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„Foraminifera assemblages from different hard substrates from the Eastern Mediterranean Sea, Israel – with a special focus on the distribution of non-indigenous species “

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List of abbreviations

aff.	species affinis, a high affinity to
ANOSIM	analysis of similarities
cf.	confer, compare
et al.	et alia, and others
LBF	Large Benthic Foraminifera
sp.	species, if species are not fully identified (singular)
spp.	species pluralis if species are not fully identified (plural)
nMDS	non-metric multidimensional scaling
WoRMS	World Register of Marine Species
*	species with an asterisk are referred to as non-indigenous species

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1 Introduction

1.1 Background

The ecosystem of the eastern Mediterranean Sea is currently undergoing significant changes due to anthropogenic impacts e.g. global warming and increased shipping traffic. Therefore, scientists developed a growing interest in this area during the last two decades. Especially regarding the growing number of non-indigenous marine organism in the Levantine Sea, the eastern basin of the Mediterranean Sea (Hyams-Kaphzan et al., 2008). Non-indigenous species in the Mediterranean Sea, which are marked with an asterisk in this thesis, origin mostly of warm water areas, e.g. the Indo-Pacific, and profit of global warming changes, thus increase their distribution up to higher latitudes (Bianchi, 2007). Though the abundance of non-indigenous species is constantly increasing, their impact on the trophic web and the marine ecosystems in the Mediterranean Sea is still unsure for the future (Bianchi, 2007). In general, non-indigenous species might be able to replace indigenous species which would lead to ecosystem changes and a possible increase in e.g. carbonate production, as it was reported by Abu Tair and Langer (2010) for the non-indigenous foraminifera *Amphistegina lobifera** in shallow waters off Cyprus. Zenetos et al. (2012) reported 986 non-indigenous species among fish, molluscs, and other marine taxa in the Mediterranean Sea, whereas 775 appear in the eastern part of the Mediterranean Sea which includes the Aegean-Levantine basin and the Marmara Sea. In this area, the occurrence of such species could be explained by an introduction through a direct way, linked to anthropological influences and enabled by either active transport as ballast water through shipping traffic, or migration through the artificial Suez Canal (Schmidt et al., 2015). Guy-Haim et al. (2017) proposed an additional possibility, considering the possible migration of foraminifera by being digested from fish before entering the Suez Canal and being excreted after reaching the Mediterranean Sea. Overall this 150-year-old waterway has led to the migration of species from the Red Sea into the Mediterranean Sea and rarely vice versa. The term “Lessepsian migration” describes this process (Por, 1978). Studies on benthic foraminiferal assemblages on the Israeli coast by Hyams-Kaphzan et al. (2008) show an increase in non-indigeneous benthic foraminifera, including larger benthic foraminifera like *Amphistegina lobifera** from the Indo-Pacific. Other studies report of affected areas in the northern part of the Israeli coast which contain up to 90% of the non-indigenous genus *Amphistegina** (Hyams et

al., 2002; Gruber et al., 2007;). Such changes in the foraminiferal communities can lead to a notable decrease of the diversity of indigenous species and in a fauna solely composed of *Amphistegina* spp.* (Streftaris and Zenetos, 2006; Abu Tair, 2011; Langer et al., 2012). The Lessepsian migration of foraminifera and following changes in foraminiferal communities along the Israeli coast might further be accelerated by future changes in temperature and salinity in the Mediterranean Sea, which are most prominent in the eastern part. In this area the sea surface temperature (SST) ranges from 13 °C in winter to 31 °C in summer and the salinity from 36 to 40 ‰ (Titelboim et al., 2019). Macias et al., 2013 observed a warming rate of 0.027 °C for the Mediterranean Sea for each year and it is estimated that this warming rate will stay constant throughout the whole century. The IPCC (2007) reported that an increase of 1.8 °C in the global-mean temperature could lead to a possible loss of 60% to 80% of indigenous species in the southern part of the European Mediterranean area. Since many tropical non-indigenous species (e.g. *Amphistegina lobifera**) are adapted to high fluctuations in SST, they might expand their biogeographical occurrence (Titelboim et al., 2019, Langer et al., 2012).

Foraminifera have played an important role in earth sciences for a long time. As a result of a relatively early appearance in earth's history compared to most other taxa applied in palaeontological research (540 ma), a short reproductive cycle and a quick response to environmental changes, foraminifera are a useful tool for reconstructing changes in marine environments, such as palaeoenvironmental, palaeoceanographic and palaeobathymetric parameters (e.g. Jorissen et al., 1995). Including between 5000 and 10 000 recent taxa (Mikhalevich, 2014), these single-celled organisms form a test wall which is composed of calcium carbonate (CaCO_3), either calcareous or porcelaneous (= high-Mg-calcite), agglutinated sediment particles, or organic compounds. Murray (1973) developed a triangle chart considering the ratio of foraminifera with different test walls to interpret paleoenvironments (Figure 1). If the number of foraminifera with a miliolid (porcelaneous) test wall is higher, it is expected that the environment has a higher salinity. If the number of hyaline or agglutinated foraminifera is higher, environments with lower salinities are expected.

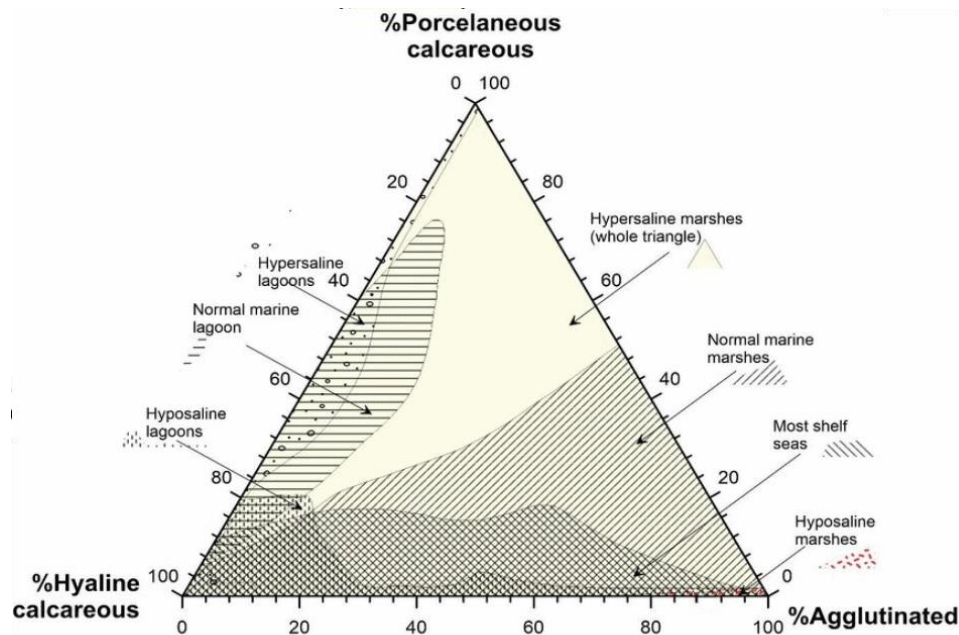


Fig. 1. The triangle chart after Murray (1973, 1991) shows various environments defined after a specific ratio of the different test walls in foraminiferal assemblages (modified by Itam et al., 2019).

