMMENT: Lines 218–228, ‘The first factor exhibited positive loadings. . . are shown in Figure 7).’: This entire passage belongs into the Results section.
ANSWER: Despite that paragraph comparing the results of the PCA, we consider that it should stay in the methodology section, as the results of our study are partly based on

these results. We consider it necessary to clearly separate abundance and area density results and findings that come partly from the PCA, from the PCA results themselves.

REF. 2 COMMENT: Line 244, ‘The exceptions are at Station 3. . . ’: And what about stations 1 and 6?
ANSWER: We decided to delete that sentence in the revised manuscript, as we considered only extra information that can be checked by the interested readers in Appendix A.

REF. 2 COMMENT: Lines 246f, ‘The 350–500-_m size fraction dominates in the western Mediterranean and is progressively reduced eastwards (Fig. 4)’: I do not see this trend. This could be due to the bad layout of figs 3 and 4 (see below).
ANSWER: Changed in the revised manuscript as follows: “The 350-500-µm size fraction in the first leg dominates in the western Mediterranean and is progressively reduced eastwards (Fig. 5)”. The sentence “mainly due to the contribution of small *G. inflata* from the 150-350 µm size fraction” is now deleted. Also is modified the following sentence of L248-249 in the revised manuscript as follows: “Higher percentages of individuals >500 µm in the first leg are found in the western part of the Mediterranean compared to the eastern part (Fig. 5).”

REF. 2 COMMENT: Line 272, ‘G. quadrilobatus’: Incorrect genus (see General Comments).
ANSWER: See the answer to the general comment 2.

REF. 2 COMMENT: Lines 274–276, ‘The PCA performed on the environmental parameters and the sample scores on the two first components clearly shows a separation, regarding Factor 1, between the western and eastern Mediterranean stations (Fig. 7).’: I do not understand how this ‘PCA’ was performed. Did it ordinate the samples on environmental data (as seems the case), then what are the black factors in fig. 7? Or is it indeed an RDA, then constrained for which environmental factors?
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Line 278, ‘station 10 is an exception’: But stations 1, 6, 20, 21, and 22 (all Western Mediterranean) all have low a abundances as well.
ANSWER: Notice that before “station 10 is an exception”, goes the phrase “In the eastern basin”, meaning that is an exception inside the eastern basin. The stations named by the referee are for the western basin and the Atlantic Ocean.

REF. 2 COMMENT: Line 279, ‘Factor 2’: Should be ‘principal component 2’ or ‘PC 2’.
ANSWER: We consider it appropriate and understandable to name it Factor 2. In the revised manuscript we name it “PCA Factor 2”.

REF. 2 COMMENT: Lines 283–285, ‘Overall, the highest absolute abundance of all foraminifera seems related to food availability and only secondarily to the carbonate system (Fig. 7a).’: While it makes the impression to be true, as it is this is eyeballing, because PCA cannot yield any significance but is only ordinating datapoints. Since many of your environmental factors show multicollinearity (as I already pointed out in my first revision) you need much more advanced, real statistical methods to say exactly whith which factors correlation is greatest. At the very least, you should use a more

appropriate ordination method for abundances (probably constrained ordination, which at least delivers a significance for the overall correlation of data with environmental factors) than PCA, which uses euclidean distances.
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Lines 286–292, ‘With the exception . . . path of Atlantic waters (Fig. 7b)’: Where do you see this? Globigerinoides ruber (white) shows a peak (the richest sample) on the cold side of the ordination space, and G bulloides seems to be more correlated with pH. To convince me that those trends are true, you would have to show me something more robust than just a PCA impression (i.e. a compositional multiple regression as described by van den Boogart and Tolosana-Delgado (2013), as I also already suggested last time).
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Lines 298f, ‘The Atlantic and the Ionian–Adriatic–Aegean grouping have similar proportions of species.’: Except that from Atlantic to Ionian–Adriatic–Aegean grouping dominances are completely shifted: G. ruber becomes much more dominant, G. bulloides and T. sacculifer are strongly reduced in abundance, O. universa is much more prevalent, and G. inflata is hardly there anymore.
ANSWER: Sentence deleted in the revised manuscript.

REF. 2 COMMENT: Lines 313f, ‘The high two-dimensional (silhouette) area-to-long axis correlation is best fitted by a power regression (Fig. S2).’: Which, as I already argued in the first review, should be forced to have zero offset. The authors argued concerning this ‘Size and mass of foraminifers relationship does not start at the origin (zero). The proloculus of planktic foraminifera measures between 15–30 _m in average, and has a certain calcite mass, which has so far not been determined (see Hemleben et al., 1989).’. This, however, only means that the model should stop short of zero. Especially when the authors argue that a zero-intercept model would not make sense because it would imply the existence of individuals with zero mass and size, is it not logical to them that non-zero-intercept model which allows a foraminifer to have mass at size zero or have a certain size without mass is even more problematic!
ANSWER: We agree about the fact that a growth curves should not go through origin since it is physically impossible. This indeed is not the case in the figure presented (Fig. S2). Above and below the regression line, the relation between the area and long axis would be certainly different, with a different slope of the line. In any case, the data points for Fig. S2 (also Fig. S4) are the result of image analysis by incident light microscope of foraminifera, and the graph just reflects the results obtained and the pattern that follow the data (a power regression in this case).

REF. 2 COMMENT: Lines 314f, ‘The same growth pattern can be seen in G. ruber (white), G. bulloides, and O. universa’: But this assumption is wrong at least in O. universa. There, size increase cannot be growth, because the spherical form is the terminal form and cannot grow considerably anymore.
ANSWER: We are aware that once the terminal chamber is reached, the individuals increase in size to a very small degree due to the incorporation of additional calcite layers (i.e. Spero et al., 2015). The data points together with the regression line show the general increasing size of the studied foraminifera. This suggests different foraminiferal ontogenetic stages such that smaller/younger ones and older/bigger ones are the end members. As we probably picked individuals in a wide range of ontogenetic

stages, we can see a curve of growth. This is what we mean by "growth pattern" in the manuscript. We change "the same growth pattern" by "similar growth patterns" to avoid any confusion.

REF. 2 COMMENT: Lines 318f, 'The specimens of G. ruber (white) from the Atlantic have the largest size followed by individuals from the Tyrrhenian Sea, and those from the eastern Ionian Sea.': If this statement is made, I already requested a statistical proof in the last review, to which the authors responded 'We do not need a statistical test to know which is the smallest value'. Since this shows a complete lack of understanding for the nature of any quantitative analysis, here is a short Statistics 101 (I again refer the authors to basic introductory literature such as Hammer and Harper (2006) or Dytham (2011): When dealing with natural values, one value will always be larger than the other when measured accurately enough. The REF. 2 COMMENT you want to answer is not, is one value larger, to which you know the answer beforehand, but is one value significantly larger. This means, is the difference you observe between the values in two random samples large enough that, taking into account uncertainty from the fact that you only sampled a couple of randomly selected specimens from the population, you can be reasonably sure that the populations the samples were drawn from differ in this value. An easy example: I measure a difference of 0.3 cm between two samples. Do the populations from which those samples have been drawn differ in size? Well, when I use the variation in the samples to estimate the uncertainty in the estimate of the mean, I can tell with a certain probability. When the standard deviation in both samples (of, say, 100 specimens each) is 0.2 cm, then the 95% confidence interval is _0.02 cm, so the two populations do differ in size with a probability of more than 95 %. If the standard deviation is 5 cm, in contrast, the 95% confidence interval is _0.5 cm, so the two populations do not show a significant difference in size. This is, what statistics is for, and in this sense, yes, you do need statistics to know which value is smaller!
ANSWER: We appreciate the referee's comment. After applying a Student's t-test, we modified the sentence as follows in the revised manuscript: "The specimens of *G. ruber* (white) from the Atlantic have a significantly larger area than those from the Tyrrhenian Sea ($p \leq 0.003$), which in turn have significantly larger area than those from the East Ionian Sea grouping ($p \leq 0.001$)."

REF. 2 COMMENT: Line 337f, 'higher density area are related to slightly lower pH and higher food availability in the western Mediterranean and Atlantic stations': This must be proven, and from the PCA I doubt the pH relationship.
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Line 340, 'opposite trend as in G. ruber (white)': Should be 'opposite trend than G. ruber (white)'.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 367f, 'Within the Mediterranean, a previous study with results comparable to ours, sampled the upper 350m (Pujol and Vergraud-Grazzini, 1995).': They also sampled with another mesh size, for which still no corrections have been applied.
ANSWER: See our reply to comment 1.

REF. 2 COMMENT: Line 401, 'smallesr': Should be 'smaller'.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Lines 409–411, ‘The lower absolute abundance of individuals in our study compared to Pujol and Vergraud-Grazzini (1995), together with low species diversity in the Mediterranean, may indicate a trend of changing conditions over the last decades, . . . ’: I still believe that this has to do more with the different mesh-sizes. The size fraction between 120 _m and 150 _m in my experience contains a lot of the standing stock of foraminifers.
ANSWER: See our reply to comment 1.

REF. 2 COMMENT: Section Factors controlling the abundance of the main species: All trends described here are purely derived from the PCA by eye, without any appropriate test. While their explanation can be valuable, their interpretation should be toned down considerably.
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Lines 445f, ‘The increasing dominance of G. ruber (white) from the western to the eastern Mediterranean Basin coincides with the eastward increasing salinity (Fig. 7d).’: Or Temperature, or CO2. It is hard to say without proper analytical techniques under this degree of multicollinearity.
ANSWER: See our reply to comment 3.

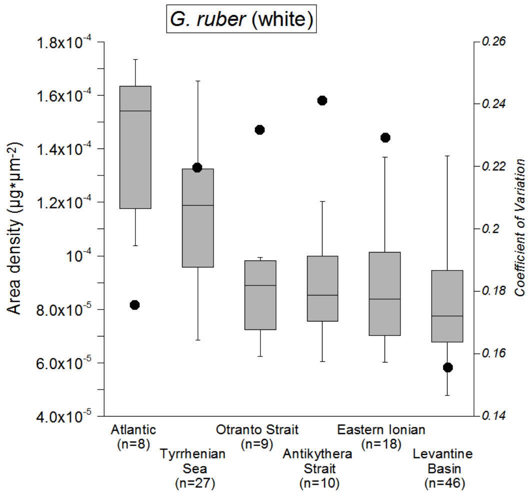
REF. 2 COMMENT: Line 537: Remove second ‘its’.
ANSWER: Changed in the revised manuscript.

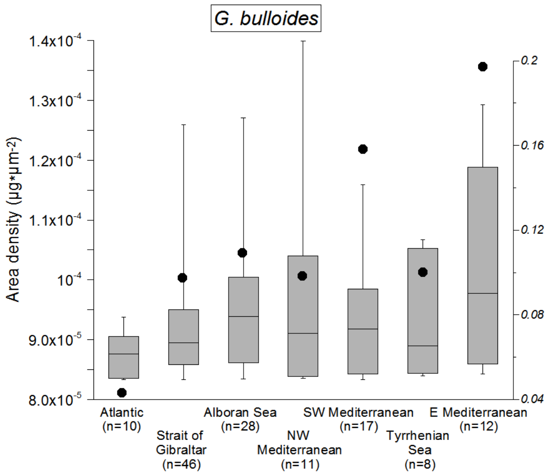
REF. 2 COMMENT: Line 548, ‘but abundances are slightly higher in the western basin to than the east.’: I highly doubt that from the PCA alone. You could prove it though.
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Line 569f, ‘In contrast, the density area of O. universa does not show any change between the western and eastern basins (Fig. 7i), and cannot be used to identify and quantify particular environmental effects.:’ I also doubt that there is a difference between basins in G. bulloides, and since the authors still refuse to use proper quantitative techniques to prove it . . .
ANSWER: See our reply to comment 3.

REF. 2 COMMENT: Line 615, ‘larger IQR indicates . . . ’: This is only true, when the variation in the sample is normalized for expected value (i.e. mean). This means, calculating the coefficient of variation, which I already requested in the first review. The authors replied ‘As also described above, in our comment to the reviewer comment about lines 480–482, we are unsure about what statistical method and/or calculation the reviewer is referring to here. Is there a distinct suggestion of some kind, with a reference? We are not sure how to calculate a “coefficient of variation” with regard to box plots and their statistics.’. No, I do not have a reference for it, because the coefficient of variation is such a basic and old method that its origins are lost in the mist of time, and you would not cite a reference as you would not cite a reference when calculating a mean value. Rather, the coefficient of variation is explained (and listed in the index) in every basic statistics book I suggested the authors to consult in my first review. It is also very easily found using Google and the search term ‘coefficient of variation’. Again, in short, variation is always correlated to mean value, so variations of samples which mean value differs must be corrected for this stochastic effect. An example: Let’s say you measured the length of twenty mice and found it to be 3_0.5 cm. You also measured the length of 20 elephants and found it to be 4_0.5 m. Which species has the higher variation? The absolute value is much larger for elephants (0.5 m) than for mice (0.5 cm), but when calculating the coefficient of variation you actually find mice to be more variable in size (0.166) than elephants (0.125). Since none of the IQRs in the manuscript are corrected (and I would recommend to use the standard deviation instead of the IQR anyways) all conclusions drawn by the authors concerning variation in their samples are invalid.

ANSWER: We added the Coefficient of Variation (CV) to Fig. 7. The CV is not influenced by the sample size (n) or the IQR. The CV of *G. ruber* between the Atlantic and the Tyrrhenian Sea is quite similar (0.04 of difference), showing little dispersion of our data between those locations. We decide to delete that sentence in the revised manuscript.





REF. 2 COMMENT: Line 624, ‘variability in density area data increases with increasing absolute density area’: Exactly as stochastically predicted. Calculate the coefficient of variation and compare again.

ANSWER: We observe that *G. ruber* CV ranges from 0.15 to 0.24, and for *G. bulloides* it goes from 0.04 to 0.2, showing little dispersion in our data between locations. We delete the following sentence in the revised manuscript: “At the same time, variability in ρ_A data increases with increasing absolute ρ_A, which resembles the distribution of data in *G. ruber* (white) (Fig. 7)”

REF. 2 COMMENT: Line 633, ‘retarded’: Should be ‘hampered’.
ANSWER: Changed in the revised manuscript.

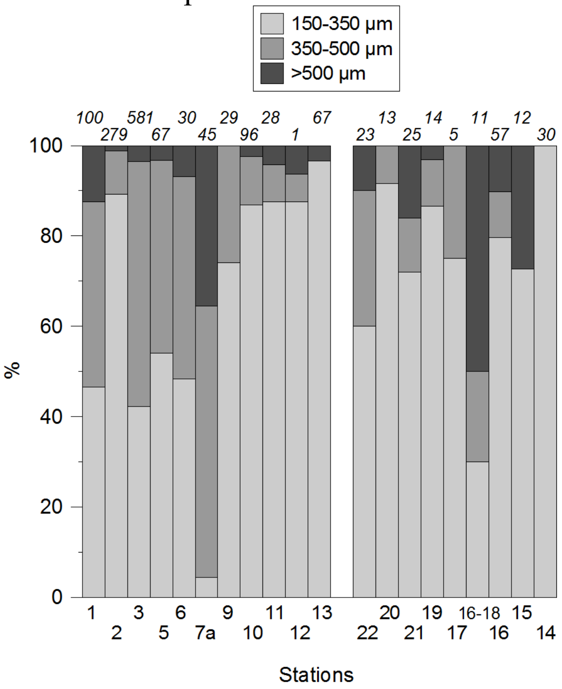
REF. 2 COMMENT: Line 636, ‘seems’: Should be ‘seem’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 640, ‘suited conditions’: Should be ‘suitable conditions’.
ANSWER: Changed in the revised manuscript.

REF. 2 COMMENT: Line 648, ‘’heavier average’: Should be ‘steeper average’, maybe.
ANSWER: We decided not to change “heavier” in the manuscript, as we considered the correct word for referring to more mass.

REF. 2 COMMENT: Line 651f, ‘All of these findings support our idea of an effect of limited alimentation on calcification.’: I do not understand this sentence.
ANSWER: That sentence is deleted in the revised manuscript.

REF. 2 COMMENT: Caption Fig 4 ‘Sample size is indicated by n below each station code.’: This information is not present in the figure.
ANSWER: We modified the legend and the figure for the revised manuscript as follows: “**Fig. 5.** Percentage of each planktic foraminifera size fraction in each station from leg 1 (stations 1 to 13) and leg 2 (stations 22 to 14). Sample size is indicated in italics at the top of each station bar.”



REF. 2 COMMENT: Figs 3 and 4: A lot of the interpretation by the authors in concerned with east-west trends. Then why are the graphs not ordered west–east, instead of by station number?

ANSWER: In the first manuscript version Figs. 3 and 4 (now re-ordered as 4 and 5) were ordered by station number. But in the second manuscript versions figures were already ordered west-east. It is not a strict west-east order, as we divide the two transects in the figures with a blank space (leg 1 and leg 2, see methodology section), but inside each transect they are ordered west-east. We consider them with an appropriate order now.

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REFEREE 3

Minor comments:

REF.3 COMMENT: Line 109: delete the double point
ANSWER: Changed in the revised manuscript.

REF.3 COMMENT: Line 171: delete the double parenthesis
ANSWER: The sentence is closing two parenthesis at the same time:
'Seawater carbonate data (total alkalinity (AT), and dissolved inorganic carbon (DIC)) were obtained from water samples retrieved at various depths during the CTD casts (see Goyet et al., 2015). We consider this sentence grammatically appropriate.

REF.3 COMMENT: Line 227: delete double parenthesis close to (without sac)). Substitute the parenthesis before G. ruber with bracket. Substitute the parenthesis after O. universa with a bracket. Delete the parenthesis after Figure 7.
ANSWER: We deleted the parenthesis after Figure 7. We consider a double parenthesis closing grammatically appropriate. With the referee's correction "area density" would be inside the category of "absolute abundances of foraminifera species", and is treated separately.
The sentence is now:
'*The sample scores of the first two factors with an overlay of absolute abundances of foraminifera species (G. ruber (white), G. bulloides, G. inflata, O. universa and T. sacculifer (without sac)) and area density (G. ruber (white), G. bulloides and O. universa) are shown in Figure 3.'*

REF.3 COMMENT: Line 248: please let space between words Overall,higher
ANSWER: Changed in the revised manuscript.

REF.3 COMMENT: Line 383: I would like only to make a small comment concerning the differences for the occurrence of G. elongatus. It is important to take in account that the time interval covered by the 2 cm of sediment analysed by Thunell (1978) is variable between some centuries to one or two millennia. This issue is important to consider because of recently Margaritelli et al (2016), in the central Tyrrhenian Sea fossil record, found G. elongatus over the last 4 millennia and the last specimens of this species are recorded in the last two centuries.
ANSWER: We appreciate the recent reference and the information regarding *G. elongatus* occurrence and the different type of information acquired in sediment versus plankton tows.

REF.3 COMMENT: Line 392: I would like to suggest to add more references concerning sedimentary cores. The manuscript is focused on living forams so that I would like to see references also concerning the last millennia (i.e., Margaritelli et al.,

2016 or others).
ANSWER: We appreciate the reference provided. We added the following references concerning more recent sedimentary core studies with the presence of *G. quadrilobatus*: Margaritelli et al., 2016; Lirer et al., 2013.

REF.3 COMMENT: Line 401: Pujol & Vergraud-Grazzini 1995 and not 1998
ANSWER: Changed in the revised manuscript.

REF.3 COMMENT: Paragraph 4.2: In this paragraph, the authors discuss the Figure 6, but the previous paragraph is mainly focused on figure 7. Is it possible to find a solution? It is enough anomalous.
ANSWER: We agree with Referee's comment. Figure order changed by order of appearance, in the text and the figure section of the manuscript: Fig. 7 turned to Fig. 3, Fig. 3 to Fig. 4, Fig. 4 to Fig. 5, Fig. 5 to Fig. 6, and Fig. 6 to Fig. 7.

REF.3 COMMENT: Line 480: please let space between words Pujol & Vergraud-Grazzini (1995),In winter
ANSWER: Changed in the revised manuscript.

REF.3 COMMENT: Line 610: please let space between words G. ruber (white)is only
ANSWER: Changed in the revised manuscript.

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Low planktic foraminiferal diversity and abundance observed in a spring 2013 West-East Mediterranean Sea plankton tow transect

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Abstract

Planktic foraminifera were collected with 150 µm BONGO nets from the upper 200 m water depth at 20 stations across the Mediterranean Sea between 02 May and 02 June, 2013. The main aim ~~was~~ is to characterize the species distribution and ~~their~~ test the ~~hypothesis of~~ covariance between foraminiferal area density (ρ_A) and seawater carbonate chemistry in a biogeochemical gradient including ultraoligotrophic conditions. Average foraminifera abundances are 1.42 ±1.43 ind.·10 m^{-3} (ranging from 0.11 to 5.20 ind.·10 m^{-3}), ~~with a total of~~ including twelve morphospecies ~~found~~. Large differences in species assemblages and ~~absolute~~ total abundances are observed between the different Mediterranean sub-basins, with an overall dominance of spinose, symbiont-bearing species indicating oligotrophic conditions. The highest values in absolute abundance ~~were~~ are found in the Strait of Gibraltar and the Alboran Sea. The western basin is dominated by *Globorotalia inflata* and *Globigerina bulloides* at slightly lower standing stocks than in the eastern basin. In contrast, the planktic foraminiferal assemblage in the warmer, saltier and more nutrient-limited eastern basin is dominated by *Globigerinoides ruber* (white). These new results ~~in combination with comparison~~when combined with~~to~~ previous findings, suggest that temperature-induced surface water stratification~~, of the surface water column, nutrient concentration and hence~~and food availability~~, seem~~ are ~~to be~~ the main factors controlling foraminiferal ~~abundances and~~ distribution. In the oligotrophic and highly alkaline and supersaturated with respect to calcite and aragonite Mediterranean surface water, standing stocks and ρ_A of *G. ruber* (white) and *G. bulloides* are affected by both food availability and ~~only secondarily by~~ seawater carbonate chemistry. ~~Increasing~~ Rapid warming,~~temperature,~~ increased ~~salinity,~~ surface ocean stratification impacting food availability and changes in trophic conditions could be the causes of reduced foraminiferal abundance, diversity, and species-specific changes in planktic foraminiferal calcification~~ in planktic foraminifera~~.

1. Introduction

The single-celled foraminifera comprise the most diverse group of calcareous zooplankton of the modern ocean. The majority of foraminifer species are benthic. About 50 morphospecies are planktic, which have a calcareous ~~exoskeleton~~ test organized in chambers (i.e., d'Orbigny, 1826; Hemleben et al., 1989; Goldstein, 1999). The species from different environments can be characterized by differences in wall structure, pore size and spatial density, spines and test shape, which are partly related to adaptation. The distribution of foraminifera is thought to be influenced by food availability, temperature, salinity, turbidity, sunlight, and predatory presence; these factors provoke an overall water depth preference, which shifts during ontogeny, and seasonal preference for each species (i.e., Schiebel and Hemleben, 2005; Hemleben et al., 1989). Some ~~of them~~species are found only in the photic zone because they are symbiont-bearing and depend on light for photosynthesis. After reproduction, the empty shells sink to the seafloor, where the~~ir~~ fossils are useful for paleoceanographic studies (e.g., Shackleton, 1968; Rohling et al., 2004; Mojtahid et al., 2015). Ecological tolerance limits of modern foraminifera are not completely defined, but progressive reduction in abundance (caused by worsening of their organic functions like food uptake, growth and reproduction, until death) is related with their departure from optimum conditions (Bé, 1977; Arnold and Parker, 1999). The absolute abundance of foraminifera is also affected by a predictable and distinct seasonal cycle for each species driven by the food ~~source~~ content and temperature of the water mass (Hemleben, 1989; Bé and Tolderlund, 1971; Jonkers and Kučera, 2015; Žarić et al., 2005; for Mediterranean examples see: Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Bárcena et al., 2004; Hernández-Almeida et al., 2011; Rigual-Hernández et al., 2012; de Castro Coppa et al., 1980).

A vast majority of studies on planktic foraminifera are based on samples from bottom sediments and sediment cores, mainly for paleoceanographic purposes, with few studies considering the modern population in the water column, including the Mediterranean Sea. The first modern study of planktic foraminifera in this specific area was based on surface sediment samples collected by the Swedish Deep-Sea expedition of 1947-48 (Pettersson, 1953). A subsequent study found different species assemblages between the western basin, the eastern basin, and the Aegean Sea (Parker, 1955). The pioneering study of foraminifera population variability in the water column of the Mediterranean was conducted by Glaçon et al. (1971) in the Ligurian Sea, showing large seasonal variations of the relative abundances of the different species. Such variations of planktic foraminiferal assemblages in the water column were also reported for the Bay of Naples (de Castro Coppa et al., 1980). Cifelli (1974) was the first to cover the broader Mediterranean, with plankton tows of the upper 250m of the water column from west Madeira in the Atlantic Ocean to the Isle of Rhodes in June 1969; they identified ~~prominent~~ different~~ced~~ relative abundances of subtropical and subpolar species in different parts of the Mediterranean.

Thunell (1978) studied the upper 2 cm of sediment cores retrieved ~~in~~ from different sites of the Mediterranean Sea and concluded that the distribution of planktic foraminifera was closely related to the distribution of the different surface water masses. ~~There are specific temperature and salinity ranges for each water mass~~Each water mass has a characteristic range of temperature and salinity (Brown et al., 2001)~~,~~

~~as Bé and Tolderlund (1971) stated for the Atlantic, ~~and a partial isolation effect in the different basins and sub-basins of the Mediterranean. Those hydrographic~~s~~ differences result in different species assemblages in each region. This contradicts somewhat with Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), who gained quantitative data with flow-metered plankton tows in the upper 350 m of the water column, through a NW-SE Mediterranean transect from September-October 1986 and February 1988, and the Alboran Sea in April 1990. They concluded that despite the W-E temperature and salinity gradients observed, those were not large enough and no close correlation was found to justify the extremely variable foraminifera assemblages, with high seasonal and geographical variations in absolute and relative abundances. They suggested that food availability is the main factor controlling their seasonal and geographical distribution and abundance.~~;~~ ~~and when nutrients are sufficient,~~ ~~h~~Hydrographic structures like eddies and fronts ~~play the main role~~exert control on the distribution of species in case food is present in ample amounts.

Despite no ~~new ~~recent plankton tow study being carried out in the entire Mediterranean Sea, three regional studies based on sediment traps were realized in the Alboran Sea (Bárcena et al., 2004; Hernández-Almeida et al., 2011) and the Gulf of Lion (Rigual-Hernández et al., 2012). The one-year time~~-~~series study of the Alboran Sea sediment traps (July 1997 – May 1998) shows~~ed~~ big differences in the main species distribution and daily ~~fluxes~~export production, driven by food availability (related with water mixing/stratification periods) and temperature (Bárcena et al., 2004; Hernández-Almeida et al., 2011). The 12-year sediment trap foraminifera flux record~~s~~ in the Gulf of Lion (October 1993 – January 2006) shows~~ed~~ a strong seasonal pattern~~ of the species~~, with more than 80% of the annual export production recorded~~bundances~~ from winter ~~and ~~to spring ~~in correlation with~~related to higher food ~~the nutrient ~~supply and mixing~~ed~~ state of the water column ~~conditions ~~(Rigual-Hernández et al., 2012).

The calcification of foraminifera is affected by the chemical state of ~~their surrounding~~ambient seawater~~s~~. Theoretically, their shell mass is positively related to temperature, pH, [Ca^{2+}], alkalinity, and [CO$_3^{2-}$], and negatively related to the [CO$_2$] of ~~the surrounding~~ambient seawater~~s~~ (Schiebel and Hemleben, 2005). Different studies conducted on water column foraminifera show differential results, as their shell mass can either be positively (Aldridge et al., 2012; Beer et al., 2010a; Marshall et al., 2013; Moy et al., 2009)~~ but also~~ or negatively related to [CO$_2$] (Beer et al. 2010a). Also, other studies report a positive effect of the temperature on foraminifera shell mass (Mohan et al. 2015; Aldridge et al., 2012; Marshall et al., 2013; Weinkauf et al., 2016). Beer et al. (2010a) suggest a species-specific relation between shell mass and [CO$_3^{2-}$], depending on the presence or absence of symbionts. Some authors suggest that other factors like ecological stress do not affect the calcification intensity (Weinkauf et al., 2013). For further studies that relate foraminiferal calcification with environmental parameters see Weinkauf et al. (2016); Table 7. From the onset of the industrial era, anthropogenic emissions of CO$_2$ have led to ocean acidification, decreasing seawater pH and [CO$_3^{2-}$], which provokes reduced stability of CaCO$_3$ that may reduce the formation of foraminiferal test~~s~~ calcite (Zeebe, 2012; de Moel et al., 2009; Moy et al., 2009).

Studies of the ecology of foraminifera in the Mediterranean waters remain scarce. Few studies exist covering the entire Mediterranean Sea.~~;~~ ~~m~~Most studies are focused on specific regions, i.e., the Gulf of Naples (de Castro Coppa et al., 1980), the Alboran Sea plus the southwestern Mediterranean (van Raden et al., 2011). Data on living planktic foraminiferal abundances ~~were ~~are provided by Cifelli (1974; spring only) and more recently by Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995). In addition, few size-normalized weight (SNW) and area density (ρ_A) studies to infer the calcification intensity ~~from~~ of water column foraminifera are available in the literature (see Schiebel et al., 2007; Beer et al., 2010a; Aldridge et al., 2012; Marshall et al., 2013; Mohan et al., 2015; Marshall et al., 2015; Weinkauf et al., 2016).~~.~~ New data are needed, since environmental conditions of the water column and associated foraminiferal assemblages might have changed over the past 20 years.

In this study, new quantitative and qualitative data are presented on living planktic foraminifera~~,~~ across the Mediterranean Sea during spring 2013. Comparisons are made with previous studies from Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), Cifelli (1974), de Castro Coppa et al. (1980), Bárcena et al. (2004), Hernández-Almeida et al. (2011), Rigual-Hernández et al. (2012) and Thunell (1978). The study by Thunell (1978) is based on surface sediments, ~~which can provide information,~~ but might be biased ~~towards faster-sinking and more hydrodynamic tests due to shorter exposure to~~by differential transportation and dissolution ~~processes~~ of tests (Thunell, 1978; Caromel et. al., 2014; Schiebel et al., 2007)~~, and towards tests with thicker walls that are better preserved (Thunell, 1978)~~. Although core top samples (0-2 cm) are suitable to infer ~~modern~~ variability of modern conditions (Thunell; 1978), they can cover the last few decades to few centuries, depending on the sedimentation rate, while our plankton tow sampling represents a ~~relative~~ “snap shot” of the modern water column (Mortyn and Charles, 2003), in this case the Mediterranean. ~~In addition, empty tests are passive particles that ocean currents may displace horizontally, but that displacement is negligible due to their quick settling velocities (Caromel et al., 2014).~~ Correlated results between plankton tows (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995) and surface sediments (~~Vergraud~~Vergnaud-Grazzini et al., 1986) at coincident places in the Mediterranean confirm the results obtained by Thunell (1978).

The objectives here are to (1) delineate new absolute abundances of planktic foraminifera within the different regions of the Mediterranean Sea during spring, (2) characterize ecological demands~~,~~ at the species level ~~their ecology through their seasonal and geographical distribution and abundance~~ by comparison with previous studies, and (3) provide new ρ_A data for comparisons between sub-basins of the Mediterranean Sea and with other studies, in the context of ocean warming and acidification over the past 20 to 40 years.

2. Oceanographic Setting

The Mediterranean Sea, with a strong thermohaline and wind-driven circulation, and a surface of approximately 2,500,000 km^2, is divided into two main basins near the Strait of Sicily: the western and eastern basins. These basins are composed of different sub-basins due to partial isolation caused by sills that influence the water circulation, and by different water properties (Rohling et al., 2015; Rohling et al., 2009). Natural connection with the ocean is through the narrow Strait of Gibraltar, where nutrient-rich Atlantic surface waters enter the Mediterranean and experience an eastward increase of temperature and salinity (Fig. 1) driven by insolation and evaporation, having a negative hydrological balance (evaporation exceeding precipitation). The Mediterranean becomes increasingly oligotrophic towards the east (Fig. 1; Fig. 2). In addition, the incoming Atlantic waters enter the Algero–Provençal Basin as far as the Tyrrhenian

Sea, and contribute to deep water formation in the Gulf of Lion in cold winters (Rohling et al., 2015; Rohling et al., 2009).

In the eastern basin, two main sources of deep-water formation are active mainly during winter in the Adriatic and the Aegean Seas. Cold dry winds cause evaporation and cooling forming denser and more saline water masses that sink to depth (Rohling et al., 2015; Rohling et al., 2009; Hassoun et al., 2015b). The same process is active in the Levantine basin, forming an intermediate water mass, which becomes progressively cooler and fresher toward the western basin. Some waters reach the Tyrrhenian Sea. Waters returning to the Atlantic through the Strait of Gibraltar at depth are cooler and saltier than the inbound waters, and compensate for the inflow from the Atlantic. The Mediterranean Sea has a large physicochemical gradient for such a small marginal sea (Rohling et al., 2015; Rohling et al., 2009; Fig. 1).

3. Methodology

3. 1. Study Area

Plankton tow samples were collected during the MedSeA (Mediterranean Sea Acidification in a Changing Climate) cruise from 02 May to 02 June 2013 on board the Spanish R/V *Ángeles Alvariño*. The transect was divided into two legs (Fig. 2). The first leg ranged from the Atlantic Ocean near the Gibraltar Strait (adjacent to Cadiz Harbour, Spain) as far as~~until~~ the Levantine sub-basin in the Eastern Mediterranean (3879 km long, 11 sampling sites). The second leg started ~~in~~ from Heraklion~~,~~ (Crete, ~~(~~Greece) into the Ionian Sea, passed south of the Adriatic and Tyrrhenian Seas, and ~~finished~~ ended in the North Algero-Provençal basin, adjacent to Barcelona, Spain (3232 km long, 9 sampling sites, Fig. 2).

3. 2. Material and methods

Twenty samples were collected with BONGO nets (mesh size 150 µm and 40 cm diameter, for further details see Posgay, 1980). Those nets sampled primarily 200 m depth, but also caught foraminifera during the net descent and ascent ~~including tow time integrating the upper water column from 200m~~ to the ocean surface, which both involve negligible towing and capturing time compared to the sampling at 200 m depth (Table 1). The sampling device was equipped with a flow-meter allowing the estimation of the volume filtered in each tow. ~~-~~The data for temperature, salinity, oxygen, and fluorescence were integrated over the upper 200m from the nearest CTD stations retrieved during the same cruise (for the complete dataset see Ziveri and Grelaud, 2015). Seawater carbonate data (total alkalinity (AT), and dissolved inorganic carbon (DIC)) were obtained from water samples ret~~i~~rieved at various depths during the CTD casts (see Goyet et al., 2015). These data were used to calculate pH, pCO_2, and $[CO_3^{2-}]$ using the software CO2Sys (Lewis and Wallace, 1998) with the equilibrium constants of Mehrbach (1973) refitted by Dickson and Millero (1987). These three parameters of the carbonate system were then integrated for the upper 200 m water depth. The nutrient concentrations ($[PO_4]$ and $[NO_3]$) were measured by OGS (Italaian National Institute of

Oceanography and Experimental Geophysics). The water samples were filtered on glass fiber filters (Whatman GF/F; 0.7 µm) and then kept at -20ºC onboard. The samples were then analyzed in the laboratory with a Bran+Luebbe3 AutoAnalyzer (see Grasshoff et al., 1999). Surface chlorophyll *a* concentration was obtained from MODIS Aqua L2 satellite data (NASA Goddard Space Flight Center: http://oceandata.sci.gsfc.nasa.gov/).

Foraminiferal samples were collected either at daytime or nighttime. Plankton samples were preserved by adding a 4 % formaldehyde solution buffered with hexamethyltetramine at pH = 8.2 on board. Individuals were not necessarily alive when collected and no distinction was made between cytoplasm-bearing tests: as alive or dead but still containing cytoplasm (see also Boltovskoy and Lena, 1970), and empty tests (dead) were considered for this study. From each sampling station, the foraminifera were isolated and identified at the species level. When necessary, samples were split into aliquots of 1/4 and 1/6.~~Samples were studied from the collecting bottles and the bottom collector, the latter representing 52.33 % of the total sample were treated in aliquots of 1/2, 1/4, 1/6, until 1/8.~~ For each sample, each species was counted and isolated according to 3 size fractions (150–350 µm, ≥350–500 µm, and~~-~~ >500 µm) to determine the absolute and relative abundances. Foraminifera smaller than 150 µm and/or~~,~~ with tests partially broken, making them unrecognizable or unmeasurable,~~and/or with organic matter attached~~ were discarded.