Species-specific responses to changes in substrate type, food availability and seasonality are described as the controlling parameters which influence benthic foraminiferal assemblages in shallow shelf environments located in the Mediterranean Sea (Gruber, 2006; Hyams-Kaphzan et al., 2008, 2009; Arieli et al., 2011). Larger benthic foraminifera (LBF) are abundant on the coast of Israel. Larger benthic foraminifera are characterised by having tests with an internal complicated architecture and large size. They occur abundantly in shelf regions of tropical and subtropical areas, mostly in environments with a high carbonate content and low nutrient concentrations (oligotrophic environments). Studies on LBF show, that many species host photosynthetic symbionts (Boudaughier-Fadel, 2018). The symbiont-bearing LBF *Amphistegina lobifera** or *Heterostegina depressa** for example usually inhabit hard substrate sediments with a high percentage of carbonate. These species are associated with warm temperatures during winter, extreme oligotrophic conditions, and a deep penetration of light (Hyams et al., 2002). While most of the studies on the Israeli coast focus on soft bottom substrates, only a few concentrate on hard bottom substrates.

1.2 Previous work and study aim

Since the opening of the Suez Canal in 1869 several studies have been carried out in the eastern Mediterranean Sea, with a focus on the occurrence of non-indigenous

marine species. In 1924 a Cambridge University Expedition to the Suez Canal was performed under the instructions of Munro Fox, having its focus on the zoology of the Canal (Por, 2012). Por (1971) mentions that the occurrence of suitable substrates and the clarity of the water in the Suez Canal are considered as the main factors which support the migration of species. Later studies on benthic foraminiferal communities of soft-bottom substrates revealed the occurrence of non-indigenous species along the Israeli shelf, e.g. Yanko et al. (1998). They studied deformed tests of foraminifera due to pollution and observed non-indigenous species including tropical symbiont-bearing LBF such as *Amphistegina lobifera**, *Heterostegina depressa**, and *Pseudohauerinella diversa**. Hyams-Kaphzan et al. (2008) reported an irregular distribution of benthic foraminifera along the Israeli shelf whereas the numerical abundance increased from the south to the north and from shallow to deeper stations. Thirty-three species of nearly 350 taxa are referred as possible Lessepsian migrants, including LBF (*Amphistegina lobifera** or *Heterostegina depressa**) and small foraminifera with hyaline and miliolid tests. Schmidt et al. (2015) studied the Indopacific non-indigenous genus *Pararotalia*, concluding that its migration into the Mediterranean Sea might be facilitated by an ongoing warming in the Mediterranean Sea.

Hyams et al. (2002) observed, that LBF tend to settle down on hard bottom substrates. They conclude that the appearance of non-indigenous LBF in the Mediterranean Sea can be explained either by recent or past migration from the Atlantic or by recent migration from the Red Sea. Hyams-Kaphzan et al. (2014) studied hard bottom habitats from several stations at two localities along the Israeli coast: Akhziv and Carmel Head. Macro-algae inhabited by benthic foraminifera were sampled from different depths (between 5-20 m) and different seasons during 2013-2014. The observed hard bottom community included 77 benthic foraminifera species, whereas 25% were non-indigeneous. One representative, the LBF *Amphistegina lobifera** was found in all samples and appeared in a range from 18 to 93%. The high abundance of non-indigenous taxa supports an endeavour of monitoring the area adjacent to the Suez Canal in a regular manner. Since benthic foraminiferal communities on hard bottom substrates along the Israeli coast are rarely studied, this master thesis aims to investigate hard bottom communities including the occurrence and possible impact of non-indigeneous species at five different stations. Three stations located in the northern part of the Israeli shelf and two in the southern part with different depth ranges between 5 and 28 m were compared. Samples at these locations were taken during

two seasons (spring and autumn) to compare the effect of seasonality on the assemblage compositions and the abundance of non-indigenous species. These results should lead to a better understanding of hard bottom communities and an extension of data in this area.

1.3 Geographical Setting

As shown in Figure 2, the study area is located along the western shore of Israel, which appears almost without any inclination as a 180 km long NE-NNE line with a width of less than 10 km in the northern part, increasing southward up to 30 km. It belongs to the eastern part of the Mediterranean Sea, also referred to as the Levantine Sea (Almagor and Hall, 1984; Neev, 1965). Sediments of the inner shelf mostly derive from siliciclastic material of the Nile River delta and scarcely from local sources, with the composition of quartz, heavy minerals and biogenic carbonate (Zviely et al., 2007; Emery and Neev, 1960; Golik, 1993, 1997).

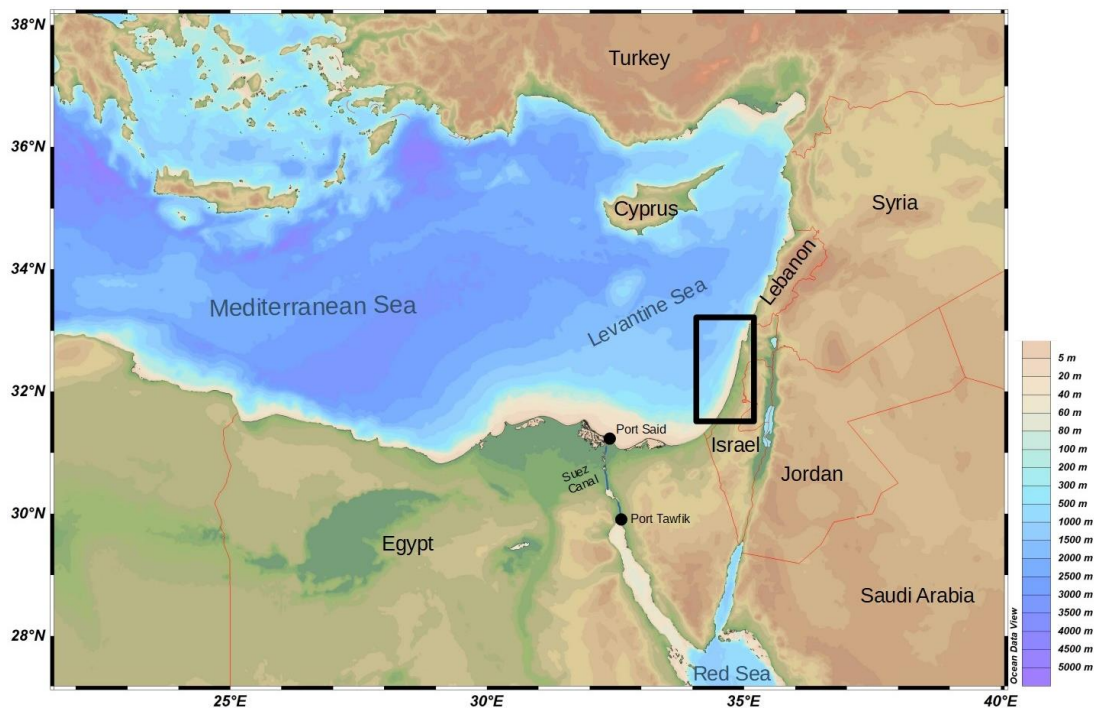


Fig. 2. A map of the eastern Mediterranean Sea shows the Suez Canal with the harbours Port Said and Port Tawfik. The rectangle points out the Israeli coast with the study area.

Varying in a width from 2.5-4 km, the Nile littoral cell stretches alongside the Israeli coast up to Haifa Bay and reaches a water depth of 35 m (Hyams-Kaphzan et al., 2008). Below this water depth sediments are progressively composed of silt and clay.

Coastal, degenerated siliciclastic sediments are substituted by autochthonous carbonate sands (Nir, 1984; Zviely et al., 2007). North to Haifa Bay, carbonate-rich sediments dominate as a result of the decreasing material transport of Nilotic material and hard substrate bottoms dominate whereas many calcareous sandstone ridges originally from the Pleistocene and vermetid rocky reefs occur in the environment (Almagor et al., 2000; Almogi-Labin et al., 2012).

In the south, the Levantine Sea is connected to the Red Sea through an artificial waterway, the Suez Canal which is situated between Port Said in the north and Port Tawfik in the south (both in Egypt). The canal extends to a total length of 162.5 km, a width of 200-300 m and a depth of 10-15 m.

1.4 Oceanographic Setting

In the Levantine Sea, the SST ranges between 13°C during winter and 31°C during summer with a salinity up to 40 ‰ (Titelboim et al., 2019). The stratification shows four water bodies, which change their expansion in a vertical manner seasonally (Schattner et al., 2015). The Levant Surface Water (LSW) is the uppermost water body and is developed during the summer. It varies in its maximal water depth from 15 m during spring, to 25 m during summer and 70 m in autumn. The LSW is limited on the downside by the Atlantic Water (AW), which is conveyed by a jet stream across the Mediterranean Sea, ultimately flowing northwards along the Israeli coast (Figure 3). It stretches between 25–100 m depth during spring, 25–105 m during summer and 80–110 m during autumn. The Levantine Intermediate Water (LIW) appears as a water mass below the AW, which emerges south-east of Crete, followed by a circulation across the Levantine Sea and finally streams towards the Atlantic. The LIW extends between 170–310 m depth during spring, 135–315 m during summer, 220–270 m during autumn and 75–325 m during winter. The Eastern Mediterranean Deep Water (EMDW) is the lowermost water body, mostly emerging in the Adriatic Sea, rarely in the Aegean Sea. It appears below 680 m depth during spring, 690 m during summer, 675 m during autumn and 695 m during winter (Schattner et al., 2015).

Nutrients in the Levantine Sea are mainly provided by the Nile. Areas which are not covered by a Nilotic input experience ultra-oligotrophic conditions (Berman et al. 1984; Krom et al. 1991; Yacobi et al. 1995; Herut et al. 2000). All stations of this master thesis are located within the water mass of the Levant Surface Water (LSW) and are mainly influenced by it.

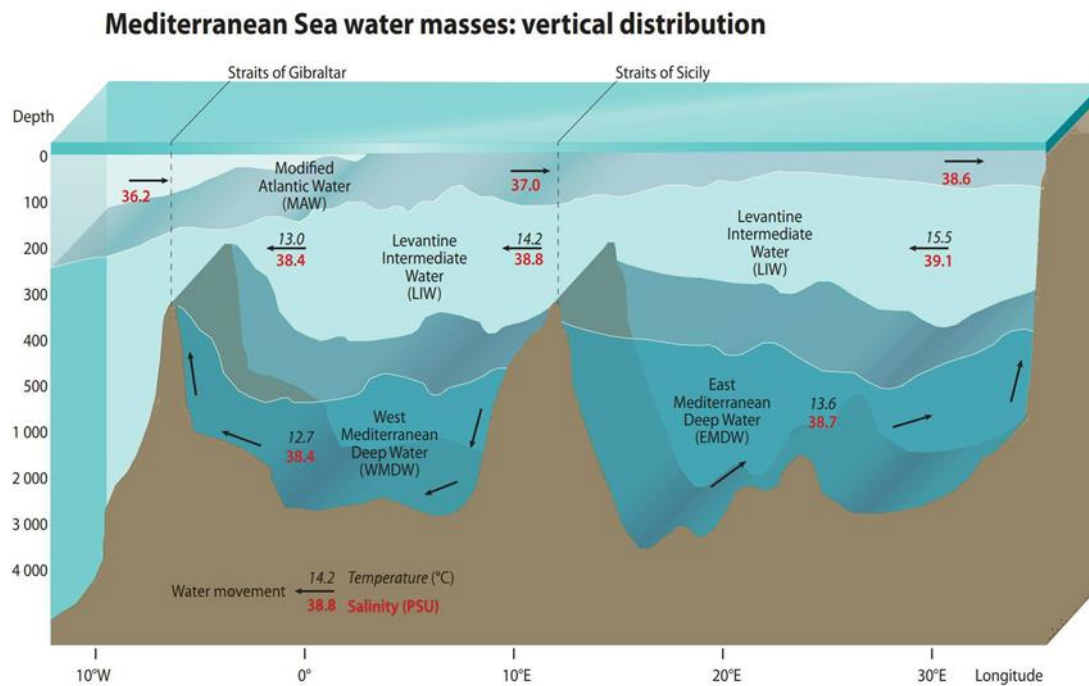


Fig. 3. Water bodies of the Mediterranean Sea with specific temperatures and salinities. The LSW is not shown in the figure above (after Zavattarelli and Mellor, 1995; Meyer Viol, 2015).

2 Material and Methods

2.1 Sampling area

Sampling of hard bottom substrates was carried out within the framework of the FWF project “Historical ecology of the Lessepsian Migration” during April/May and October 2018. This project aims for a better knowledge about the distribution of non-indigenous species in the eastern Mediterranean Sea. In total, 17 stations were covered during the spring sampling and 48 stations during the autumn sampling. In this thesis five stations are described, divided into two regions: north and south coast of Israel (Figure 4).

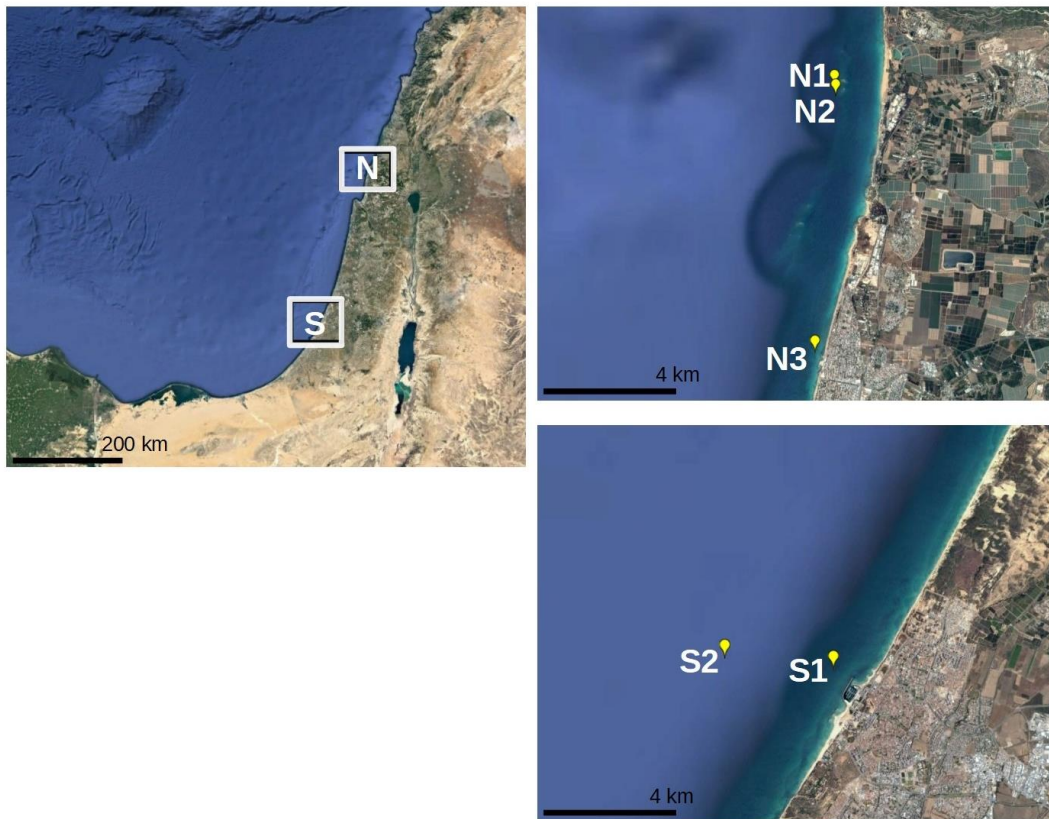


Fig. 4. The samples N1-N3 were taken in the northern part (N), S1 and S2 in the southern part (S) of the Israeli coast (modified after Google Earth).