We classified the different foraminifera species by visual identification ~~under~~ using ~~optical~~ incident light microscopy. Following the morphometric guidelines and taxonomic nomenclature proposed by Aurahs et al. (2011) for *Globigerinoides ruber* (white), *Globigerinoides ruber* (pink) and *Globigerinoides elongatus*. For *Trilobatus sacculifer* (with sac) and *T. sacculifer* (without sac) we ~~used~~ followed Spezzaferri et al. (2015). The taxonomy of Hemleben et al. (1989) was ~~used~~ applied~~as a guide~~ to classify *Globigerina bulloides, Orbulina universa, Globorotalia inflata, Globorotalia menardii*, and *Hastigerina pelagica*. ~~*Globigerinoides*~~ *Trilobatus sacculifer* ~~*quadrilobatus*~~ morphotype *quadrilobatus* was inferred from ~~Papp and Schmid (1985)~~Spezzaferri et al. (2015) after André et al. (2013); this morphotype is referred as *T. quadrilobatus* in this study and is treated separately from *T. sacculifer* (without sac). ~~*G.bulloides* could not be differentiated from *Globigerina falconensis* in our samples and are treated together; the *G. bulloides/G. falconensis* plexus is referred to as *G. bulloides* in our study.~~ The *Globigerinella siphonifera/G. calida/ G. radians* plexus (see Weiner et al., 2015) is treated as *G. siphonifera* in our study.

For the area density (ρ_A) study, we selected three main species: *G. ruber, G. bulloides*, and *O. universa*. All specimens, without partially broken tests and/or with organic matter attached, of these three species were photographed with a *Canon EOS 650 D* camera device attached to a *Leica Z16 AP0* microscope to measure their long axis and silhouette area using the software ImageJ (Schneider et al., 2012). For each station and each of the three selected species, the individuals were weighed together by triplicate with a Mettler Toledo XS3DU microbalance (±1 µg of nominal precision) within 50 µm size fraction increments (150-200 µm, 200-250 µm, etc.). Cytoplasm-filled or empty dry-weighed foraminifera tests were weighted together since dry cytoplasm has no statistically significant effect on the weight of tests >150 µm (Schiebel et al., 2007). Specimens containing notable organic matter attached to the outside of the test were discarded. The maximum number of individuals weighed together was ~~5~~five.~~;~~ ~~in~~ At some stations, individuals were measured individually ~~as no~~in case more than one specimen~~s~~ was not~~ere~~ available. In all ~~the~~ cases, the mean weight per specimen of the three weightings was applied. The silhouette area obtained was then used to ~~measure~~ calculate the ρ_A (Weinkauf et al., 2013; Marshall et al., 2013; Marshall et al., 2015).

3.3. Statistical methods

~~We performed a principal~~Principal component analysis (PCA; Varimax rotation) of the environmental parameters (temperature, salinity, oxygen, fluorescence, NO_3, PO_4, pH, pCO_2 and CO_3^{-2}) characterizing the 20 stations was extracted using SPSS Statistic 23 software. ~~The PCA was performed on the environmental parameters: temperature, salinity, oxygen, fluorescence, NO_3, PO_4, pH, pCO_2, and [CO_3^{-2}], from every station.~~ The two first PCA factors~~components, which together~~ explain about 77 % of the total variance in environmental parameters~~, were obtained~~ (Fig. ~~7~~3).~~:~~ The first factor exhibited positive loadings on the nutrients and the fluorescence and negative loadings on temperature and salinity (and to a lesser degree on [CO_3^{2-}]; Table 2). The~~is~~ first factor explains 56.99% of the total variance and depicts well the general trend observed in the Mediterranean Sea with in general colder and more productive waters in the western basin and warmer and less productive waters in the eastern one~~represents the strong west-east gradient characterizing the Mediterranean Sea as the water becomes warmer, saltier and more oligotrophic eastwards~~. The second factor explains about 20.02% of the total variance and is characterized by positive loadings of~~n~~ pH and oxygen concentrations (and to a lesser degree on [CO_3^{-2}]) and~~ a~~ negative loading of~~n~~ the pCO_2 (Table 2). It is interpreted as~~ the~~ variations of the carbonate system ~~properties~~ in the Mediterranean Sea with in general lower pH/[CO_3^{-2}] in the western basin compared to the eastern basin~~ slightly lower surface water pH in the western basin compared to the eastern basin~~. The sample scores of~~n~~ the first ~~2~~ two factors with an overlay of absolute abundances of foraminifera species (*G. ruber* (white), *G. bulloides*, *G. inflata*, *O. universa* and *T. sacculifer* (without sac)) and area density (*G. ruber* (white), *G. bulloides* and *O. universa*) are shown in Figure ~~7~~3~~)~~.

4. Results

4. 1. Absolute and relative abundance

The absolute abundance of planktic foraminifera collected with BONGO nets has a mean value of 1.42 ±1.43(SD) individuals·10 m^{-3}. A maximum value of 5.2 ind.·10 m^{-3} in the Strait of Gibraltar is followed by 4.14 ind.·10 m^{-3} in the Alboran Sea, 3.61 ind.·10 m^{-3} in the Tyrrhenian Sea, and 3.00 ind.·10 m^{-3} off southern Crete (Fig. ~~3~~4; Fig. ~~7a~~3a). With the exception of these four regions, a standing stock of 1.7 ind.·10 m^{-3} is not surpassed at~~in~~ any other station. A minimum standing stock occurs in the Adriatic Sea (0.11 ind.·10 m^{-3}). The westernmost stations ~~(~~2 and 3~~,)~~ with the highest Atlantic influence, have the highest abundance values (4.67 ind.·10 m^{-3} on average), followed by the eastern Mediterranean Stations 9 to 13 (1.31 ind.·10 m^{-3}~~), and the western Mediterranean (Stations 5, 6, 20, 21 and 22; 0.77 ind.·10 m^{-3}) with a clearer difference within the southwest (Stations 5 and 6; 1.08 ind.·10 m^{-3}) and the northwest (Stations 20 to 22; 0.56 ind.·10 m^{-3}~~; Fig. ~~3~~4; Fig. ~~7a~~3a; Appendix A). Pervasively, the most common size fraction of foraminifera is 150–350 µm (65.57%; Fig. ~~4~~5), especially due to the ~~contribution~~ presence of *G. ruber* (white) and *G. bulloides*.

~~The exceptions are at Station 3 with a high presence of 350–500-µm sized *G. inflata*, and Station 7a mainly due to >500-µm sized *O. universa*, and 350–500-µm sized *G. siphonifera* and *G. inflata*.~~ The 350-500-µm size fraction in the first leg dominates in the western Mediterranean and is progressively reduced eastwards (Fig. 5~~4~~)~~, mainly due to the contribution of small *G. inflata* from the 150-350 µm size fraction~~. H~~Overall, h~~igher percentages of individuals >500 µm in the first leg are found in the western part of the Mediterranean compared to the eastern part (Fig. ~~4~~5). The highest percentages of >500 µm tests are found at the Strait of Sicily and the Northern Ionian Sea (St. 7a, 16-18; Fig. ~~4~~5; Fig. S1; Appendix A). In concordance with Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), no differences are observed between samples collected during day and night. However, due to the extremely low standing stocks the above observations are mere snapshots, and may not be generalized.

The most abundant species is *G. ruber* (white) (with an average of 0.30 ind.·10 m^{-3}, representing 21.49% of the total assemblage); its highest abundances are found in the Tyrrhenian Sea (St. 19, 1.69 ind.·10 m^{-3}) and in the eastern Mediterranean (Stations 10 and 13). ~~It~~ *Globigerinoides ruber* (white) is not present in the Adriatic Sea, at Station 16–18, and in the northwestern Mediterranean. It is found in low numbers in the southwestern Mediterranean, Atlantic, and Strait of Gibraltar stations (Fig. ~~3~~4; Fig. ~~7d~~3d). Individuals >350 µm in ~~test~~ long test axis are rare (Appendix A). *G. inflata* is the second most abundant species (0.29 ind.·10 m^{-3}; 20.19%), mainly due to its high abundance in the Alboran Sea (3.5 ind.·10 m^{-3}; 61.08% of the sample). It is mainly present in the western Mediterranean ~~until the Strait of Sicily. East of the Strait of Sicily, it is only found with low abundances at the westernmost stations~~ (Fig. ~~3~~4; Fig. ~~7b~~3b). The dominant size fraction is 350-500 µm (Appendix A). *G. bulloides* has an average abundance of 0.24 ind.·10 m^{-3} (17.20 %), mainly due to its abundance in the Strait of Gibraltar (2.31 ind.·10 m^{-3}; 47.34 %). It is slightly more abundant in the southwestern Mediterranean and the Tyrrhenian Sea than in the eastern Mediterranean. It is a quite ubiquitous species being absent at four stations (Fig. ~~3~~4; Fig. ~~7e~~3e). It rarely appears in the >350-µm test-size fraction (Appendix A).

*Trilob*at*us sacculifer* (without sac~~; also referred as *T. trilobus*;~~ on average 0.13 ind.·10 m^{-3}; 9.16 %), is especially notable at the Strait of Gibraltar (50.91 %; Fig. ~~3~~4; Fig. ~~7c~~3c). *O. universa* is ubiquitous in the whole Mediterranean Sea with the exception of the three Stations 6, 9, and 14 (Fig. ~~3~~4; Fig. ~~7f~~3f). Its average abundance is 0.12 ind.·10 m^{-3} (8.70 %). Its dominant size fractions are ~~≥~~>350 µm (Appendix A; Fig. ~~4~~5). *G. elongatus* (0.09 ind.·10 m^{-3}; 6.41 %) is found mostly at the same stations as *G. ruber* (white), but is usually less abundant (Fig. 4~~3~~). It is most frequent in the ~~≥~~350-500-µm test-size fraction, and some individuals >500 µm are found in the Atlantic (Appendix A). The other species and morphotypes appear in very low numbers: ~~*G*~~*T*. *quadrilobatus* (0.07 ind.·10 m^{-3}), *G. siphonifera* (0.03 ind.·10 m^{-3}), *G. ruber* (pink) (0.02 ind.·10 m^{-3}), *H. pelagica* (0.008 ind.·10 m^{-3}), *G. menardii* (0.001 ind.·10 m^{-3}) and *T. sacculifer* (with sac) (0.001 ind.·10 m^{-3}; Fig. 4~~3~~; Appendix A).

The PCA performed on the environmental parameters and the sample scores of~~n~~ the two first components shows a clear~~ly shows a~~ separation~~, regarding Factor 1,~~ between the western and eastern Mediterranean stations in Factor 1 (Fig. ~~7~~3). The western basin~~, which~~ is characterized by ~~more~~ higher food availability ~~for~~ to the foraminifera, lower temperatures, ~~and~~ lower salinit~~y~~ies, ~~is where the~~and highest absolute planktic foraminifera abundances ~~are the highest~~ (Fig. ~~7a~~3a). In the eastern basin, station 10 is an exception with a considerable contribution ~~from~~ of *G. ruber* (white) to the absolute abundances (Fig. ~~7a~~3a). ~~Regarding~~ In PCA Factor 2, the stations ~~more~~ influenced by the incoming waters from the Atlantic ~~have the~~and lowest [CO_3^{-2}] values score highest. The stations where absolute abundances show some affinity for higher [CO_3^{-2}] values conditions are in the NW Mediterranean, the Tyrrhenian Sea, and in the northern Ionian Sea (stations 14, 15 and 16). ~~The majority of the Ionian Sea stations and all the Levantine Basin stations show average values (Fig. 7a~~3a~~).~~ Overall, ~~the~~ highest absolute abundances of ~~all~~ the total planktic foraminifera assemblage seems to be related to food availability, and only secondarily to the carbonate system (Fig. ~~7a~~3a).

With the exception of the Tyrrhenian Sea (St. 19), *G. ruber* (white) abundance is ~~positively correlated~~related with warmer and saltier waters, and lower pH (St. 9, 10, 11, 12, 13, 14, 15; Fig. ~~7d~~3d). The opposite is observed for *G. bulloides*, and higher abundances occur where more food is availab~~i~~le and at stations where pH is higher (Fig. ~~7e~~3e). *O. universa* shows an ubiquitous distribution with no remarkable trends within the two PCA factors (Fig. ~~7f~~3f). The ~~irregular~~ more patchy abundance distribution of *T. sacculifer* (without sac) does not follow any ~~remarkable~~ trend (Fig. ~~7c~~3c). *G. inflata* positively correlates with food availability, and the regional distribution follows the path of Atlantic waters (Fig. ~~7b~~3b).

To show the relative abundance of the various species, some stations were grouped together to achieve a minimum number of foraminifera (>95 tests); the grouping was set by location proximity in which foraminiferal assemblages were similar. The stations at the Strait of Sicily and the western Mediterranean (Stations 20, 21, 22) are not shown due to ~~a~~ low numbers of individuals (< 90; Fig. ~~5~~6). ~~Some similarities can be seen between the Tyrrhenian Sea and the eastern Mediterranean, and also between the Alboran Sea and the southwestern Mediterranean. The Atlantic and the Ionian-Adriatic-Aegean grouping have similar proportions of species. On the other hand, t~~The Tyrrhenian Sea and the eastern Mediterranean stations were dominated by *G. ruber* (white), the Alboran Sea by *G. inflata*. The dominance of a single species in the southwestern Mediterranean is less clear, which might be due to low numbers of individuals (*G.inflata* being the main species followed by *G. bulloides* as in the Alboran Sea~~ station~~). *T. sacculifer* (without sac) has a high relative abundance in the Atlantic Ocean and in the Strait of Gibraltar, being the main and the second most abundant species, respectively. At all other stations analyzed, *T. sacculifer* (without sac) is less abundant. *G. bulloides* is most frequent in the entire western Basin and the Atlantic Ocean, being the main species in the Strait of Gibraltar. It is less frequent in the Tyrrhenian Sea, and in the eastern Basin and its sub-basins. *G. bulloides* contrasts with *G. ruber* (white), which always represents a small percentage of the assemblage in the western Mediterranean but dominates the Tyrrhenian Sea and the eastern Basin (Fig. 6~~5~~; Appendix A).

4. 2. Area density (ρ_A)

Due to their high abundance, *G. ruber* (white), *G. bulloides*, and *O. universa* were analyzed for their area density (ρ_A; Fig. 7 ~~6~~ including their Coefficient of Variation (CV); Fig. 3~~7~~g-i). The ~~high~~ two-dimensional (silhouette) area-to-long axis correlation is best fitted by a power regression (Fig. S2). ~~The same~~Similar growth patterns can be seen in *G. ruber* (white), *G. bulloides*, and *O. universa* with that correlation,

~~represented ~~graphically represented by~~in~~ the shape of a power function (Fig. S2). ~~They ~~Planktic foraminifera grow~~ slightly~~ faster when they are younger and smaller (steepest in the lower left part of the regression line) and~~ slightly~~ slower when they are~~grow~~ older and bigger (less steep in the upper right part of the regression line; Fig. S2). The specimens of *G. ruber* (white) from the Atlantic have a significantly larger area than those from the Tyrrhenian Sea ($p \leq 0.003$), which in turn have significantly larger area than those from the East Ionian Sea grouping ($p \leq 0.001$).~~The specimens of *G. ruber* (white) from the Atlantic have the largest size followed by individuals from the Tyrrhenian Sea, and those from the eastern Ionian Sea.~~ ~~For ~~In the other two species *G. bulloides* and *O. universa*, a similar trend is observed regarding the two basins, with the eastern Mediterranean ~~having ~~hosting the smallest individuals, while the largest individuals occurred in the Atlantic and the northwestern Mediterranean (Fig. S2). The different locations were grouped using the same criteria as in Fig. 6~~5~~.

The long axis-to-weight relation of *G. ruber* (white) specimens yielded an $r^2 = 0.841$ (linear regression throughout this paragraph; Fig. S3), followed by *O. universa* ($r^2 = 0.63$), and *G. bulloides* ($r^2 = 0.516$; Fig. S3). *O. universa* was finally discarded for comparisons between ρ_A at different locations due to a low area-weight correlation and no remarkable trend observable between locations (Fig. S4c; Fig. ~~7i~~3i); while data from *G. ruber* (white) correlate well (Fig. S4a). The eastern Mediterranean specimens are the lightest ~~for ~~in both species (*G. ruber* (white), *G. bulloides*), with more extreme W-E differences ~~for ~~in *G. ruber* (white) than in *G. bulloides* (Fig. S4d-e).

The ρ_A of *G. ruber* (white) specimens from six locations were compared (Fig. ~~6~~7). The data of all the locations show a similar CV value. The eastern Mediterranean individuals have the lowest median ρ_A (approximately between $7.5\cdot10^{-5}$ and $9\cdot10^{-5}$ $\mu g\cdot\mu m^{-2}$), with lower values eastward, and a small interquartile range ($IQR = Q_3 - Q_1$). The Atlantic individuals of *G. ruber* (white) show the highest median value ($1.55\cdot10^{-4}$ $\mu g\cdot\mu m^{-2}$) and IQR. The ρ_A of Tyrrhenian individuals ranges between those from the eastern Mediterranean and Atlantic Ocean ($1.2\cdot10^{-4}$ $\mu g\cdot\mu m^{-2}$). The ρ_A of *G. ruber* (white) for each station was compared with the two PCA factors; higher ρ_A are related to slightly lower pH and to higher food availability in the western Mediterranean and Atlantic stations (Fig. ~~7g~~3g).

For *G. bulloides* specimens, seven locations were compared (Fig. ~~6~~7). The data from these locations show similar CV values. ~~The ~~Specimens from the Atlantic have~~s~~ the lowest median ρ_A ($8.75\cdot10^{-5}$ $\mu g\cdot\mu m^{-2}$) and the smallest IQR, showing an opposite trend ~~as in~~than *G. ruber* (white). Also contrary to *G. ruber* (white), *G. bulloides* from the eastern Mediterranean tend to have a higher median ρ_A ($9.75\cdot10^{-5}$ $\mu g\cdot\mu m^{-2}$) and a larger IQR. The differences in ρ_A between the eastern and western Mediterranean are smaller in *G. bulloides* than in *G. ruber* (white). The ρ_A of *G. bulloides* at each station was compared with the two PCA factors. Results show a less clear overall trend for *G. bulloides* than for *G. ruber* (white), with ~~the ~~higher ρ_A associated with slightly higher pH in the eastern Mediterranean ~~sea water ~~(Fig. ~~7h~~3h).