The assemblages of benthic foraminifera, including living and dead specimens, were investigated at different localities, water depths and seasons (Table 1). All samples were covered by the fraction sizes 125 – 500 μm and 500 μm – 1 mm except of the spring sample of N3. At this station only the fraction size 125 – 500 μm was available due to a different sampling method.

Tab. 1. The table shows the sampling data of the samples. NA = not available.

Station	Location	Sampling date	Season	Water depth [m]	Latitude [N]	Longitude [E]	Temperature on bottom [°C]
N1	Akhziv	01.05.2018	Spring	20	33.07247	35.09228	20
N1	Akhziv	29.10.2018	Autumn	18.3	33.07247	35.09228	25
N2	Akhziv	01.05.2018	Spring	14	33.07037	35.09260	NA
N2	Akhziv	29.10.2018	Autumn	11.8	33.07037	35.09260	25
N3	Nahariyya	01.05.2018	Spring	4.9	33.01317	35.08712	20
N3	Nahariyya	29.10.2018	Autumn	4.9	33.01317	35.08712	25
S1	Ashkelon	30.04.2018	Spring	11.8	31.68683	34.55156	22
S1	Ashkelon	31.10.2018	Autumn	11.3	31.68683	34.55156	25
S2	Ashkelon	02.05.2018	Spring	24.7	31.68909	34.52569	20
S2	Ashkelon	31.10.2018	Autumn	28	31.68909	34.52569	25

2.2 Sampling methods and faunal analysis

Hard substrate samples were collected from two regions on the Israeli coast: Ashkelon in the southern region, Akhziv and Nahariyya in the northern region (Figure 3). At each station, samples were taken at different water depths (4.9-28 m) during spring and autumn in 2018 (Table 1). Sampling was accomplished by scuba divers using an air-lift sampling method (Figure 5). Within a 1 m² quadrat frame the hard-bottom substrate was sampled through a suction pipe tied to a net bag. The mesh size measured 500 µm to keep the collected substrate inside the net bag. Thus, a possible sediment loss through the net bag cannot be not excluded and the sample material of the fraction size 125 – 500 µm used in this master thesis covers only residues of the sediment. However, most of the living specimens are usually attached to the substrate or algae, therefore it is expected that the major part of the living specimens was stuck

in the net bag. As shown in Figure 5, the depression generated within the tube is enabling the transportation of sediment from the underground through the pipe into the net bag (Bianchi et al., 2004). The spring sample of the station N3 was sampled by hand, whereas only the fraction size 125-500 μm was sampled.

On board, the material of the hard-bottom substrate was first sieved into several fraction sizes and then instantly fixated with ethanol. The samples with a fraction size $<500 \mu\text{m}$ were additionally stained with Rose Bengal (2 g/l Rose Bengal), with the aim to observe the presence of living foraminifera within the assemblages (Schönfeld, 2012). With this method, the protoplasm of living specimens is stained in a red-pink shade.

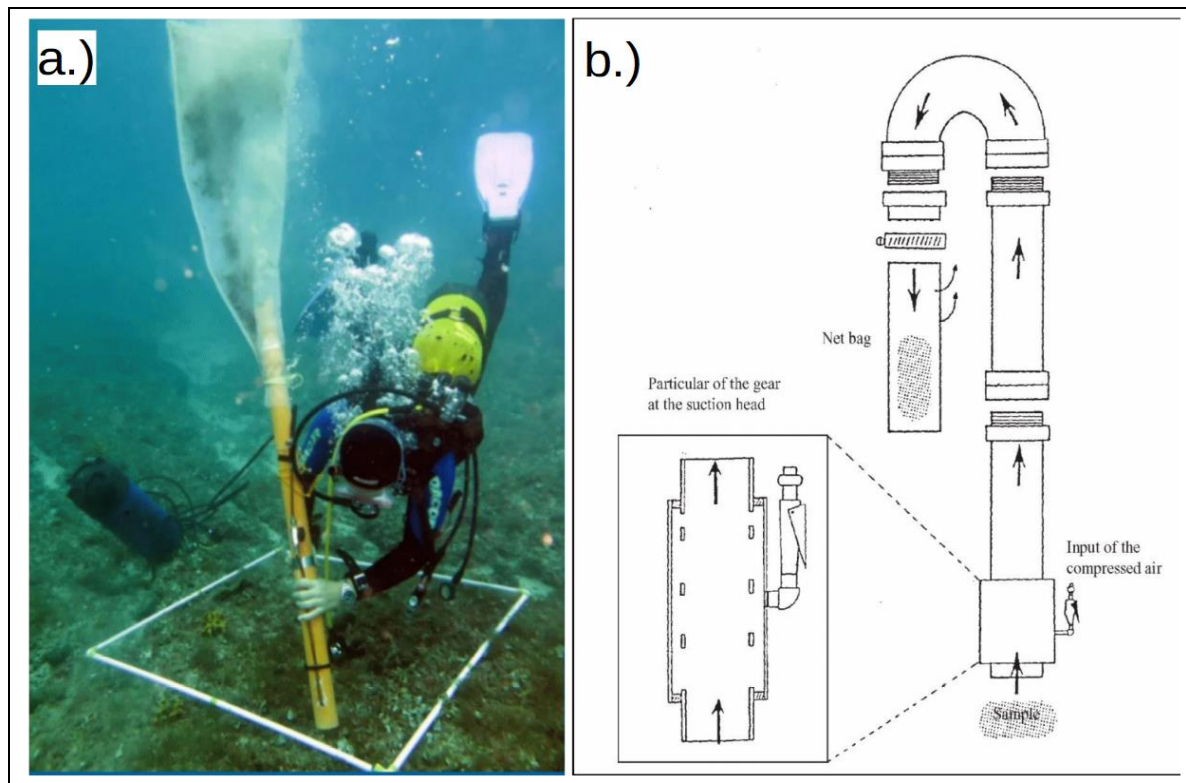


Fig. 5. a.) Scuba diver collecting a hard-bottom substrate on the Israeli coast during field work in Spring, 2018 (Photo by Paolo Albano). **b.)** Sketch of an air-lift sampler shows the sampling direction (Bianchi et al., 2004; modified after Benson, 1989).

2.3 Processing of hard bottom substrate samples

In the laboratories at the University of Vienna hard bottom substrate samples of the fraction size 500 μm – 1 mm were air-dried for one day, stained with Rose Bengal for two weeks and subsequently dried in the drying cabinet at 60 °C. Samples were then washed over 500 μm sieves and dried at 60 °C. The dry-weight of the sieved samples

with a fraction size 500 μm - 1mm ranged between 22.65 and 115.12 gram. Hard bottom samples with the fraction size $<500\mu\text{m}$ were wet fractioned into the size classes 125-500 μm and 63-125 μm , and dried at 60 $^{\circ}\text{C}$. The dry-weight of the sieved samples with a fraction size 125-500 μm varied between 3.04 and 52.69 gram. Dried samples of the fraction sizes 125-500 μm and 500 μm -1 mm were split into aliquots either with an ASC micro splitter or a custom-made macro splitter. The split-size was defined by reaching a minimum of 300 benthic foraminifera per split, including living and dead specimens, for each size fraction. Finally, all individuals were separated from the sediment and placed into microfossil slides.

2.4 Faunal analysis

All individuals and test fragments were counted, with the separation of living and dead specimens. To avoid misinterpretation of stained test walls, two criteria had been established. First, living specimens with multi-chambered test walls had to show a red-pink colouration in the oldest chambers. Second, the staining ought not to show a patchy pattern (Figure 6). Individuals with an agglutinated or miliolid test wall were broken to expose stained cytoplasm. A stereo microscope was used to identify the foraminifera within the samples. Taxonomic identification of foraminifera was mainly based on Cimerman and Langer (1991), Hottinger et al. (1993) and Milker and Schmiedl (2012). For identification and documentation purposes, images of the individuals were taken with a Scanning Electrone Microscope (SEM, Inspect S50; Fei, Japan).

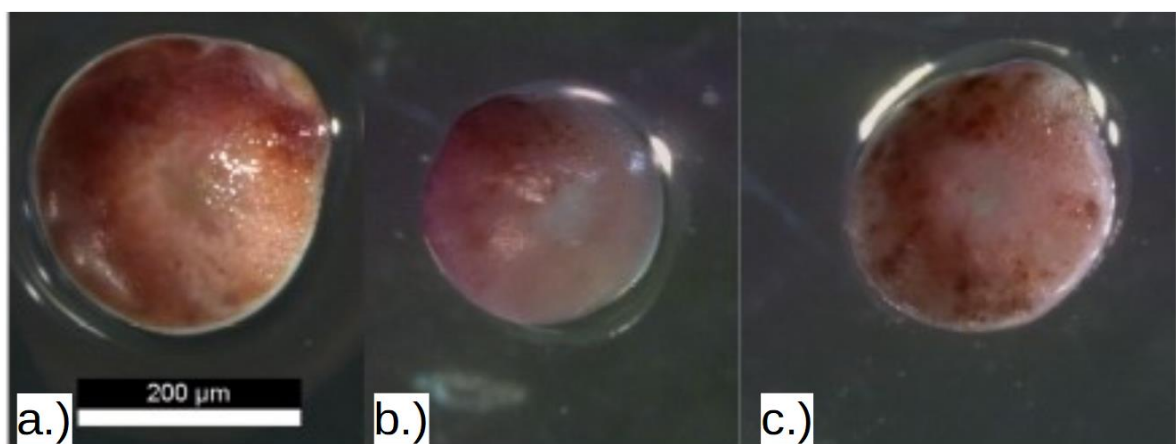


Fig. 6. a.) The specimen of an *Amphistegina lobifera** on the left was identified as a living individual due to a consistent colouring. **b.), c.)** The other two specimens of the same species were identified as dead individuals considering the patchy pattern and weak colouration.

2.5 Statistical analysis

Statistical analysis of benthic foraminiferal assemblages commonly refer to a certain sample size or weight. This way, a comparison of absolute data between the samples is possible. Since the sampling material of this thesis is not referred to either a sample size or a weight, the abundances of all species are represented as relative data in percentages. Diversity indices were calculated for the live and the total assemblage for the samples of the fraction size 500 μm – 1 mm. Because of a possible material loss of the fraction size 125 – 500 μm , diversity indices were only calculated for the live assemblages considering the attachment of living specimens on algae or sediment particles with a size > 500 μm . All diversity indices including the rarefaction of the samples were computed with the software PAST.

In addition, and to compare the samples concerning the effect of location, water depth and season, a non-metric multidimensional scaling (nMDS) plot and an ANOSIM test were performed with the data of the same assemblages as used for the diversity indices. The nMDS plot and the ANOSIM test were computed using the VEGAN package in the statistical software R (Oksanen et al. 2019, R core team 2020).

2.5.1 Diversity indices

2.5.1.1 Individual Rarefaction Method

The individual rarefaction method shows a species accumulation curve in a graph which expresses if the material of a sample covers enough individuals to represent the original species diversity of the sampling area. The more material of a sample is available the higher is the possibility that all species were covered in the samples. If this is the case and a sample represent the original species diversity of the sampling area, the species accumulation curve flattens in the graph. If the observed sample does not represent the original species diversity of the sampling area, the curve shows an increase in the graph.

2.5.1.2 Shannon-Wiener Index

The Shannon-Wiener Index H' is used to characterize species diversity in a community. It includes abundance as well as evenness of the observed species. The Index itself

ranges from 0 to infinity theoretically, but in practice does not exceed 5.0 (Washington, 1984). The higher the number of species, the higher the Index (Krebs, 2014).

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

Equ. 1. Equation of the Shannon-Wiener Index, whereas p_i describes the number of individuals and s the number of species.

2.5.1.3 Evenness

In the field most biological communities are covered by several species with a different number of specimens. The evenness measures if species are distributed evenly in an assemblage. The range varies from 0 to 1 while one is the maximum and means that all species in an assemblage are equally abundant (Krebs, 2014).

$$E = \frac{H'}{\ln S}$$

Equ. 2. Equation of the evenness. H' describes the Shannon-Wiener Index and S the number of species.

2.5.1.4 Dominance

In contrast to the evenness, the dominance shows if a sample is dominated by a certain species. It ranges from 0 to 1 whereas 1 means no diversity. The bigger the value of the dominance, the lower the diversity.

$$D = \sum \left(\frac{n_i}{n} \right)^2$$

Equ. 3. Equation of the dominance, whereas n_i describes the number of individuals of a certain species n and n describes the species.

2.5.1.5 Chao-1

‘Chao 1’ estimates the true species diversity in a non-parametric way (Krebs, 2014). F_1 represents the number of species in a sample which occur once (singletons). The

appearance of singletons leads to the suggestion that there were more rare species which were not found. If all species have been observed twice or more times, it is likely that no more species would be found (Chao, 1984).

$$S_{Chao1} = S_{obs} + f_1 \frac{(f_1 - 1)}{[2(f_2 + 1)]}$$

Equ. 4. Equation of Chao-1. S_{obs} means the number of species which were observed in total. The number of species with a single occurrence is described by the term f_1 , and the number of species with two occurrences by the term f_2 .

2.5.2 Non-metric multidimensional scaling (nMDS) and ANOSIM test

Non-metric multidimensional scaling is a method to compare samples of different assemblages and to reduce the information from multiple dimensions to compute it into two dimensions. The function measures dissimilarities and is a non-parametric method, which only uses rank information (Oksanen, 2015). In this thesis the species and their abundances were compared. The shorter the distance of the stations within a graph, the more similar are the communities to each other. The 2D-stress value defines, if the nMDS plot represents the reduced dimensions either excellent or poor. Values < 0.05 represent an excellent result, > 0.3 a poor result. The lower the 2D-stress value, the better the representation.

The ANOSIM (Analysis of similarities) test uses a dissimilarity matrix as input and is a non-parametric test. The idea is to observe if distances within groups are equal or greater than the distances between groups by comparing their means using ranked dissimilarities (Anderson and Walsh, 2013). The ANOSIM statistic R value which compares these means ranges from -1 to 1. The closer the value is to 1, the higher is the dissimilarity between groups. These results are statistically significant if the significance shows values lower than 0.05. An ANOSIM test can indicate dissimilarities due to certain differences, e.g. location, water depth or season (Anderson and Walsh, 2013).

3 Results

3.1 Faunal analysis

In total 128 species were identified in all samples during spring and autumn whereas 16 were identified as non-indigenous species. 67 species were among foraminifera with a miliolid test wall, 10 of them were non-indigenous. There were 55 among foraminifera with a hyaline test wall, 6 of them were non-indigenous. Six species included an agglutinated test wall, none of them were non-indigenous.

3.1.1 Species list

To use the correct species terms, all species were compared to the current terms presented by the webpage <http://www.marinespecies.org/> (May, 2020). Non-indigenous species were marked with an asterisk.

Phylum: **FORAMINIFERA** Eichwald, 1830

Order: **LITUOLIDA**

Family: **TROCHAMMINIDAE** Schwager, 1877

Ammoglobigerina globigeriniformis Parker & Jones, 1865

Identified after: *Milker & Schmiedl (2012)*.

Order: **TEXTULARIINA** Delage & Hérouard, 1896

Family: **TEXTULARIIDAE** Ehrenberg, 1838

Sahulia conica d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Textularia conica* d'Orbigny, 1839.