5. Discussion

5. 1. Abundance and diversity patterns

Absolute abundance values of 4.2 individuals per 10 m^{-3} ~~(≥~~(>150 µm) on average are low in comparison with ~~other water column foraminifera~~earlier studies, even ~~for~~ in oligotrophic regions. For example, in the oligotrophic northern Red Sea, less than 100 ind.·10 m^{-3} (>125 µm) were reported from surface waters, and standing stocks were much higher than 100 ind.·10 m^{-3} at most of the sites sampled in 1984 and 1985 (Auras-Schudnagies et al., 1989). In the oligotrophic to mesotrophic Caribbean and Sargasso Seas, standing stocks were up to 786 ind.·10 m^{-3} (>100 µm) and 907 ind.·10 m^{-3} (>202 µm), respectively (Schmuker and Schiebel, 2002, and references therein). In the Atlantic, south of the Azores Islands, Schiebel et al. (2002) counted an average of 66.15 ind.·10 m^{-3} for the upper 100 m in August 1997, and 422.97 ind.·10 m^{-3} in January 1999 (>100 µm). S~~Other s~~imilar studies show higher abundances of one or two orders of magnitude (i.e. Sousa et al., 2014; Boltovskoy et al., 2000; Kuroyanagi and Kawahata, 2004; Rao et al., 1991; Ottens, 1992; Schiebel et al., 1995). At higher latitudes, in the Fram Strait (Arctic Ocean), Pados and Spielhagen (2014) obtained approximate values of 117 ind.·10 m^{-3} from the upper 500 m in late June-early July of 2011. Mortyn and Charles (2003), in February-March 1996, at 200 m depth range in the Atlantic sector of the Southern Ocean, found as a minimum value 0.1 ind.·10 m^{-3}, with an approximate mean of 73 ind.·10 m^{-3}.

Within the Mediterranean, a previous study with results comparable to ~~ours~~the data presented here, sampled the upper 350 m of the water column (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). In~~For~~ the Alboran Sea, samples were obtained during a similar period of the year (April 1990) with values around 16, 6 and 9 ind.·10 m^{-3}, greater than in the Station 3 (4.14 ind.·10 m^{-3}). Samples from different seasons have higher abundances, with highest values in February (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995), and a high annual average of 9.3 ind.·10 m^{-3}. Regarding Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), western Mediterranean abundances are higher than the eastern ones, due to more oligotrophic conditions and higher temperature and salinities in the east that limit foraminiferal production during winter and late summer. ~~In concordance with Pujol and Vergraud-Grazzini (1995), no differences are observed between samples collected during day and night.~~

Comparing with previous studies that covered the Mediterranean, we notice that Thunell (1978, surface sediments) and Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995, water column) did not find *G. menardii*, while ~~it~~ the species was reported by Cifelli (1974) in very low abundances. The fact that *G. menardii*, which has a preference for tropical waters, is not found in the surface sediments suggests that it is a new species in the Mediterranean Sea (Cifelli, 1974). Its recent presence in the Mediterranean Sea could be related to the warming of surface~~the~~ waters. All other species found in our study were also found in the past studies covering the Mediterranean Sea (Cifelli, 1974; Thunell, 1978; Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). It remains unclear whether ~~Pujol and Vergraud~~Vergnaud~~-Grazzini (1998) found *G. falconensis* and classified it with *G. bulloides*, or if~~ Thunell (1978) found *G. elongatus* and *T. sacculifer* (without sac) and classified them as *G. ruber* and *G. sacculifer*, respectively. Also, it is not certain if Cifelli (1974) found *G.*

calida and classified it with *G. aequilateralis* (older synonym of *G. siphonifera*). From the figures in Cifelli (1974), we suspect that *G. elongatus* was classified ~~as~~ with *G. ruber*. In the same way, we do not find any evidence of *T. sacculifer* (with sac) from the figures presented by Cifelli (1974), but we cannot discard the possibility that this species was classified as *Globigerinoides trilobus*~~ (*T. sacculifer* without sac)~~.

~~*Globigerinoides*~~ *Trilobatus quadrilobatus* was not found in any previous plankton tow studies in the Mediterranean, but is abundant in sedimentary cores (i.e. Margaritelli et al., 2016; Lirer et al., 2013; Cramp et al., 1988; Rio et al., 1990); there exists the possibility to classify it with *~~G~~T. sacculifer* or *T~~G~~. trilobus* in previous studies as suggested by Hemleben et al. (1989). Some species, which are absent from our samples, reached high frequencies in the aforementioned studies, i.e., *Turborotalita quinqueloba*, *Neogloboquadrina pachyderma*, and *Globorotalia truncatulinoides*. The fact that these species were not sampled in the present study may be due to their absence or presence at extremely low abundances of adult specimens at the sampled stations in May, as they present generally low abundances in spring according to a 12-year sediment trap record in the Gulf of Lion (Rigual-Hernández et al., 2012). Another possibility is their presence in test sizes smaller than 150 µm~~, which is smaller than the mesh size of~~ (our BONGO nets)~~,~~. For example,~~a possibility potentially supported by~~ Pujol and Vergnaud-Grazzini (1995) used a mesh size of~~:~~ 120 µm for sampling, which included *T. quinqueloba*.~~previous Mediterranean studies using smallesr mesh sizes (see Pujol and Vergraud-Grazzini, 1998, 120 µm mesh size; Rigual-Hernández et al., 2012, 63-150 µm mesh size).~~

To propose a quantitative comparison of the number of species found in previous studies in the Mediterranean, we used the morphospecies identified in them by the authors of each study. We identified 12 morphospecies, which is clearly less than Cifelli (1974), Thunell (1978) and Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), ~~with~~ reporting 18 morphospecies in total. ~~At Station 3 of this study (Alboran Sea), we found 8 morphospecies; whereas Rigual-Hernández et al. (2012) found 12 morphospecies during the same season.~~ The lower absolute abundance of individuals in our study compared to Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), together with low species diversity in ~~the Mediterranean~~this study, may indicate a trend of changing conditions over the last decades, as it has been reported for temperature and salinity (Yáñez et al., 2010), alkalinity (Cossarini et al., 2015; Hassoun et al., 2015a), and water mass mixing (Hassoun et al., 2015b). These changing conditions could also imply changes in the ecology and distribution of planktic foraminifera, as discussed below; see also Field et al. (2006). Note that our mesh size is larger than that of Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995)~~ and Rigual-Hernández et al. (2012)~~, but ~~is~~ similar to that of Cifelli (1974)~~:~~ who used a mesh size of 158 µm. A larger mesh size would explain the lower numbers in absolute abundance and reduced diversity.~~,~~ In contrast, ~~but~~ the higher diversity observed by Cifelli (1974) using a wider mesh for sampling in June supports our idea of changing ecological conditions.

The western part of the first transect (from the Atlantic to the Strait of Sicily) has a higher percentage of larger size fractions than the eastern part. The main cause of the increase in test size is a change in species composition. For example, large sized *G. inflata* (especially in the 350-500 µm fraction) are present with higher abundances in the west than in the east. The same is true for the presence of large *O. universa* (especially in the >500 µm size fraction), plus the contribution of *G. siphonifera*, which is larger ~~in~~ at stations where it is more frequent (Appendix A; Fig. ~~4~~5).

5. 2. Factors controlling the abundance of the main species

~~This~~ Abundance is discussed~~ion focuses on~~ for the five ~~main~~ most frequent species ~~of~~in our samples. The spinose and symbiont-bearing species~~:~~ *G. ruber* (white), *O. universa*, and *T. sacculifer* (without sac), which mainly inhabit tropical and subtropical waters. *G. ruber* (white) is the main species in the Atlantic. *O. universa* is rather ubiquitous, also~~ being~~ present in warm transitional Atlantic waters (Bé and Tolderlund, 1971). The spinose and ~~non~~symbiont-barren~~ic~~ species *G. bulloides*~~,~~ tolerates a wide temperature range and is typical of subpolar and transitional regions as well as upwelling areas, ~~and is~~it is also found in subtropical and tropical waters at~~ a much~~ lower abundances~~, characterized by its wide temperature range~~ (Thunell, 1978; Bé and Tolderlund, 1971). The non-spinose species *G. inflata* is typical of the temperate Atlantic Ocean (Bé and Tolderlund, 1971).

5. 2. 1. *Globigerinoides ruber* (white)

~~In our study, *G. ruber* (white) is found in the Atlantic with slightly higher absolute abundances and higher relative abundances than in the western Mediterranean Basin, where it is found in low abundances. Temperature-related factors may be the main cause, with warmer Atlantic waters (16.1 ºC) with respect to the western Mediterranean (14.3 ºC in the SW, 14.0 ºC in the NW; Fig. 1). These results are in agreement with the observations made by Cifelli (1974) in June 1969, where *G. ruber* (white) was by far more abundant in the eastern than the western Mediterranean Basin, being the most abundant species in the Levantine Basin and the south Ionian Sea;~~ In our study and the one by Cifelli (1974), *G. ruber* (white) occurs with higher abundances in the eastern compared to the western Mediterranean Basin, being the most abundant species in the Levantine Basin and the South Ionian Sea. Also like Cifelli (1974), in our study, *G. ruber* (white) from the Atlantic station is found with slightly higher relative abundances than in the western Mediterranean Basin. Temperature-related factors may be the main cause, i.e.: warmer Atlantic waters (16.1 ºC) compared to the western Mediterranean (14.3 ºC in the SW, 14.0 ºC in the NW; Fig. 1a). In the South Ionian Sea and the Levantine Basin~~for these two locations~~ it seems that *G. ruber* (white) occurs~~is present~~ independent of ~~the~~ seasons, winter included, which is also true for the pink variety (see also Thunell, 1978; Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). The increasing dominance of *G. ruber* (white) from the western to the eastern Mediterranean Basin coincides with~~ the~~ eastward increasing salinity and temperature (Fig. ~~7d~~3d; Table 2). Its higher relative abundance in the eastern basin results from the ability of *G. ruber* to thrive in food-depleted conditions (Hemleben et al., 1989).

G. ruber (white) remains scarce (St. 9, 14, 15) or absent (St. 16-18) ~~in May~~ in the Ionian Sea stations (Fig. ~~3~~4), increasing its abundance towards the Tyrrhenian Sea. On the other hand, in the Ionian Sea, it exhibits relative abundances ~~below~~ around 40 % to more than 60 % in the surface sediments (Thunell, 1978), and decreases towards the Tyrrhenian Sea. This situation could be due to higher food availability in the Tyrrhenian Sea in comparison to the Ionian Sea observed during May 2013 (Fig. 1c; Fig. ~~7d~~3d) plus a small difference in temperature between both seas (Fig. 1a; Fig. ~~7d~~3d). ~~This may not be the typical spring situation, as due to surface sediment evidence, the Ionian Sea sediments are enriched in *G. ruber* tests (Thunell, 1978) and May is the most productive season in terms of foraminiferal tests (Rigual-Hernández, 2012; Bárcena et al., 2004; Hernández-Almeida et al., 2011).~~ Also, we note that in May 1979, a scarce presence of *G. ruber* was reported in the Bay of Naples (de Castro Coppa et al., 1980), whereas in our study *G. ruber* is present at 47 % in the Tyrrhenian Sea, being the ~~main~~ dominant species.

The dominance of *G. ruber* (white) and abundance peaks in May in the eastern Mediterranean (this study), coincides with the positive temperature gradient between Station 9 and Station 13 (16.2–17.3 °C; Fig. 1). In late summer, *G. ruber* experiences its ~~largest expansion and presence~~highest abundance ~~owing to~~at warmer temperatures and more oligotrophic conditions, clearly being the main species from the north of Algeria to the Levantine Basin (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). *G. ruber* (pink) is the dominant species at the Strait of Sicily and eastwards (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995), whereas in May 2013 it ~~only has residual presence in~~was rare at some locations, ~~(~~especially around Crete~~; this study)~~. In February, at low sea surface tempreatures,~~presumably due to temperature decrease,~~ *G. ruber* (pink) almost disappears from the Mediterranean ~~and the other morphotypes are present in low numbers~~ (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Rigual-Hernández et al., 2012)~~, suggesting that~~ . Presumably, *G. ruber* (white) ~~and *G. elongatus* are~~ is better adapted to ~~colder~~ lower temperatures than the pink variety. ~~Hydrographic conditions and consequently~~To conclude, food availability seems to be the limiting factor~~s~~ for the~~its~~ abundance of *G. ruber* once it has reached its optimum temperature range (Table 2).

5. 2. 2. *Globorotalia inflata*

The presence of *G. inflata* is related to cold~~ol~~ waters and high food availability (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Rigual-Hernández et al., 2012), following high ~~phosphate~~ nutrient concentrations (Ottens, 1992). This explains its higher abundance in the cooler nutrient-rich western basin, and its progressive scarcity toward the warmer oligotrophic eastern Mediterranean (Fig. 1; Cifelli, 1974; Thunell, 1978). The same pattern is observed in late summer. From spring to late summer, *G. inflata* shows a displacement from the eastern Alboran Sea to the northwestern Mediterranean, decreasing frequency in the Algero–Provençal Basin and the southwestern Mediterranean Basin, maintaining a residual presence in the eastern basin (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). In winter, ~~with cooler~~at lower temperatures, the opposite process happens, and *G. inflata* becomes the dominant species in the Alboran Sea (Bárcena et al., 2004) and the southwestern basin, with high frequencies in the Strait of Sicily and toward the Ionian Sea. Eastwards its presence is maintained at only residual levels (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). Its distribution along the seasons shows that *G. inflata* is less frequent~~scarce~~ or absent in warmer, stratified and nutrient-depleted regions of the Mediterranean than in more productive waters.

G. inflata is absent in the Tyrrhenian Sea, despite temperature ranges being comparable to those observed in the southwestern Mediterranean, where this species is abundant (this study). In contrast, in May 1979, *G. inflata* was reported ~~in May 1979~~ in the Tyrrhenian Sea as the main species, and ~~became~~ practically absent in the warmer summer months (de Castro Coppa et al., 1980). *G. inflata* is reported in sediment trap data in the Gulf of Lion (Rigual-Hernández et al. (2012), close to our northwestern Mediterranean stations (St. 20, 21, 22) ~~in~~ at which *G. inflata* is absent. In addition, the absolute abundances of *G. inflata* are closely related to the PCA Factor 1~~ of the PCA~~, suggesting a certain affinity with food availability inferred from nutrient~~s~~ concentrations and fluorescence data (see sample scores in Fig. ~~7b~~3b; Table 2). ~~We suggest that in the Mediterranean~~Consequently, food depletion may play~~s~~ a more important role in limiting ~~its~~ the distribution of *G. inflata* than ~~warm~~ temperature~~s~~.

The ~~spring~~ distribution of *G. inflata* during spring, with *G. bulloides* as a secondary species in the Alboran Sea ~~matches with~~confirm the findings of other studies (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; van Raden et al., 2011). *G. inflata* peak abundances appear more to the west than those reported by Cifelli (1974) to the east of the Balearic Islands. Those peaks can be associated with nutrient-rich upwelling areas rich in foraminifer prey within ~~its~~ the temperature range of *G. inflata* (Fig. 1; Fig. 2).

5. 2. 3. *Globigerina bulloides*

~~In accordance with~~Following Cifelli (1974), *G. bulloides* is the dominant species in the Atlantic~~ station~~ close to the Strait of Gibraltar, whereas in our study it shares dominance with other species (Station 1; Fig. ~~3~~4). The *G. bulloides* dominance in the Strait of Gibraltar during late spring–early summer confirms the findings of Cifelli (1974). The abundance peak of *G. bulloides* in the Strait of Gibraltar (this study), coincides with high nutrient concentration and upwelling (Figs. 1, 2, and ~~3~~4), ~~making~~ with s~~S~~tation 2 holding highest standing stocks of~~the most rich in~~ planktic foraminifera of ~~all~~ the whole transect analyzed here. This confirms its association with upwelling, ~~where~~ and the production of phyto~~- and zoo~~plankton~~ic blooms control its abundances, as it is an~~as the major food source of this opportunistic species (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Sousa et al., 2014; Bárcena et al., 2004; Hernández-Almeida et al., 2011; Rigual-Hernández et al., 2012). ~~It~~ Consequently, higher standing stocks of *G. bulloides* are ~~positively correlates~~related with higher nutrient concentration~~fluorescence peaks since it feeds on phytoplankton~~ (i.e., Mortyn and Charles, 2003; ~~Bárcena et al., 2004; Rigual-Hernández et al., 2012;~~ Fig. 1; Fig. 3e; Table 2).

In April (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; van Raden et al., 2011) and May (this study), *G. bulloides* is ~~found to be~~ the second most abundant species, surpassed by *G. inflata*, in the westernmost Alboran Sea. High temperature anomalies could provoke an inverse situation, thanks to ~~faster~~ more suitable environmental conditions for *G. bulloides*, which profits from more successful reproduction than~~reproduction, plus adding the fact that~~ *G. inflata*, which instead ~~being~~ stays further from its optimum temperature (Bárcena et al., 2004). One month later, *G. bulloides* ~~it~~ is found to be the dominant species replacing *G. inflata*, which is still dominant in the eastern Alboran Sea (Cifelli, 1974). Its ubiquity and ~~higher~~ larger abundance in the western basin with respect to the east is supported by previous studies (i.e., Cifelli, 1974; Thunell, 1978), with a higher difference in abundance in February than in September–October (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Rigual-Hernández et al., 2012). In late summer, it~~its presence is more secondary~~decreases in numbers, with abundance peaks only around the Strait of Sicily and south of Sardinia. In winter, *G. bulloides* occurs at maximum relative but lower absolute a~~A~~bundance peaks ~~at the same locations plus~~ in the Gulf of Lion, as well as in the Strait of Sicily and south of Sardinia

~~occur during winter, but with larger absolute abundances~~ (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995; Rigual-Hernández et al., 2012).