Textularia agglutinans d'Orbigny, 1839

Identified after: *Merkado et al. (2015)*.

Plate: 1A

Textularia pala Czjžek, 1848

Plate: 1B

Identified after: *Milker & Schmiedl (2012)*.

Textularia truncata Höglund, 1947

Identified after: *Cimerman & Langer (1991)*.

Textularia sp.1

Plate: 1C

Similar to *Textularia agglutinans* in the juvenile stadium. Last chambers are flattened to an 90° angle and have a bigger width than those of individuals of *Textularia agglutinans*.

Textularia spp.

Order: **MILIOLIDA** Ehrenberg, 1839

Family: **Alveolinidae** Ehrenberg, 1839

Borelis schlumbergeri* Reichel, 1937

Plate: 1D

Identified after: *Reiss & Hottinger (1984)*. Non-indigenous after *Zenetos et al. (2010)*.

Family: **CRIBROLINOIDAE** Cushman & LeRoy, 1939

Adelosina cliarensis Heron-Allen & Earland, 1930

Identified after: *Cimerman & Langer (1991)*.

Adelosina colomi Le Calvez & Le Calvez, 1958

Identified after: *Milker & Schmiedl (2012)*.

Adelosina dubia d'Orbigny in Fornasini, 1905

Identified after: *Milker & Schmiedl (2012)*.

Adelosina intricata Terquem, 1878

Identified after: *Meric et al. (2014)*.

Adelosina mediterranensis Le Calvez & Le Calvez, 1958

Identified after: *Milker & Schmiedl (2012)*.

Adelosina cf. mediterranensis

Similar to *Adelosina mediterranensis* but sutures are missing due to abrasion.

Adelosina partschii d'Orbigny, 1846

Identified after: *Meric et al. (2014)*.

Adelosina pulchella d'Orbigny, 1826

Identified after: *Meric et al. (2014)*.

Adelosina aff. pulchella

Specimens are similar to the specimens of *Adelosina pulchella* but without visible sutures and a shorter neck.

Adelosina sp.1

The specimen shows deformed chambers.

Adelosina spp.

Family: **FISCHERINIDAE** Millett, 1898

Vertebralina striata d'Orbigny, 1826

Identified after: *Milker & Schmiedl (2012)*.

Wiesnerella auriculata Egger, 1893

Identified after: *Milker & Schmiedl (2012)*.

Family: **HAUERINIDAE** Schwager, 1876

Affinetrina planciana d'Orbigny, 1839

Identified after: *Samir et al. (2003)*.

Plate: 1E-F

Articulina pacifica* Cushman, 1944

Plate: 1G

Identified after: Jones (1994). Non-indigenous after Zenetos et al. (2012).

***Articulina* spp.**

Cycloforina* aff. *contorta

The neck of this specimen is shorter than that of the *Cycloforina contorta*.

***Cycloforina* sp.1**

Identified after: Milker & Schmiedl (2012).

***Cycloforina* spp.**

Flintinoides labiosa d'Orbigny, 1839

Plate: 1I

Identified after: Milker & Schmiedl (2012). There it is referred to as *Miliolinella labiosa* d'Orbigny 1839.

Massilina secans d'Orbigny, 1826

Identified after: Meric et al. (2014).

Miliolinella elongata Kruit, 1955

Identified after: Cimerman & Langer (1991).

Miliolinella subrotunda Montagu, 1803

Plate: 1H

Identified after: Cimerman & Langer (1991).

***Miliolinella* spp.**

Pseudomassilina australis* Cushman, 1932

Plate: 1J

Identified after: Hottinger et al. (1993). Non-indigenous after Zenetos et al. (2012).

Pseudoschlumbergerina ovata* Sidebottom, 1904

Plate: 1K-L

Identified after: Guy-Haim et al. (2017). There it is referred to as a non-indigenous species.

Pseudotriloculina limbata d'Orbigny in Fornasini, 1905

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Quinqueloculina limbata* d'Orbigny in Fornasini, 1905.

Pseudotriloculina subgranulata* Cushman, 1918

Plate: 2A-B

Identified after: *Makled & Langer (2011)*. Non-indigenous after *Zenetos et al. (2012)*.

Pyrgo oblonga d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Pyrgo striolata Brady, 1884

Plate: 2C-D

Identified after: *Makled & Langer (2011)*.

Quinqueloculina agglutinans d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Siphonaperta agglutinans* d'Orbigny 1839.

Quinqueloculina berthelotiana d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Quinqueloculina bicarinata d'Orbigny in Terquem, 1878

Identified after: *Panchang & Nigam (2014)*.

Quinqueloculina bosciana d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Quinqueloculina cf. Multimarginata*

Plate: 2E

Identified after: *Razak et al. (2015)*. Non-indigenous after *Zenetos et al. (2012)*.

Quinqueloculina disparilis d'Orbigny in Schlumberger, 1893

Identified after: *Cimerman & Langer (1991)*.

Quinqueloculina irregularis d'Orbigny in Terquem, 1878

Identified after: *Cimerman & Langer (1991)*. There it is referred to as *Siphonaperta irregularis* d'Orbigny 1839.

Quinqueloculina laevigata d'Orbigny, 1839

Identified after: *Cimerman & Langer (1991)*.

Quinqueloculina lamarckiana d'Orbigny, 1839

Plate: 2F

Identified after: *Meric et al. (2014)*.

Quinqueloculina pseudobuchiana Luczkowska, 1974

Plate: 2G-H

Identified after: *Milker & Schmiedl (2012)*.

Quinqueloculina seminula Linnaeus, 1758

Identified after: *Cimerman & Langer (1991)*.

Quinqueloculina schlumbergeri Wiesner, 1923

Identified after: *Cimerman & Langer (1991)*. There it is referred to as *Quinqueloculina stelligera* Schlumberger, 1893.

Quinqueloculina aff. tropicalis

Plate: 2K-L

Specimens differ to *Quinqueloculina tropicalis* in an elongated aperture and the absence of a rim.

Quinqueloculina ungeriana d'Orbigny, 1846

Identified after: *Cimerman & Langer (1991)*.

Quinqueloculina variolata d'Orbigny in Terquem, 1878

Identified after: *Meric et al. (2014)*. There it is referred to as *Lachlanella variolata* d'Orbigny in Terquem, 1878.

Quinqueloculina viennensis Le Calvez & Le Calvez, 1958

Identified after: *Milker & Schmiedl (2012)*.

Quinqueloculina vulgaris d'Orbigny, 1826

Identified after: *Meric et al. (2014)*.

***Quinqueloculina* sp.1**

Plate: 2I-J

The test wall is porcellaneous and imperforate. The chamber arrangement is “quinqueloculine.” From one side four chambers are visible and from the other side three. The chambers show an undulating structure. The aperture is triangular and provided with a short tooth.

***Quinqueloculina* spp.**

Sigmoilina costata Schlumberger, 1893

Identified after: *Milker & Schmiedl (2012)*.

Siphonaperta horrida Cushman, 1947

Identified after: *Milker & Schmiedl (2012)*.

***Siphonaperta* spp.**

Triloculina marioni Schlumberger, 1893

Identified after: *Cimerman & Langer (1991)*.

Triloculina oblonga Montagu, 1803

Identified after: *Milker & Schmiedl (2012)*.

Triloculina plicata Terquem, 1878

Identified after: *Milker & Schmiedl (2012)*.

Triloculina schreiberiana d'Orbigny, 1839

Identified after: *Cimerman & Langer (1991)*.

Triloculina trigonula Lamarck, 1804

Identified after: *Meric et al. (2014)*.

***Triloculina* spp.**

Family: **NUBECULARIIDAE** Jones, 1875

***Nubeculina* sp.1**

Identified after: *Milker & Schmiedl (2012)*.