G. bulloides decreases in abundance ~~when~~ at food ~~is~~ depletion~~ed, observable~~ in the eastern Mediterranean, where it is always ~~has lower absolute~~ less abundant~~ces~~ than in the western basin, at lower conditions ~~also in the summer months in the Gulf of Lion, when food is depleted and not renewed~~ due to water column stratification (Rigual-Hernández et al., 2012). During spring to late summer in the eastern basin, *G. bulloides* is less frequent, ~~being more present~~and is more abundant just east of the Strait of Sicily (Cifelli, 1974; Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). During winter its abundance increases and it becomes the second most abundant species in the Levantine Basin preceded by *G. ruber* (white), and it is also one of the main species in the Ionian Sea. ~~Levantine waters have p~~Permanent eddies ~~that~~ in the Levantine Basin sustain phytoplankton blooms, explaining the presence of *G. bulloides* in winter (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). ~~It is noticeable that northwards of~~In the northern Levantine Basin and in the Aegean Sea its abundances are comparable to those in the western basin regarding surface sediment data from Thunell (1978).

G. bulloides has more affinity for cooler upwelled waters than warmer more stratified waters (Sousa et al., 2014; Thunell, 1978), being present in subtropical waters only ~~in cooler~~during the colder months (Ottens, 1992). The coldest station of the first leg of this study (Strait of Gibraltar, 14.2 ºC) coincides with ~~its~~ an abundance peak of *G. bulloides*, and it is absent from the warmest station (off the Nile Delta, 17.6 ºC; Fig. 1a), which is also ~~is~~ one of the most depleted stations in foraminiferal prey (Fig. 1c; Fig. 2). ~~Its Its affinity for fresher and cooler waters matches with its low abundance in the eastern basin and its higher abundances in the western basin (northwestern basin included, despite its low absolute abundances but being the main species there; see also Rigual-Hernández et al., 2012), and with its seasonal distribution~~. ~~Its presence and~~To conclude, the distribution of *G. bulloides* seems to be limited by ~~a combination of low nutrient concentration and limited~~ food availability, caused by stratification and consequent nutrient depletion of the surface water column, and increased sea surface temperatures (Table 2).

5. 2. 4. *Orbulina universa*

Orbulina universa was found to be ubiquitous by Pujol and ~~Vergraud~~Vergnaud-Grazzini (1995), being present in all the stations and seasons, reaching peak abundances in the southwestern Mediterranean both in late-summer and winter. Regarding our data, it follows the same pattern during spring, being absent from only three stations (St. 6, 9, and 14; Fig. ~~3~~4; Fig. ~~7f~~3f). No abundance peak occurs in spring (~~our data) and in the report of Cifelli (1974),~~Cifelli, 1974, and this paper) but abundances are slightly higher in the western basin ~~to~~ than in the east. These~~at~~ small differences can be caused by more nutrient-rich upwelling areas (cf. Sousa et al., 2014; Morard et al., 2013) in the western basin or by higher salinities in the eastern than western basin.

5. 2. 5. *Trilobatus sacculifer* (without sac)

In June, *T. sacculifer* (without sac) ~~is quite ubiquitous~~has a wide distribution and represents 5 % of the assemblage in the Strait of Gibraltar (Cifelli, 1974). ~~At our stations,~~ *T. sacculifer* constituted up to 25 % of the assemblages in May 2013, and was absent from seven stations (St. 5, 7a, 14, 15, 16-18, 20, 22). Low~~er~~ relative abundance occurred ~~percentages were found~~ in April in the Alboran Sea (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995). In September–October *T. sacculifer* shows high abundances and is one of the main species from north of Minorca to the southwestern Mediterranean ~~until~~as far as the Strait of Sicily, where it is rare. In late summer, it progressively decreases in numbers to the~~considerably and progressively~~ east~~wards~~, where *G. ruber* ~~the highly~~ domina~~n~~tes assemblages ~~*G. ruber* is maintained as the most abundant species~~ (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995), probably due to slightly higher temperature and salinitie~~sy~~ ~~tolerance~~ (see also Bijma et al., 1990). On the other hand, in February *T. sacculifer* (without sac) disappears from the north Levantine Basin and its abundance~~s lowers~~ considerably decreases ~~, being a residual species in terms of relative abundance in all the Mediterranean~~ (Pujol and ~~Vergraud~~Vergnaud-Grazzini, 1995).

5. 3. Factors controlling planktic foraminiferal test weight

The area density (ρ_A) of tests of both *G. ruber* (white) and *G. bulloides* follow a systematic change from the Atlantic towards the eastern Mediterranean (Fig. ~~6~~7). Therefore, the ρ_A of these two species is interpreted and discussed for possible environmental effects and biological prerequisites in the following. In contrast, the ρ_A of *O. universa* does not show any change between the western and eastern basins (Fig. ~~7i~~3i), and cannot be ~~used to identify and quantify~~interpreted for any particular environmental effects.

5.3.1 Unknown control of the ρ_A of *O. universa*

Since environmental and biological factors may affect individuals of the different genotypes of O. universa to varying degrees, we could not detect any systematic change in ~~No systematic change between the western and eastern basins in the~~ ρ_A in the data presented here. ~~of *O. universa* could be explained by an insufficient understanding of the ecology of the different morphotypes and genotypes of *O. universa*.~~ Only one out of three genotypes of *O. universa* (i.e. Type III, after Darling and Wade, 2008) ~~is recorded~~occurs in the Mediterranean Sea (Mediterranean species, after de Vargas et al., 1999), The Mediterranean Type III has been found to include two sub-types, Type IIIa and Type IIIb (André et al., 2014). The different genotypes and morphotypes of *O. universa* tolerate wide ranges of salinity and temperature in surface waters (i.e., de Vargas et al., 1999). Whereas the various types of *O. universa* differ in the pore-size (de Vargas et al., 1999; Morard et al., 2009; Marshall et al., 2015), their pore-size is also affected by environmental conditions including water temperature (i.e., Bé et al., 1973). Likewise, thickness of the test wall has been described to vary between types (de Vargas et al., 1999; Morard et al., 2009; Marshall et al., 2015), and is as well affected by environmental conditions and ontogenetic stage of specimens. Adult *O. universa* have been shown to continuously add calcite layers to the proximal surface of the same sphere (Spero, 1988; Spero et al., 2015). ~~Since environmental and biological factors may affect individuals of the different genotypes of *O. universa* to varying degrees, we could not detect any systematic change in ρ_A in the data presented here.~~

~~The *O. universa* weight-area data of our study are compared with those of Marshall et al. (2015) from Cariaco Basin sediment trap specimens, including *O. universa* Type I (M_{thick}) and Type III (M_{thin})~~

~~specimens, suggesting thinner test walls in the latter. In the area range of $3\cdot10^5$–$4\cdot10^5$ µm^2, our weight data coincide with the expected Mediterranean Type III variety (Fig. S4c; Marshall et al., 2015), but at $2\cdot10^5$–$2.5\cdot10^5$ µm^2 we see a mix of both types until at $1.5\cdot10^5$ µm^2 Type I coincides more with our results (Fig. S4c; Marshall et al., 2015). We suggest that different groups of the Mediterranean *O. universa* variety coexist in the Mediterranean with differences in the wall thickness.~~

~~The various interfering effects, which control the ρ_A of *O. universa* in the Mediterranean Sea, may also explain differences in the weight-long axis relation data reported from other regions of the world ocean: Bijma et al. (2002) weighed *O. universa* in the 500–600 µm size fraction in the Caribbean Sea and reported a weight ranging from 28 to 60 µg. Lombard et al. (2010) measured a weight of 20–70 µg for specimens sampled off Catalina Island, California, in the same size fraction of 500–600 µm. Our weight-long axis relation data range from 24 to 45 µg (Fig. S3c) for the same size fraction of 500–600 µm, ranging at the lower limit of the weight-long axis relations measured in the Caribbean (Bijma et al., 2002) and off California (Lombard et al., 2010), which may be caused either by differences in genotypes or environmental conditions, or both. Thinner walls overall in our specimens with respect to the mentioned studies could be a possible explanation for the differences in ρ_A (Marshall et al., 2015). In our samples from the Mediterranean, individuals exceeding 60 µg have long axis larger than 650 µm.~~ The reason why the ρ_A of *O. universa* is particularly low and highly variable in the Mediterranean despite high carbonate ion concentration ([CO_3^{2-}]) and pH (Fig. 1) might be sought in factors other than, and in addition to, chemical and physical conditions, namely the changing availability of food along the transect from the Atlantic Ocean to the Levantine Basin.

5.3.2 Factors affecting the ρ_A of *G. ruber* (white) and *G. bulloides*

~~In the same way as in *O. universa*, the~~The ρ_A of *G. ruber* (white) is only partly controlled by carbonate chemistry, being instead affected by other factors like food availability, similar to *O. universa*. ~~However, i~~In contrast to *O. universa*, the ρ_A data of *G. ruber* and *G. bulloides* follow systematic correlations. High ρ_A of *G. ruber* in the Atlantic and Tyrrhenian Sea correlates with enhanced primary production (enhanced fluorescence, Fig. 1d; Fig. ~~7g~~3g; Table 2), and presumably enhanced food availability (Fig. ~~6~~3g; Fig. 7~~g~~; Fig. 2, also noticeable in Fig. S2d~~-e~~ and Fig. S4d~~-e~~). ~~At the same sites, larger IQR indicates more variability in test calcite production of *G. ruber* (white) specimens, although a limited number of samples together with the low and uneven sampling size impede any further interpretation of the data (Fig. 6~~7~~).~~ Under more oligotrophic conditions, low ρ_A of *G. ruber* (white) might be caused by limited food availability. An opposite trend ~~occurs~~ is reported for~~in~~ *G. ruber* (white) from sediment trap samples ~~from~~ in the Madeira Basin, in which, apart from showing a negative significant correlation between calcification intensity and productivity, ρ_A shows ~~a~~ positive correlation with temperature (Weinkauf et al., 2016).

The relationship between food availability and ρ_A in *G. bulloides* is opposite to ~~that in~~ *G. ruber* (white) (Fig. ~~6~~3g-h; Fig. 7~~g-h~~; Table 2). The ρ_A of *G. bulloides* tests increases from the Atlantic toward the eastern Mediterranean. ~~At the same time, variability in ρ_A data increases with increasing absolute ρ_A, which resembles the distribution of data in *G. ruber* (white) (Fig. 6~~7~~):~~ In both species larger IQRs are found toward higher absolute ρ_A (Fig. 7).

An opposite trend in ρ_A of the two species *G. ruber* (white) and *G. bulloides* had earlier been described from the Arabian Sea, and could neither be assigned to changes in $[CO_3^{2-}]$ of ambient seawater nor growth conditions (Beer et al., 2010a). Due to its symbionts, *G. ruber* would rather have an advantage over symbiont-barren *G. bulloides* in oligotrophic waters, and support formation of test calcite through CO_2 consumption and increasing $[CO_3^{2-}]$ and pH (see also Köhler-Rink and Kühl, 2005). Those findings may still point toward differences in growth conditions: Reproduction of both *G. ruber* and *G. bulloides* might be ~~retarded~~ hampered under less optimal conditions, and additional calcite layers might be added to the proximal test ~~surface~~ before reproduction, similar to the process described for *O. universa* (see above). Therefore, tests may grow heavier under less than optimal food availability, given that carbonate chemistry of ambient seawater does not seem~~s~~ to limit the formation of test calcite in our samples.

Comparing weight-to-long axis relations, *G. ruber* (255–350 µm size fraction) from plankton tows of the western Arabian Sea have an average weight of 11.5 ±0.69 µg (de Moel et al., 2009), which is heavier than the individuals from our study (5.9 ±0.31 µg; Fig. S3a; Appendix A). The difference in weight-to-long axis relation may indicate that *G. ruber* ~~was~~ is produced under more ~~suited~~ suitable conditions for shell calcite formation in the Arabian Sea especially during non-upwelling periods and still higher overall primary productivity and food availability. However, the comparison might be biased by the fact that *G. ruber* (white) and *G. elongatus* were not separately analyzed ~~together in the study of~~by de Moel et al. (2009).

Data for supra-regional comparison of the weight-to-long axis relation of *G. bulloides* from the water column ~~are found~~possible for the 200–250 µm size fraction: ~~in~~ In the north Atlantic (56-63 °N), in June 2009, ~~(~~Aldridge et al.~~,~~ (2012) ~~with~~ report a range of 1.75–2.92 µg ($r^2 = 0.52$). ~~For that~~In the same size fraction, our results (36 °N) show heavier tests in the Alboran Sea (3.46 ±0.15 µg), and similar weights at the Strait of Gibraltar (2.57 ±0.00 µg; Fig. S3b). For the same water depth as in our samples, Schiebel et al. (2007) found~~-~~ heavier average weight-to-long axis relations in fall (5.19 ±0.25 µg) than ~~during~~ in spring (4.21 ±0.2 µg) in the eastern ~~n~~North Atlantic~~ (47 °N)~~, and 5.51 ±0.31 µg during the SW monsoon in the Arabian Sea~~ (16 °N)~~. In general, higher ρ_A occurs at lower latitudes and lower ρ_A at higher latitudes (see also Schmidt et al., 2004). ~~All of these findings support our idea of an effect of limited alimentation on calcification.~~ For *G. bulloides* and *G. ruber*, ~~I~~increased longevity and ongoing production of additional calcite layers at the proximal side of shells may result in an increased ρ_A, given that seawater carbonate chemistry is only partially affecting the calcite formation ~~in planktic foraminifera~~ in our samples.

6. Conclusions

Absolute and relative abundances of planktic foraminifera were studied from plankton tow samples across the Mediterranean, collected in May 2013. The samples show large differences in species abundance and assemblages between the different basins and sub-basins of the Mediterranean Sea. Absolute abundance and diversity of planktic foraminifer assemblages are low in comparison to other regions of the world ocean. Average standing stocks in the upper 200 m of the water column ~~range from~~are 1.42 ±1.43 ind.·10 m^{-3}, including twelve morphospecies in total. Planktic foraminifer assemblages are indicative of changing temperatures and salinities, as well as trophic conditions, between the eastern and the western Mediterranean Sea. Highest standing stocks of total planktic foraminifera occurred in the Strait of Gibraltar and the Alboran Sea. Overall, the largest foraminiferal tests occurred in the western ~~part of the transect~~Mediterranean, driven by the assemblage composition, and the presence of large *G. inflata*.

Globigerinoides ruber was the most abundant species; its dominance in the east compared to the west~~,~~ is likely caused by stratification of the surface water column, enhanced SST, and trophic conditions. *G. ruber* is a symbiont-bearing species, which might be an advantage over symbiont-barren species like *G. bulloides* under oligotrophic and food-limited conditions as in the Levantine Basin. *G. bulloides* was more abundant in upwelled waters in the Strait of Gibraltar, in the Alboran Sea, and in the western Mediterranean. *O. universa* was present at ~~rather~~ balanced standing stocks along the entire transect from the west to the east. In general, distribution patterns of the main planktic foraminiferal species in the Mediterranean seem to be mainly related to a combination of food availability, controlled by sea surface ~~and~~ temperature and stratification.

In the Mediterranean surface waters are supersaturated ~~waters~~ with respect to calcite and aragonite (Schneider et al., 2007; Gemayer et al., 2015).~~,~~ ~~foraminiferal c~~Calcification and ρ_A of the most frequent planktic foraminifera species, *G. ruber* (white) and *G. bulloides*, are largely affected by ~~trophic conditions and~~ food availability. *G. ruber* is more affine to oligotrophic conditions, and grows heaviest tests in less food-limited waters in the western basin near Gibraltar and in the Tyrrhenian Sea. In contrast, *G. bulloides* grows heaviest tests under more food-limited conditions in the eastern Mediterranean Sea. We speculate that reproduction is hindered when the species-specific food sources are limited, while individuals continue adding calcite to the outer shell, and grow heavier tests than individuals that reproduced earlier in ontogeny.

These observations highlight the need for more interdisciplinary studies on the causes of changing foraminiferal assemblages and decreasing shell production, especially in the Mediterranean as a marginal basin, which is assumed particularly sensitive to changes of the environment and global climate.

Appendices

Appendix A. Planktic foraminifera data from BONGO nets: relative and absolute abundances, and weight and size parameters. The nomenclature *G. bulloides* represents the *G. bulloides/G. falconensis* plexus, and *G. siphonifera* represents the *G. siphonifera/ G. calida/ G. radians plexus*.

Location	Atlantic	Gibraltar	Alboran Sea	South-Central Western Med.	Strait of Sardinia	Strait of Sicily	South of Ionian Sea	Off Southern Crete	Eastern Basin	Off Nile Delta	Off Lebanon	Antikythera Strait	Eastern Ionian Sea	Adriatic Sea	Otranto Strait	Northern Ionian Sea	Tyrrhenian Sea	North-Central Western Med.	Central Western Med.	Catalano-Balear
Station	1	2	3	5	6	7a	9	10	11	12	13	14	15	17	16	16-18	19	20	21	22
Absolute abundance (individuals*10 m^{-3})																				
Total numbers																				
G. ruber (white)	0.079	0.037	0.007	0.022	0	0	0.212	1.314	0.403	0.247	1.260	0.389	0.102	0	0.338	0	1.688	0	0	0
G. elongatus	0.118	0.019	0.007	0	0.024	0	0	0.282	0.054	0.027	0.202	0.269	0	0	0.182	0.070	0.537	0	0.025	0
T. sacculifer (without sac)	0.236	1.323	0.028	0	0.047	0	0.047	0.219	0.027	0.082	0.050	0	0	0.023	0.234	0	0.256	0	0.025	0
G. bulloides	0.148	2.311	0.456	0.501	0.142	0	0.165	0.094	0.054	0	0.076	0	0.102	0	0.052	0.023	0.307	0.197	0.102	0.147
G. inflata	0.118	0.503	3.514	0.545	0.449	0.358	0.071	0.125	0.027	0	0	0	0	0.023	0	0	0	0	0	0
O. universa	0.128	0.093	0.014	0.218	0	0.291	0	0.219	0.054	0.027	0.050	0	0.077	0.023	0.468	0.141	0.281	0.028	0.179	0.177
G. siphonifera	0.029	0.056	0.043	0.022	0	0.313	0	0.063	0	0	0.025	0	0	0	0	0	0	0	0.102	0
~~G~~T. quadrilobatus	0.010	0.335	0.007	0.087	0	0.045	0.118	0.063	0.027	0	0	0	0	0.023	0	0	0.230	0.112	0.204	0.236
H. pelagica	0	0	0	0	0	0	0	0.125	0	0.027	0	0	0	0	0	0	0	0	0	0
T. sacculifer (with sac)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.026	0	0	0
G. ruber (pink)	0	0.075	0	0	0.024	0	0.024	0.125	0	0.027	0	0.120	0	0	0	0	0	0	0	0
G. menardii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.029
Unknowns	0.118	0.447	0.064	0.065	0.024	0	0.047	0.375	0.108	0	0.025	0.120	0.026	0.023	0.208	0.023	0.281	0.028	0	0.088
Total	0.985	5.120	4.141	1.460	0.709	1.006	0.683	3.003	0.753	0.439	1.689	0.898	0.307	0.114	1.482	0.258	3.607	0.365	0.638	0.678
150-350 µm size fraction																				
G. ruber (white)	0.030	0.037	0.007	0.022	0	0	0.212	1.314	0.403	0.247	1.109	0.389	0.102	0	0.338	0	1.560	0	0	0
G. elongatus	0.020	0	0	0	0.024	0	0	0.282	0.054	0.027	0.202	0.269	0	0	0.182	0.047	0.460	0	0.026	0
T. sacculifer (without sac)	0.148	1.174	0.029	0	0.047	0	0	0.188	0.027	0.082	0.050	0	0	0.023	0.234	0	0.230	0	0.026	0
G. bulloides	0.128	2.199	0.449	0.415	0.142	0	0.165	0.094	0.054	0	0.076	0	0.102	0	0.052	0.023	0.307	0.197	0.077	0.118
G. inflata	0.069	0.335	1.176	0.109	0.095	0.022	0	0.063	0	0	0	0	0	0.023	0	0	0	0	0	0
O. universa	0	0.075	0.007	0.087	0	0	0	0.094	0	0	0	0	0	0	0.208	0	0.026	0	0.026	0
G. siphonifera	0	0.019	0.029	0	0	0.022	0	0	0	0	0.025	0	0	0	0	0	0	0	0.102	0
T~~G~~. quadrilobatus	0.010	0.280	0.007	0.087	0	0	0.071	0.063	0.027	0	0	0	0	0.023	0	0	0.230	0.112	0.204	0.236
H. pelagica	0	0	0	0	0	0	0	0.063	0	0	0	0	0	0	0	0	0	0	0	0
G. ruber (pink)	0	0.075	0	0	0.024	0	0.024	0.125	0	0.027	0	0.120	0	0	0	0	0	0	0	0
Total	0.404	4.193	1.703	0.719	0.331	0.045	0.471	2.284	0.564	0.384	1.462	0.778	0.205	0.068	1.014	0.070	2.814	0.309	0.459	0.354
350-500 µm size fraction																				
G. ruber (white)	0.049	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.051	0	0	0
G. elongatus	0.088	0.019	0.007	0	0	0	0	0	0	0	0	0	0	0	0	0.023	0.077	0	0	0
T. sacculifer (without sac)	0.079	0.130	0	0	0	0	0.047	0.031	0	0	0	0	0	0	0	0	0.026	0	0	0
G. bulloides	0.020	0.112	0.029	0.022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.026	0.029
G. inflata	0.049	0.149	2.138	0.414	0.307	0.313	0.071	0.031	0.027	0	0	0	0	0	0	0	0	0	0	0
O. universa	0.049	0.019	0.007	0.109	0	0.067	0	0.125	0.027	0	0	0	0	0.023	0.130	0.023	0.153	0.028	0.051	0.118
G. siphonifera	0.020	0.019	0.007	0.022	0	0.201	0	0.031	0	0	0	0	0	0	0	0	0	0	0	0
T~~G~~. quadrilobatus	0	0	0	0	0	0.022	0.047	0	0	0	0	0	0	0	0	0	0	0	0	0
H. pelagica	0	0	0	0	0	0	0	0.063	0	0.027	0	0	0	0	0	0	0	0	0	0
T. sacculifer (with sac)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.026	0	0	0
G. menardii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.029
Total	0.354	0.447	2.188	0.567	0.307	0.604	0.165	0.282	0.054	0.027	0	0	0	0.023	0.130	0.047	0.333	0.028	0.077	0.177

(**Appendix A**, cont.).

Location	Atlantic	Gibraltar	Alboran Sea	South-Central Western Med.	Strait of Sardinia	Strait of Sicily	South of Ionian Sea	Off Southern Crete	Eastern Basin	Off Nile Delta	Off Lebanon	Antikythera Strait	Eastern Ionian Sea	Adriatic Sea	Otranto Strait	Northern Ionian Sea	Tyrrhenian Sea	North-Central Western Med.	Central Western Med.	Catalano-Balear
Station	1	2	3	5	6	7a	9	10	11	12	13	14	15	17	16	16-18	19	20	21	22
>500 µm size fraction																				
G. ruber s.l.	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T. sacculifer (without sac)	0.001	0.019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G. inflata	0	0.019	0.135	0.022	0.047	0.022	0	0.031	0	0	0	0	0	0	0	0	0	0	0	0
O. universa	0.079	0	0	0.022	0	0.224	0	0	0.027	0.028	0.050	0	0.077	0	0.130	0.117	0.102	0	0.102	0.059
G. siphonifera	0.010	0.019	0.007	0	0	0.089	0	0.031	0	0	0	0	0	0	0	0	0	0	0	0
T~~G~~. quadrilobatus	0	0	0	0	0	0.022	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0.108	0.056	0.143	0.044	0.047	0.358	0	0.063	0.027	0.027	0.050	0	0.077	0	0.130	0.117	0.102	0	0.102	0.059
Relative abundance (%)																				
G. ruber (white)	8.00	0.72	0.17	1.49	0	0	31.03	43.75	53.57	56.25	74.63	43.33	33.33	0	22.81	0	46.81	0	0	0
G. elongatus	12.00	0.36	0.17	0	3.33	0	0	9.38	7.14	6.25	11.94	30.00	0	0	12.28	27.27	14.89	0	4.00	0
T. sacculifer (without sac)	24.00	25.45	0.69	0	6.67	0	6.90	7.29	3.57	18.75	2.99	0	0	20.00	15.79	0.00	7.09	0	4.00	0
G. bulloides	15.00	44.44	11.02	34.33	20.00	0	24.14	3.13	7.14	0	4.48	0	33.33	0	3.51	9.09	8.51	53.85	16.00	21.74
G. inflata	12.00	9.68	84.85	37.31	63.33	35.56	10.34	4.17	3.57	0	0	0	0	20.00	0	0	0	0	0	0
O. universa	13.00	1.79	0.34	14.93	0	28.89	0	7.29	7.14	6.25	2.99	0	25.00	20.00	31.58	54.55	7.80	7.69	28.00	26.09
G. siphonifera	3.00	1.08	1.03	1.49	0	31.11	0	2.08	0	0	1.49	0	0	0	0	0	0	0.00	16.00	0
T~~G~~. quadrilobatus	1.00	6.45	0.17	5.97	0	4.44	17.24	2.08	3.57	0	0	0	0	20.00	0	0	6.38	30.77	32.00	34.78
H. pelagica	0	0	0	0	0	0	0	4.17	0	6.25	0	0	0	0	0	0	0	0	0	0
T. sacculifer (with sac)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.71	0	0	0
G. ruber (pink)	0	1.43	0	0	3.33	0	3.45	4.17	0	6.25	0	13.33	0	0	0	0	0	0	0	0
G. menardii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.35
Unknowns	12.00	8.60	1.55	4.48	3.33	0	6.90	12.50	14.29	0	1.49	13.33	8.33	20.00	14.04	9.09	7.80	7.69	0	13.04
Weight and size																				
G. ruber (white)																				
size fraction (µm)	250-300							200-250	200-250		200-250	250-300			250-300		200-250			
nº of individuals	1							4	4		4	2			4		4			
average size (µm)	285							221	215.25		221.5	281			268		218.5			
average weight (µg)	4.667							1.583	2.417		2	3.167			5.5		2.083			
SD (µg)	0.577							0.144	0.289		0	0.577			0		0.144			
size fraction (µm)	350-400							250-350	250-300		250-300	300-350					250-300			
nº of individuals	4							5	1		3	1					5			
average size (µm)	390							267	261		264	317					280.6			
average weight (µg)	14.333							3.867	2.667		5.111	6.667					4.8			
SD (µg)	0.289							0.115	0.577		0.192	0.577					0.2			
size fraction (µm)	400-450							300-350	350-400		300-350						300-350			
nº of individuals	1							3	1		2						5			
average size (µm)	412							313.333	356		323.5						343.4			
average weight (µg)	14.667							7.444	5.667		11						9.867			
SD (µg)	1.155							0.385	1.155		0						0.231			
size fraction (µm)								350-400									350-400			
nº of individuals								2									4			
average size (µm)								374									366			
average weight (µg)								8.833									9.083			
SD (µg)								0.764									0.144			

(**Appendix A**, cont.).

Location	Atlantic	Gibraltar	Alboran Sea	South-Central Western Med.	Strait of Sardinia	Strait of Sicily	South of Ionian Sea	Off Southern Crete	Eastern Basin	Off Nile Delta	Off Lebanon	Antikythera Strait	Eastern Ionian Sea	Adriatic Sea	Otranto Strait	Northern Ionian Sea	Tyrrhenian Sea	North-Central Western Med.	Central Western Med.	Catalano-Balear
Station	1	2	3	5	6	7a	9	10	11	12	13	14	15	17	16	16-18	19	20	21	22
size fraction (µm)																	400-450			
nº of individuals																	2			
average size (µm)																	413			
average weight (µg)																	16.167			
SD (µg)																	1.258			
G. bulloides																				
size fraction (µm)	300-350	200-250	200-250	350-400	300-350														400-450	300-350
nº of individuals	2	7	8	1	1														1	3
average size (µm)	326.5	228.143	227.875	364	337														414	318.333
average weight (µg)	4.5	2.571	3.458	4.667	4														11.667	8.222
SD (µg)	0.5	0	0.144	0.577	1														0.577	0.385
size fraction (µm)		250-300	250-300																	400-450
nº of individuals		12	2																	1
average size (µm)		263.75	270																	441
average weight (µg)		2.833	2.833																	20.333
SD (µg)		0	0.289																	1.155
size fraction (µm)		300-350	350-400																	
nº of individuals		2	4																	
average size (µm)		310.5	386.5																	
average weight (µg)		4.5	9.667																	
SD (µg)		0.5	0.144																	
size fraction (µm)		350-400	400-450																	
nº of individuals		2	2																	
average size (µm)		375.5	429																	
average weight (µg)		5.833	11																	
SD (µg)		0.289	0																	
size fraction (µm)		400-450	450-500																	
nº of individuals		1	1																	
average size (µm)		447	477																	
average weight (µg)		9.333	7.333																	
SD (µg)		0.577	0.577																	
O. universa																				
size fraction (µm)	350-400	250-300	500-550	400-450		450-500		300-350	350-400	700-750	650-700		700-750	450-500	300-350	400-450	400-450	400-450	450-500	350-400
nº of individuals	3	1	1	2		1		1	1	1	1		2	1	1	1	1	1	2	1
average size (µm)	390	286	501	445		479		342	398	719	687		722.5	452	347	444	441	441	479.5	377
average weight (µg)	17.667	7	20.667	11.667		31		3	6.333	47	43		24.167	14.333	5.333	18.667	24.333	22.667	31	20
SD (µg)	0.333	0	0.577	0.289		1		0	0.577	1	0		0.289	0.577	0.577	0.577	0.577	0.577	0.5	1
size fraction (µm)	400-450			450-500		500-550		350-400	500-550		750-800		750-800		350-400	550-600	450-500		550-600	400-450
nº of individuals	1			3		2		3	1		1		1		1	1	1		1	2
average size (µm)	444			479		539.5		373.667	539		781		785		369	559	455		571	425.5
average weight (µg)	28.667			22.889		33.833		6.556	25.667		54.667		53.667		6.667	34.333	23.667		45	24.167
SD (µg)	1.155			0.192		0.289		0.385	0.577		0.577		0.577		0.577	0.577	0.577		1	0.577
size fraction (µm)	500-550			650-700		600-650		400-450							400-450	600-650	500-550		650-700	450-500
nº of individuals	1			1		1		1							1	2	6		2	1
average size (µm)	527			656		603		439							412	640	534.5		676	482
average weight (µg)	36.667			25.667		50.667		13.667							13	54.833	30.278		84.333	35
SD (µg)	0.577			1.155		0.577		1.155							0	0.289	0.096		0.289	1
size fraction (µm)	550-600					650-700		450-500							450-500	650-700			750-800	500-550
nº of individuals	6					6		1							1	2			1	1
average size (µm)	578.667					674.333		460							476	656.5			762	509
average weight (µg)	45.389					47.889		17.333							24	63.333			136	42
SD (µg)	0.096					0.096		1.155							1	0.289			0	0
size fraction (µm)	600-650					700-750									500-550					
nº of individuals	1					2									3					
average size (µm)	605					720									527.333					
average weight (µg)	48.667					34									21.778					
SD (µg)	0.577					0									0.192					

(**Appendix A**, cont.).

Location	Atlantic	Gibraltar	Alboran Sea	South-Central Western Med.	Strait of Sardinia	Strait of Sicily	South of Ionian Sea	Off Southern Crete	Eastern Basin	Off Nile Delta	Off Lebanon	Antikythera Strait	Eastern Ionian Sea	Adriatic Sea	Otranto Strait	Northern Ionian Sea	Tyrrhenian Sea	North-Central Western Med.	Central Western Med.	Catalano-Balear
Station	1	2	3	5	6	7a	9	10	11	12	13	14	15	17	16	16-18	19	20	21	22
size fraction (µm)	650-700					750-800									550-600					
nº of individuals	1					1									1					
average size (µm)	651					772									570					
average weight (µg)	50.667					48									17.333					
SD (µg)	0.577					1									1.528					
size fraction (µm)															600-650					
nº of individuals															1					
average size (µm)															625					
average weight (µg)															23					
SD (µg)															0					
size fraction (µm)															650-700					
nº of individuals															2					
average size (µm)															654.5					
average weight (µg)															31.167					
SD (µg)															0.289					

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Tables

Table 1. Date, time, location, volume filtered and environmental parameters of the sampled stations. Sea surface temperature (SST) and sea surface salinity (SSS) measured at 5 m depth. The remaining parameters are averaged from 5 to 200 depth with their respective SDs in parenthesis.

Table 2. Loadings of the environmental parameters in the PCA (left column) and additional Pearson correlation coefficients (r) for relationships between stations scores on factor 1 and 2 and the abundances / density area of selected species (upper middle / right columns) and between the environmental parameters and the abundances / density area of selected species (lower middle / right columns). r-values in bold are significant at $p<0.05$, *$p<0.1$.

Table 1.

Leg	Station Code	Station Name	Day (DD/MM/YYYY)	Time	Latitude	Longitude	Volume (m^3)	Temperature (ºC)	SST (ºC)	Salinity (PSU)	SSS (PSU)	Fluorescense (µg/l)	pH	$[CO_3^{-2}]$ (mmol/kg)
1	1	Atlantic	03/05/2013	0:03	36º03’	-6º65’	1016	16.08 (0.84)	17.88	36.27 (0.10)	35.95	0.36 (0.32)	8.06 (0.05)	178.89 (22.25)
	2	Gibraltar	03/05/2013	12:47	35º94’	-5º56’	537	14.22 (1.05)	17.11	37.51 (0.81)	36.35	0.11 (0.06)	8.06 (0.02)	179.90 (6.15)
	3	Alboran Sea	05/05/2013	20:55	36º12’	-4º19’	1403	15.06 (1.17)	16.87	37.13 (0.68)	36.37	0.45 (0.44)	8.09 (0.03)	191.50 (13.84)
	5	South-Central Western Mediterranean	08/05/2013	10:44	38º54’	5º56’	459	14.33 (1.19)	16.99	37.95 (0.23)	37.65	0.18 (0.22)	8.10 (0.02)	200.36 (10.06)
	6	Strait of Sardinia	09/05/2015	20:34	38º27’	8º69’	423	14.34 (1.16)	17.50	38.23 (0.19)	37.77	0.19 (0.26)	8.08 (0.03)	199.89 (15.38)
	7a	Strait of Sicily	11/05/2013	0:20	37º04’	13º18’	447	15.12 (0.86)	17.27	38.16 (0.52)	37.43	0.23 (0.23)	8.09 (0.01)	207.14 (3.38)
	9	South of Ionian Sea	12/05/2013	11:31	35º12’	18º29’	425	16.17 (1.01)	19.53	38.78 (0.10)	38.64	0.13 (0.14)	8.12 (0.02)	232.36 (3.30)
	10	Off Southern Crete	14/05/2013	14:40	33º81’	24º27’	320	16.51 (1.44)	19.58	39.00 (0.39)	36.60	0.12 (0.19)	8.11 (0.01)	232.38 (8.43)
	11	Eastern Basin	15/05/2013	13:01	33º50’	28º00’	372	17.21 (1.30)	20.59	38.80 (0.44)	36.19	0.10 (0.07)	8.12 (0.02)	243.57 (10.26)
	12	Off Nile Delta	17/05/2013	3:14	33º22’	32º00’	364	17.59 (1.46)	21.82	38.99 (0.25)	37.45	0.15 (0.12)	8.11 (0.02)	239.99 (9.93)
	13	Off Lebanon	17/05/2013	16:15	34º23’	33º23’	397	17.35 (1.33)	21.58	38.73 (1.48)	no data	0.16 (0.13)	8.11 (0.02)	238.28 (7.52)
2	14	Antikythera Strait	20/05/2013	6:06	36º70’	23º42’	334	16.66 (1.21)	20.00	39.07 (0.03)	39.15	0.12 (0.08)	8.13 (0.01)	241.84 (6.26)
	15	Eastern Ionian Sea	21/05/2013	21:25	36º40’	20º81’	391	16.52 (1.31)	20.27	39.05 (0.01)	39.10	0.15 (0.15)	no data	no data
	17	Adriatic Sea	23/05/2013	21:09	41º84’	17º25’	440	14.67 (1.30)	18.76	38.82 (0.05)	39.12	0.20 (0.21)	8.10 (0.02)	218.53 (14.65)
	16	Otranto Strait	24/05/2013	23:49	40º23’	18º84’	385	15.67 (1.15)	19.49	38.70 (1.34)	30.47	0.16 (0.15)	8.13 (0.01)	236.93 (12.88)
	16-18	Northern Ionian Sea	25/05/2013	9:30	39º07’	18º70’	426	no data	no data	no data	no data	no data	no data	no data
	19	Tyrrhenian Sea	27/05/2013	12:40	39º83’	12º52’	391	14.74 (1.47)	18.60	38.30 (0.20)	37.97	0.18 (0.24)	8.12 (0.02)	216.97 (11.27)
	20	North-Central Western Mediterranean	29/05/2013	20:00	41º32’	5º66’	356	13.88 (0.94)	15.52	38.29 (0.20)	33.75	0.36 (0.24)	8.14 (0.02)	219.89 (11.27)
	21	Central Western Mediterranean	30/05/2013	10:30	40º07’	5º95’	392	13.98 (0.95)	16.78	37.66 (1.74)	37.37	0.17 (0.21)	8.11 (0.01)	204.41 (7.70)
	22	Catalano-Balear	31/05/2013	13:55	40º95’	3º32’	339	14.08 (1.33)	16.81	38.43 (0.08)	38.34	0.25 (0.39)	8.13 (0.02)	218.43 (13.11)

Table 2.