Family: **PENEROPLIDAE** Schultze, 1854

Peneroplis pertusus Forsskål in Niebuhr, 1775

Plate: 3A

Identified after: *Cimerman & Langer (1991)*.

Peneroplis planatus Fichtel & Moll, 1798

Plate: 3B

Identified after: *Cimerman & Langer (1991)*.

***Peneroplis* spp.**

Family: **RIVEROINIDAE** Saidova, 1981

Pseudohauerinella diversa* Cushman, 1946

Plate: 3C

Identified after: *Hottinger et al. (1993)*. There it is referred to as *Hauerina diversa*. Non-indigenous after *Zenetos et al. (2010)*.

***Pseudohauerinella* spp.**

Family: **SORITIDAE** Ehrenberg, 1839

Sorites orbiculus* Forsskål in Niebuhr, 1775

Plate: 3D-E

Identified after: *Guy-Haim et al. (2017)*. Non-indigenous after *Zenetos et al. (2010)*.

***Sorites* spp.**

Family: **SPIROLOCULINIDAE** Wiesner, 1920

Spiroloculina angulata* Cushman, 1917

Plate: 3F-G

Identified after: *Meric et al. (2014)*. Non-indigenous after *Zenetos et al. (2010)*.

Spiroloculina angulosa d'Orbigny in Fornasini, 1904

Identified after: *Cimerman & Langer (1991)*.

Spiroloculina antillarum* d'Orbigny, 1839

Plate: 3H-I

Identified after: *Hottinger et al. (1993)*. Non-indigenous after *Zenetos et al. (2010)*.

Spiroloculina communis Cushman & Todd, 1944

Identified after: *Hottinger et al. (1993)*.

Spiroloculina excavata d'Orbigny, 1846

Identified after: *Milker & Schmiedl (2012)*.

Spiroloculina excisa Cushman & Todd, 1944

Identified after: *Loeblich & Tappan (1994)*.

Spiroloculina subimpressa Parr, 1950

Identified after: *Jones (1994)*.

***Spiroloculina* sp.1**

Plate: 3J

The sutures of the chambers and the miliolid tooth are like those of the species *Spiroloculina excisa*. The number of chambers and their shape are similar to those of the species *Quinqueloculina granulocostata*.

***Spiroloculina* sp.2**

***Spiroloculina* sp.3**

***Spiroloculina* spp.**

Order: **ROTALIIDA**

Family: **ACERVULINIDAE** Schultze, 1854

***Planogypsina* sp.1**

Sutures are hardly visible due to abrasion.

***Sphaerogypsina globulus* Reuss, 1848**

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Sphaerogypsina globula*.

Family: **AMMONIIDAE** Saidova, 1981

***Ammonia beccarii* Linnaeus, 1758**

Plate: 3K-L

Identified after: *Cimerman & Langer (1991)*.

***Ammonia batava* subsp. *compacta* Hofker, 1964**

Identified after: *Temelkov et al. (2006)*.

***Ammonia tepida* Cushman, 1926**

Identified after: *Cimerman & Langer (1991)*.

***Ammonia* sp.1**

Plate: 4C-D

Like the molecular type T5 after Hayward et al. (2004). There it is identified as *Ammonia aoteana* Finlay, 1940.

***Ammonia* sp.2** d'Orbigny, 1839

Plate: 4A-B

Similar to the ***Ammonia parkinsoniana*** after *Cimerman & Langer (1991)*.

***Ammonia* spp.**

Family: **AMPHISTEGINIDAE** Cushman, 1927

Amphistegina lobifera* Larsen, 1976

Plate: 4E

Identified after: *Hottinger et al. (1993)*. Non-indigenous after *Zenetos et al. (2010)*.

***Amphistegina* spp.**

Family: **ANOMALINIDAE** Cushman, 1927

Epistomaroides punctulate* d'Orbigny, 1826

Plate: 4F

Identified after: *Hottinger et al. (1993)*. Non-indigenous to the northern coast of Israel after *Almogi-Labin & Hyams-Kaphzan (2012)*.

Family: **ASTERIGERINATIDAE** Reiss, 1963

Asterigerinata mamilla Williamson, 1858

Plate: 4G-H

Identified after: *Milker & Schmiedl (2012)*.

Family: **ASTRONONIONIDAE** Cushman & Edwards, 1937

Astrononion stelligerum d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Family: **BOLIVINITIDAE** Cushman, 1927

Bolivina variabilis Williamson, 1858

Identified after: *Milker & Schmiedl (2012)*.

Family: **BULIMINIDAE** Jones, 1875

Bulimina elongata d'Orbigny, 1846

Identified after: *Milker & Schmiedl (2012)*.

Family: **CALCARINIDAE** d'Orbigny, 1826

Neorotalia calcar d'Orbigny in Deshayes, 1830

Identified after: *Hottinger et al. (1991)*.

Pararotalia calcariformata* McCulloch, 1977

Plate: 4I-J

Identified after: *Meric et al. (2013)*. Non-indigenous after *Zenetos et al. (2010)*.

***Pararotalia* spp.**

Family: **CANCRISIDAE** Chapman, Parr & Collins, 1934

Cancris auricula Fichtel & Moll, 1798

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Cancris auriculus* (Fichtel & Moll, 1798).

***Gyroidinoides* spp.**

***Valvulineria* spp.**

Family: **CIBICIDIDAE** Cushman, 1927

***Cibicides pseudolobatus* Perelis & Reiss, 1975**

Identified after: *Milker & Schmiedl (2012)*.

***Cibicides refulgens* Montfort, 1808**

Identified after: *Milker & Schmiedl (2012)*.

***Cibicides* sp.1**

***Cibicides* spp.**

***Cibicidoides lobatus* Walker & Jacob, 1798**

Plate: 4K-L

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Lobatula lobatula* Walker & Jacob, 1798.

***Cibicidoides pseudoungeriana* Cushman, 1922**

Plate: 5A-B

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Cibicides pseudoungerianus* Cushman, 1922.

Cibicidoides variabilis d'Orbigny, 1826

Plate: 5C-D

Identified after: *Cimerman & Langer (1991)*. There it is referred to as *Cibicidella variabilis* d'Orbigny, 1826.

Family: **CYMBALOPORIDAE** Cushman, 1927

Cymbaloporetta squamosa d'Orbigny, 1839

Plate: 5E-F

Identified after: *Jones (1994)*.

Family: **DISCORBINELLIDAE** Sigal, 1952

Discorbinella bertheloti d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Hanzawaia rhodiensis* Terquem, 1878

Plate: 5G

Identified after: *Avnaim-Katav et al. (2013)*. There it is referred to as *Discorbinella rhodiensis* Terquem, 1878. Non-indigenous after *Zenetos et al. (2010)*.

Family: **ELPHIDIIDAE** Galloway, 1933

Criboelphidium excavatum Terquem, 1875

Plate: 5H

Identified after: *Lei & Li (2016)*. There it is referred to as *Elphidium excavatum* Terquem, 1875.

Elphidium aculeatum d'Orbigny, 1846

Plate: 5J

Identified after: *Milker & Schmiedl (2012)*.

Elphidium charlottense Vella, 1957

Plate: 5I

Identified after: *Symphonia & Nathan (2019)*.

Elphidium crispum Linnaeus, 1758

Plate: 5K

Identified after: *Milker & Schmiedl (2012)*.

Elphidium macellum Fichtel & Moll, 1798

Identified after: *Milker & Schmiedl (2012)*.

Elphidium striatopunctatum* Fichtel & Moll, 1798

Plate: 5L

Identified after: *Guy-Haim et al. (2017)*. Non-indigenous after *Zenetos et al. (2010)*.

***Elphidium* spp.**

Porosononion granosum d'Orbigny, 1846

Plate: 6A

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Elphidium granosum* d'Orbigny, 1846.