	PCA results		Abundances						Density area		
	Factor 1	Factor 2	*G.ruber* (white)	*T. Sacculifer* (without sac)	*G. bulloides*	*G. inflata*	*O. universa*	TOTAL	*G. bulloides*	*G.ruber* (white)	*O. universa*
Factor 1	1		-0.297	**0.353**	**0.511**	0.242	0.009	**0.309**	**-0.369**	**0.324**	**-0.449**
Factor 2	0	1	0.121	**-0.549**	**-0.470**	-0.209	-0.127	**-0.406**	0.279	-0.296	0.133
Environmental factor loadings:											
Temperature	**-0.825**	-0.030	**0.346***	-0.158	**-0.333***	-0.154	-0.198	-0.154	0.294	**-0.324***	**0.464**
Salinity	**-0.777**	**0.532**	0.296	**-0.353***	**-0.425***	**-0.479**	-0.005	**-0.393***	**0.346***	**-0.721**	**0.355***
Oxygen	-0.084	**0.602**	-0.149	**-0.675**	**-0.684**	-0.241	0.042	**-0.682**	0.050	0.072	**0.509**
Fluorescence	**0.721**	-0.185	**-0.378***	-0.101	-0.020	**0.459**	-0.063	0.028	-0.275	**0.738**	-0.246
[NO3]	**0.912**	-0.113	**-0.344***	**0.460**	**0.567**	0.166	-0.063	0.290	-0.295	0.156	**-0.548**
[PO4]	**0.893**	-0.272	**-0.361***	**0.461**	**0.579**	0.293	-0.168	**0.340***	-0.264	0.252	**-0.538**
pH	-0.189	**0.969**	0.215	**-0.559**	**-0.563**	**-0.351***	0.117	**-0.448**	0.263	**-0.381***	0.236
$p\text{CO}_2$	0.086	**-0.941**	-0.170	**0.589***	**0.554**	0.196	-0.160	**0.378***	-0.167	0.154	-0.177
$[\text{CO}_3^{2-}]$	**-0.594**	**0.729**	**0.352***	**-0.451**	**-0.566**	**-0.452**	-0.016	**-0.447**	**0.406***	**-0.614**	**0.434**
	N = 20	N = 20	N=13	N=13	N=16	N=10	N=17	N=20	N=16	N=13	N=17

Figures

Fig. 1. **(a)** Temperature (ºC), **(b)** salinity, **(c)** fluorescence ($\mu g \cdot l^{-1}$), **(d)** pH, and **(e)** [CO_3^{2-}] ($\mu mol \cdot kg^{-1}$) values of the water column of the transect. Values follow a color scale (under every graph), also values shown in the isometric lines. X axis: water depth. Y axis: longitude (degrees). Measurement locations indicated with white dots, with the coinciding stations numbered at top. The station number and the map section are shown on the map (f). For station code names see Table 1. Note reversed color scale at (d) and (e). Software used: Ocean Data View (Schlitzer, 2016).

Fig. 2. Sampled stations with BONGO nets (dots). The numbers in the picture represent the station codes: First transect: 1 to 13, second transect: 14 to 22. For station code names see Table 1. Color scale at right represents the values of surface chlorophyll concentration (in µg/l), retrieved from *MODIS Aqua (L2)*, from the closest day as possible, specified in the upper part, of the first transect.

Fig. 3. Sample scores on the two PCA factors with the loadings of the environmental parameters on each factor represented by the red axis. The black axis represents the overlay of the absolute abundance values (individuals·10 m^{-3}) according to~~of~~ every station scores of **(a)** all the foraminifera sample, **(b)** *G. inflata*, **(c)** *T. sacculifer* (without sac), **(d)** *G. ruber* (white), **(e)** *G. bulloides*, and **(f)** *O. universa*. Overlay of the Area density (ρ_A) values ($\mu g \cdot \mu m^{-2}$) of **(g)** *G. ruber* (white), **(h)** *G. bulloides*, and **(i)** *O. universa*. In blue colour western Mediterranean stations (incl. Atlantic and Strait of Gibraltar), in red color the eastern Mediterranean stations.

Fig. 4~~3~~. Absolute abundance of planktic foraminifera from BONGO nets during leg 1 (stations 1 to 13) and leg 2 (stations 22 to 14). Category 'Others' is comprised of *G. siphonifera/G. calida/ G. radians* plexus, *~~G~~T. quadrilobatus*, *H. pelagica*, *G. ruber* (pink), *G. menardii* and *T. sacculifer* (with sac).

Fig. ~~4~~5. Percentage of each planktic foraminifera size fraction in each station from ~~(a)~~ leg 1 (stations 1 to 13) and ~~(b)~~ leg 2 (stations 22 to 14). Sample size is indicated in italics ~~by *n* below each station code~~at the top of each station bar.

Fig. ~~5~~6. Relative abundance of planktic foraminifera (%). Category 'Others' is comprised of *G. siphonifera/G. calida/ G. radians* plexus, *~~G~~T. quadrilobatus*~~ plexus~~, *H. pelagica*, *G. ruber* (pink), *G. menardii* and *T. sacculifer* (with sac). Less than 1% values are not shown. Number in parenthesis indicates the total individuals of each location.

Fig. 7. Area density of *G. ruber* (white) and *G. bulloides* in box-and-whisker plots representation for the different location groupings in the Mediterranean. Box extends from the lower (Q_1) to upper (Q_3) quartiles values of the data, with a line at the median (Q_2). Whiskers extend from the quartiles to values comprised within a 1.5 interquartile range (IQR = $Q_3 - Q_1$) distance: Q_1 - 1.5·IQR; Q_3 + 1.5·IQR. The Coefficient of Variation (CV) of each location grouping is represented as a black dot.

Figure 1

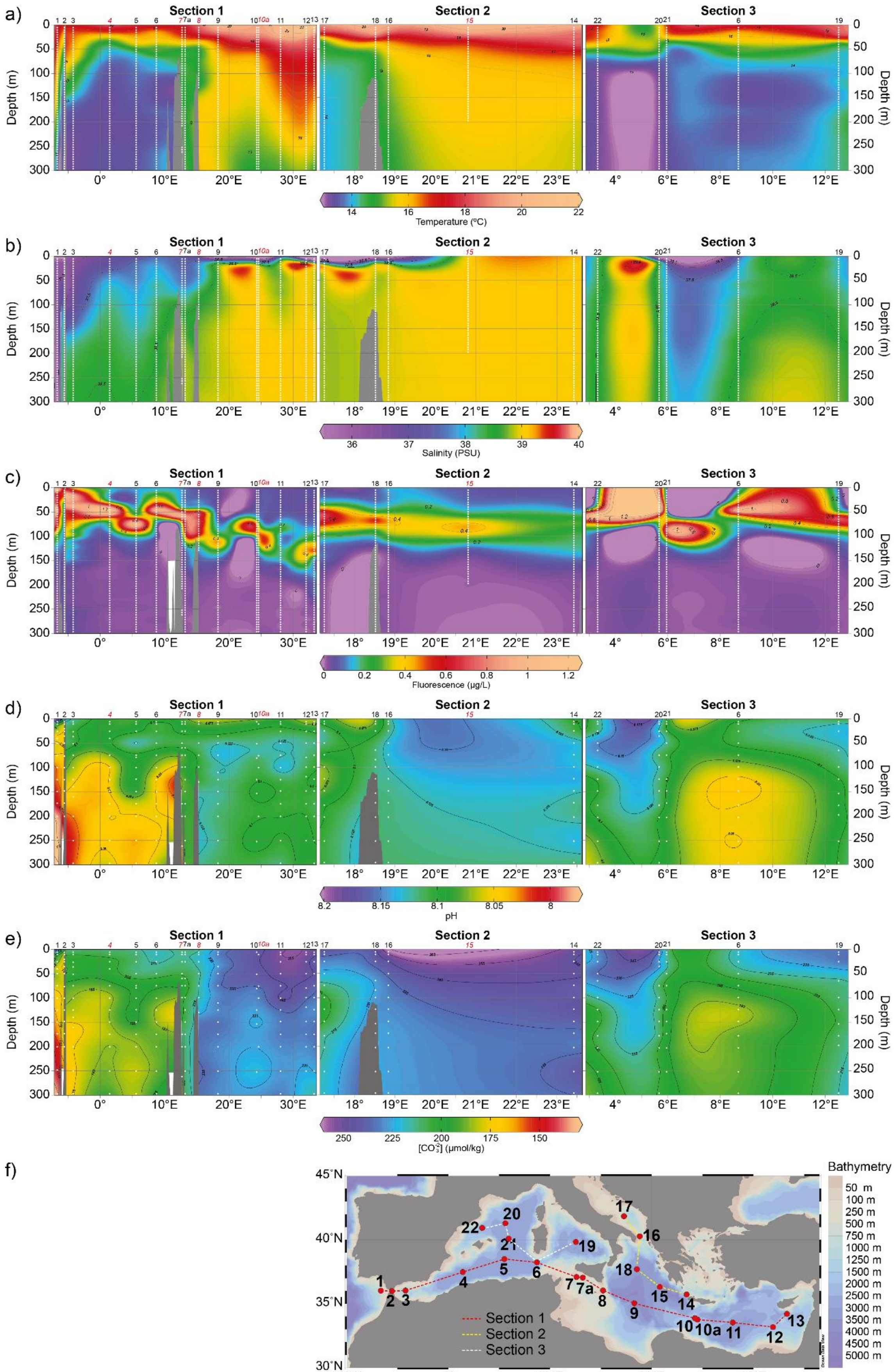

a)
b)
c)
d)
e)
f)
Section 1
Section 2
Section 3
Depth (m)
0°
10°E
20°E
30°E
18°
19°E
20°E
21°E
22°E
23°E
4°
6°E
8°E
10°E
12°E
Temperature (ºC)
Salinity (PSU)
Fluorescence (µg/L)
pH
[CO$_3^{2-}$] (µmol/kg)
Bathymetry
45°N
40°N
35°N
30°N
10°W
0°
10°E
20°E
30°E
Section 1
Section 2
Section 3

Figure 2

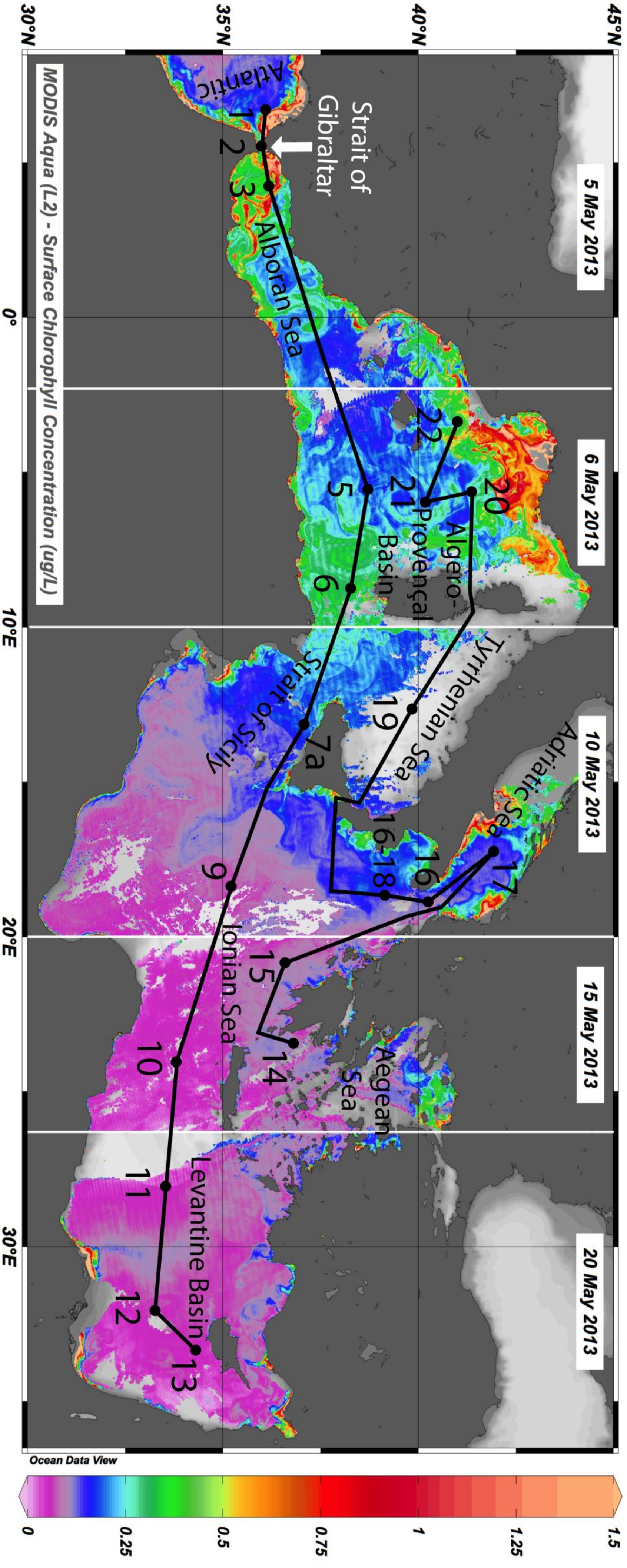

MODIS Aqua (L2) - Surface Chlorophyll Concentration (ug/L)
30°N
35°N
40°N
45°N
0°
10°E
20°E
30°E
5 May 2013
6 May 2013
10 May 2013
15 May 2013
20 May 2013
Atlantic
Strait of Gibraltar
Alboran Sea
Algero-Provençal Basin
Tyrrhenian Sea
Strait of Sicily
Adriatic Sea
Ionian Sea
Aegean Sea
Levantine Basin
1
2
3
5
6
7a
9
10
11
12
13
14
15
16
16-18
17
19
20
21
22
Ocean Data View
0
0.25
0.5
0.75
1
1.25
1.5

Figure 3

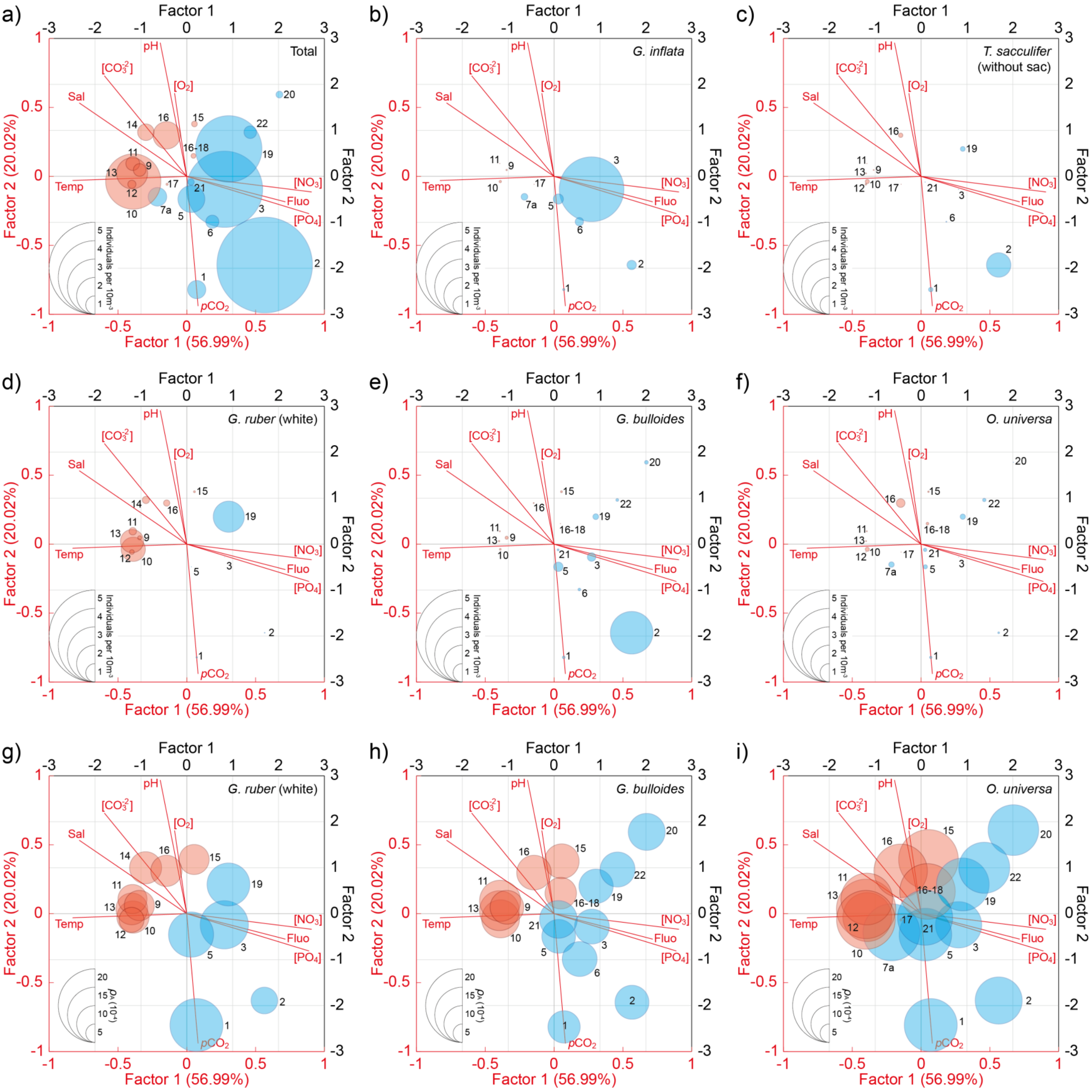

a)
b)
c)
d)
e)
f)
g)
h)
i)
Factor 1
Factor 2
Factor 1 (56.99%)
Factor 2 (20.02%)
Total
G. inflata
T. sacculifer (without sac)
G. ruber (white)
G. bulloides
O. universa
pH
[CO$_3^{2-}$]
[O$_2$]
Sal
Temp
[NO$_3$]
Fluo
[PO$_4$]
pCO$_2$
Individuals per 10m^3
ρ_A (10^{-4})
1
2
3
5
6
7a
9
10
11
12
13
14
15
16
16-18
17
19
20
21
22
-3
-2
-1
0
1
2
3
-1
-0.5
0
0.5
1
4
5
10
15
20

Figure 4

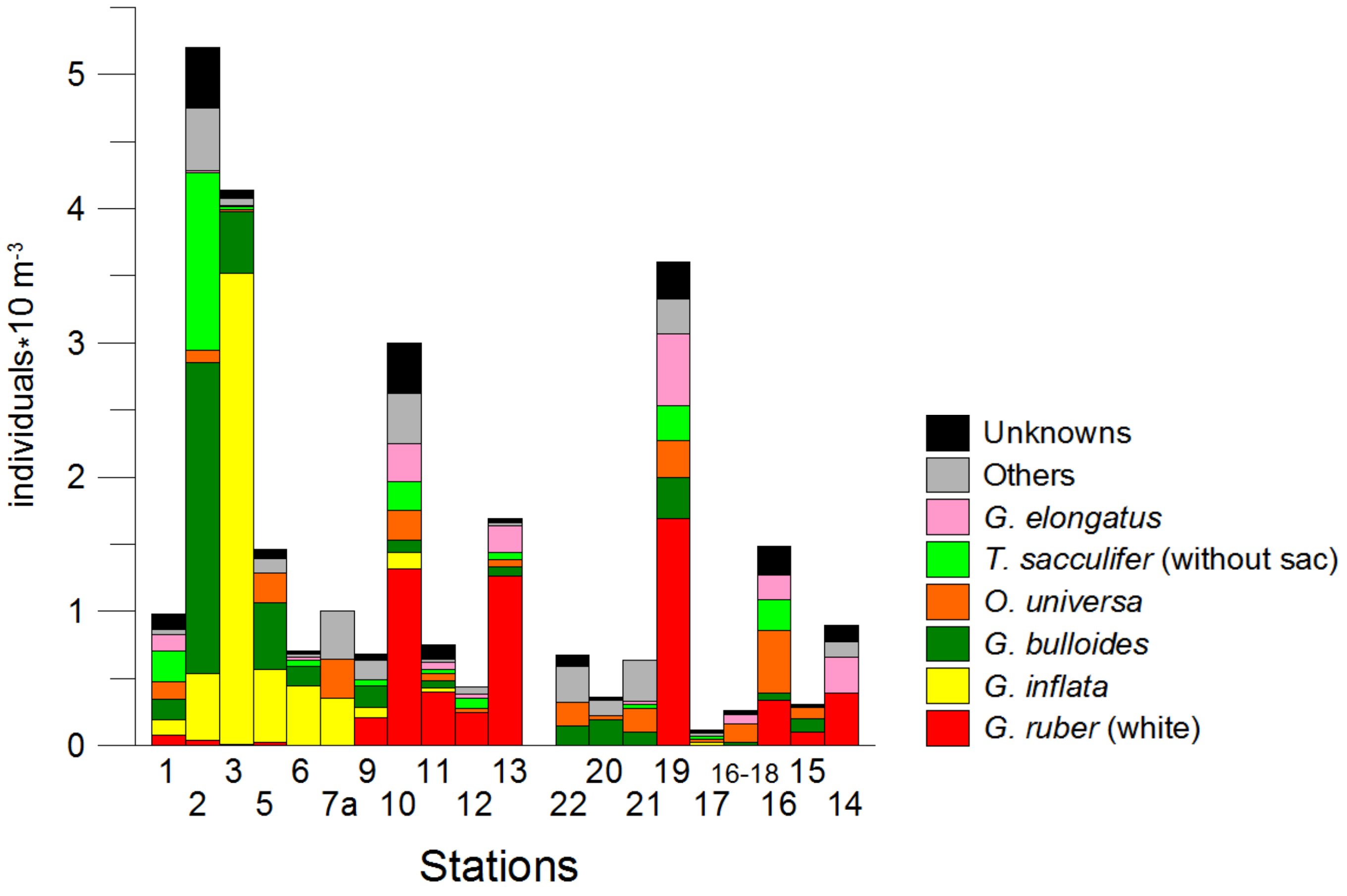

individuals*10 m^{-3}
0
1
2
3
4
5
1
2
3
5
6
7a
9
10
11
12
13
22
20
21
19
17
16-18
16
15
14
Stations
Unknowns
Others
G. elongatus
T. sacculifer (without sac)
O. universa
G. bulloides
G. inflata
G. ruber (white)

Figure 54

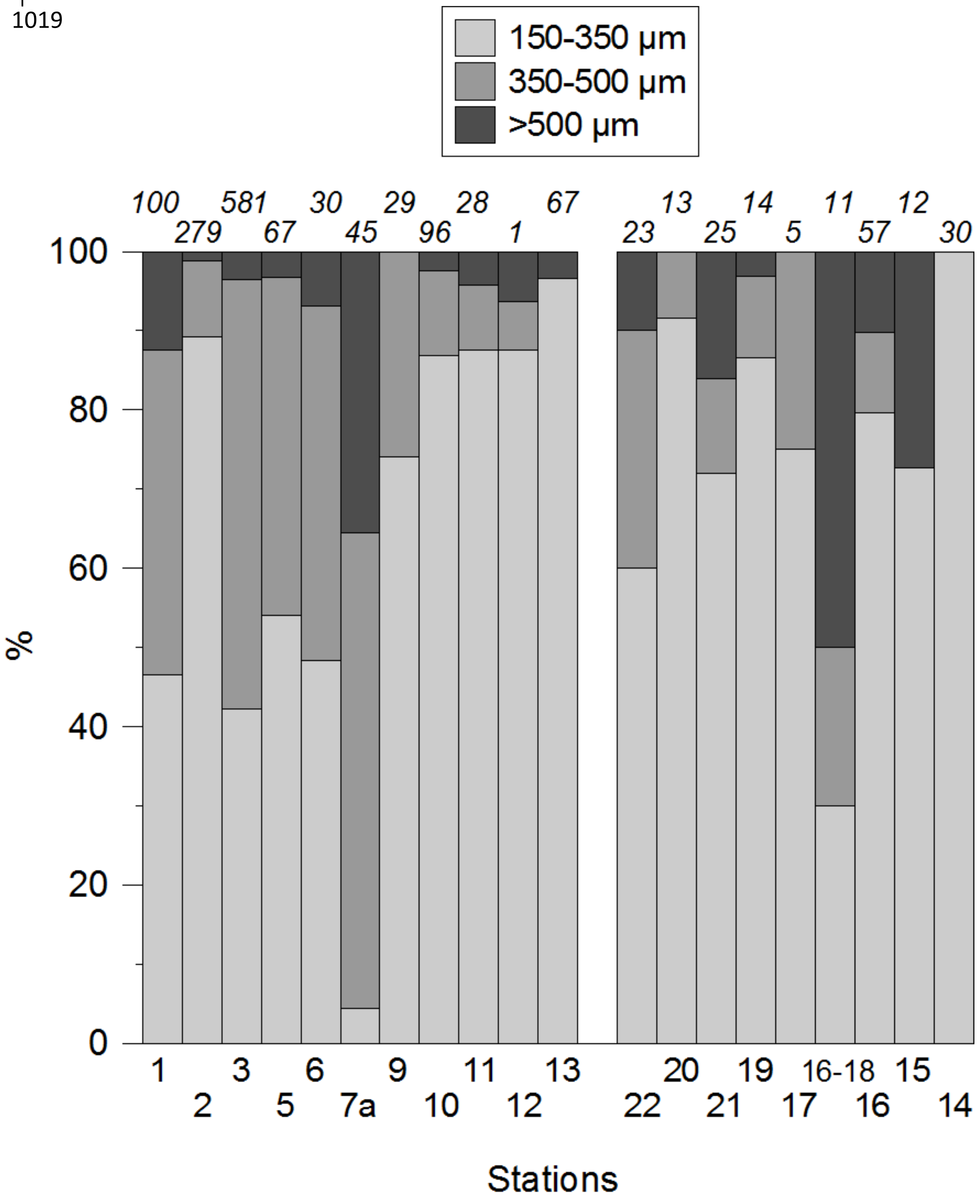

150-350 µm
350-500 µm
>500 µm
100
279
581
67
30
45
29
96
28
1
67
13
23
14
25
5
11
57
12
30
100
80
60
40
20
0
%
1
2
3
5
6
7a
9
10
11
12
13
20
22
19
21
16-18
17
15
16
14
Stations

Figure 6~~5~~

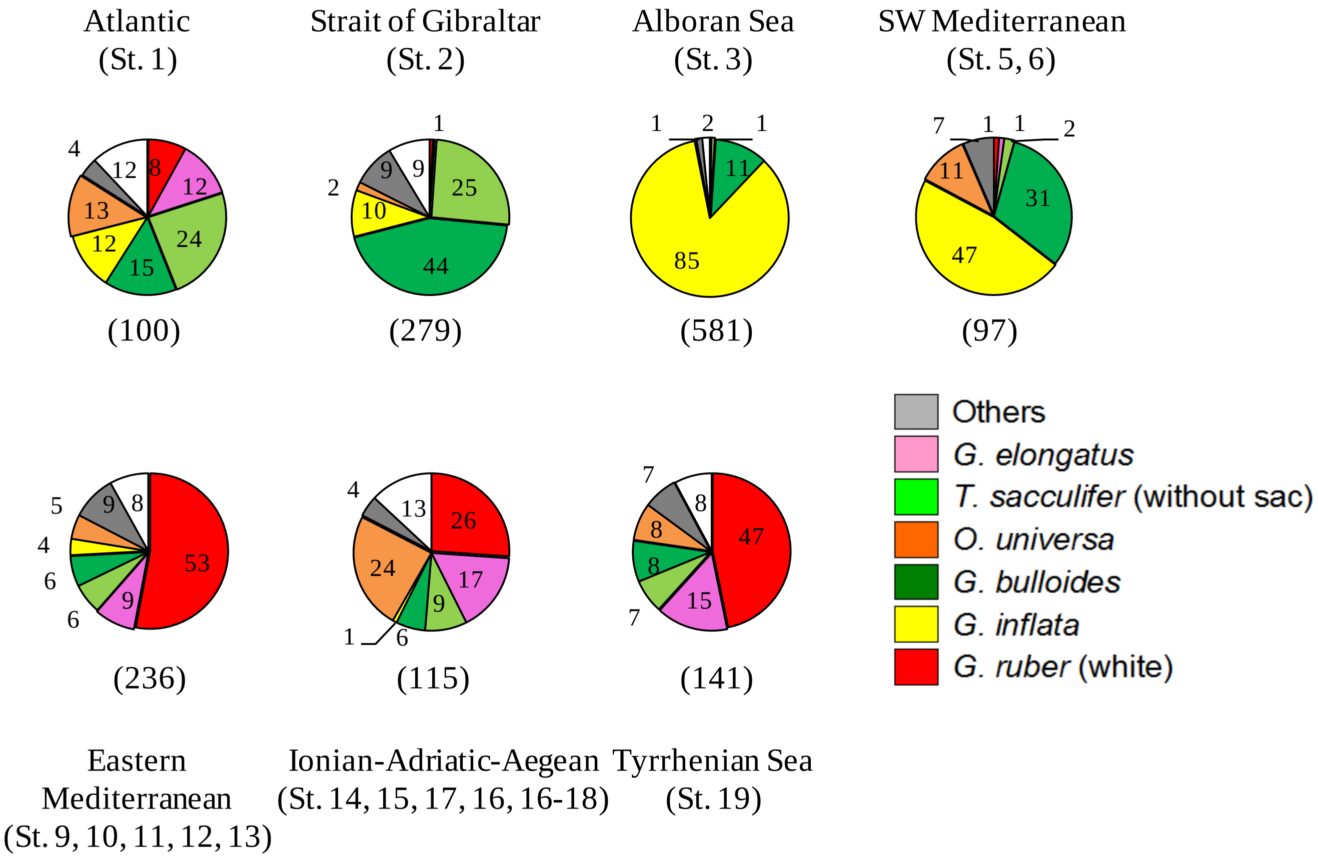
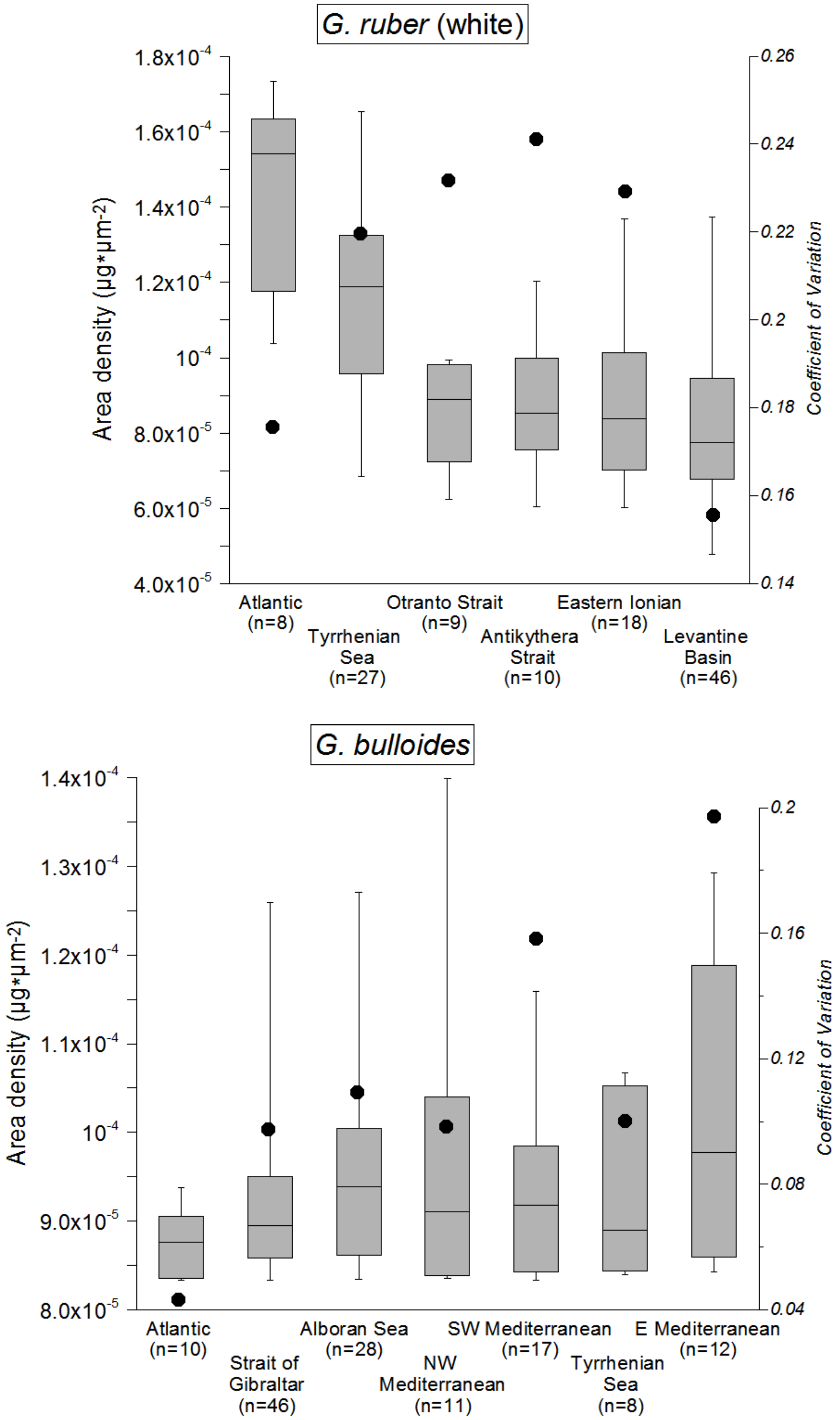

Atlantic
(St. 1)
4
12
8
12
13
24
12
15
(100)
Strait of Gibraltar
(St. 2)
1
2
9
9
25
10
44
(279)
Alboran Sea
(St. 3)
1
2
1
11
85
(581)
SW Mediterranean
(St. 5, 6)
7
1
1
2
11
31
47
(97)
Others
G. elongatus
T. sacculifer (without sac)
O. universa
G. bulloides
G. inflata
G. ruber (white)
5
9
8
4
6
6
9
53
(236)
4
13
26
24
17
9
1
6
(115)
7
8
8
47
8
15
7
(141)
Eastern
Mediterranean
(St. 9, 10, 11, 12, 13)
Ionian-Adriatic-Aegean
(St. 14, 15, 17, 16, 16-18)
Tyrrhenian Sea
(St. 19)

Figure 7


G. ruber (white)
Area density (µg*µm-2)
1.8x10-4
1.6x10-4
1.4x10-4
1.2x10-4
10-4
8.0x10-5
6.0x10-5
4.0x10-5
Coefficient of Variation
0.26
0.24
0.22
0.2
0.18
0.16
0.14
Atlantic (n=8)
Tyrrhenian Sea (n=27)
Otranto Strait (n=9)
Antikythera Strait (n=10)
Eastern Ionian (n=18)
Levantine Basin (n=46)
G. bulloides
Area density (µg*µm-2)
1.4x10-4
1.3x10-4
1.2x10-4
1.1x10-4
10-4
9.0x10-5
8.0x10-5
Coefficient of Variation
0.2
0.16
0.12
0.08
0.04
Atlantic (n=10)
Strait of Gibraltar (n=46)
Alboran Sea (n=28)
NW Mediterranean (n=11)
SW Mediterranean (n=17)
Tyrrhenian Sea (n=8)
E Mediterranean (n=12)