Family: **EPONIDIDAE** Hofker, 1951

Eponides concameratus Montagu, 1808

Identified after: *Cimerman & Langer (1991)*.

Family: **GLABRATELLIDAE** Loeblich & Tappan, 1964

Conorbella pulvinata Brady, 1884

Identified after: *Milker & Schmiedl (2012)*.

Glabratella hexacamerata Seiglie & Bermúdez, 1965

Plate: 6B-C

Identified after: *Milker & Schmiedl (2012)*.

Pileolina patelliformis Brady, 1884

Plate: 6D-E

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Glabratella patelliformis* Brady, 1884.

Planoglabratella opercularis d'Orbigny, 1839

Identified after: *Milker & Schmiedl (2012)*.

Family: **HAYNESINIDAE** Mikhalevich, 2013

Haynesina depressula Walker & Jacob, 1798

Identified after: *Milker & Schmiedl (2012)*.

Family: **NUMMULITIDAE** Blainville, 1827

Heterostegina depressa* d'Orbigny, 1826

Plate: 6F

Identified after: *Hottinger et al. (1993)*. Non-indigenous after *Zenetos et al. (2010)*.

Family: **PLANORBULINIDAE** Schwager, 1877

Planorbulina mediterraneensis d'Orbigny, 1826

Plate: 6G

Identified after: *Milker & Schmiedl (2012)*.

Family: **REUSSELLIDAE** Cushman, 1933

Reussella spinulosa Reuss, 1850

Plate: 6H

Identified after: *Milker & Schmiedl (2012)*.

Family: **ROSALINIDAE** Reiss, 1963

Gavelinopsis praegeri Heron-Allen & Earland, 1913

Identified after: *Milker & Schmiedl (2012)*.

Neoconorbina terquemi Rzehak, 1888

Identified after: *Milker & Schmiedl (2012)*.

Rosalina bradyi Cushman, 1915

Identified after: *Milker & Schmiedl (2012)*.

Rosalina floridensis Cushman, 1930

Identified after: *Hottinger et al. (1993)*.

Rosalina globularis d'Orbigny, 1826

Plate: 6I-J

Identified after: *Milker & Schmiedl (2012)*.

Rosalina* aff. *globularis

Plate: 7A-B

Like *Rosalina globularis*. Shows a higher curvature of chambers compared to those of *Rosalina globularis* which gives the individuals a conical shape.

Rosalina macropora Hofker, 1951

Plate: 6K-L

Identified after: *Milker & Schmiedl (2012)*.

Rosalina williamsoni Chapman & Parr, 1932

Identified after: *Milker & Schmiedl (2012)*. There it is referred to as *Discorbis williamsoni* Chapman & Parr, 1932.

***Rosalina* spp.**

Tretomphalus bulloides d'Orbigny, 1839

Plate: 7C

Identified after: *Jones (1994)*.

Family: **TRICHOHYALIDAE** Saidova, 1981

Buccella granulata di Napoli Alliata, 1952

Identified after: *Milker & Schmiedl (2012)*.

Order: **POLYMORPHINIDA**

Family: **POLYMORPHINIDAE** d'Orbigny, 1839

***Polymorphina* sp.1**

The aperture is hardly visible. The habitus shows a longer length than width.

***Polymorphina* sp.2**

The aperture is hardly visible. The habitus shows almost the same length as width.

Order: **SPIRILLINIDA**

Family: **SPIRILLINIDAE** Reuss & Fritsch, 1861

Spirillina limbata Brady, 1879

Identified after: Milker & Schmiedl (2012).

Order: **CARTERINIDA**

Family: **CARTERINIDAE** Loeblich & Tappan, 1955

Carterina spiculotesta Carter, 1877

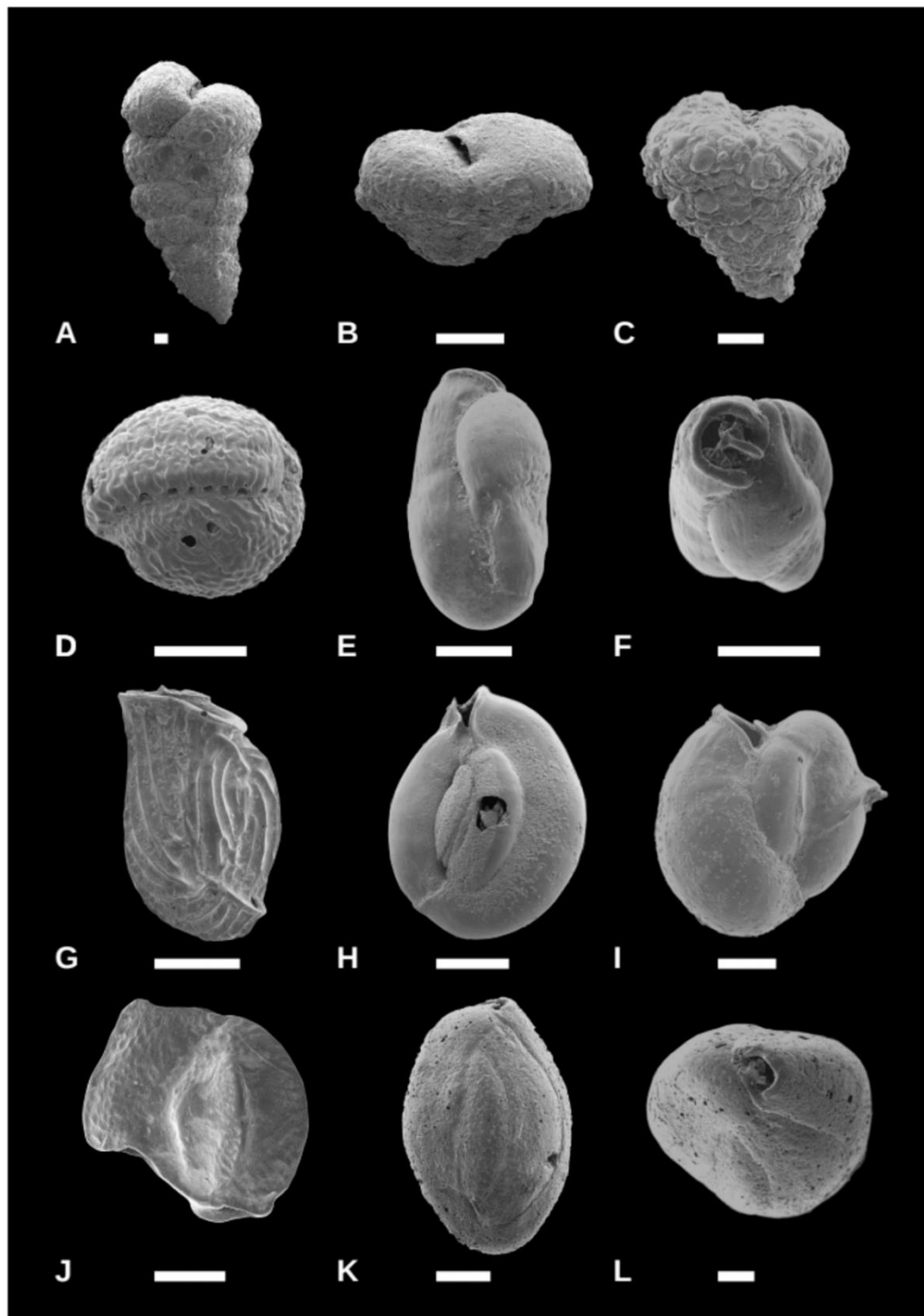
Plate: 7D

Identified after: *Pawlowski et al. (2014)*.

3.1.2 Plates

In the following plates, all non-indigenous species are shown together with the most common or remarkable species which were observed throughout this study.

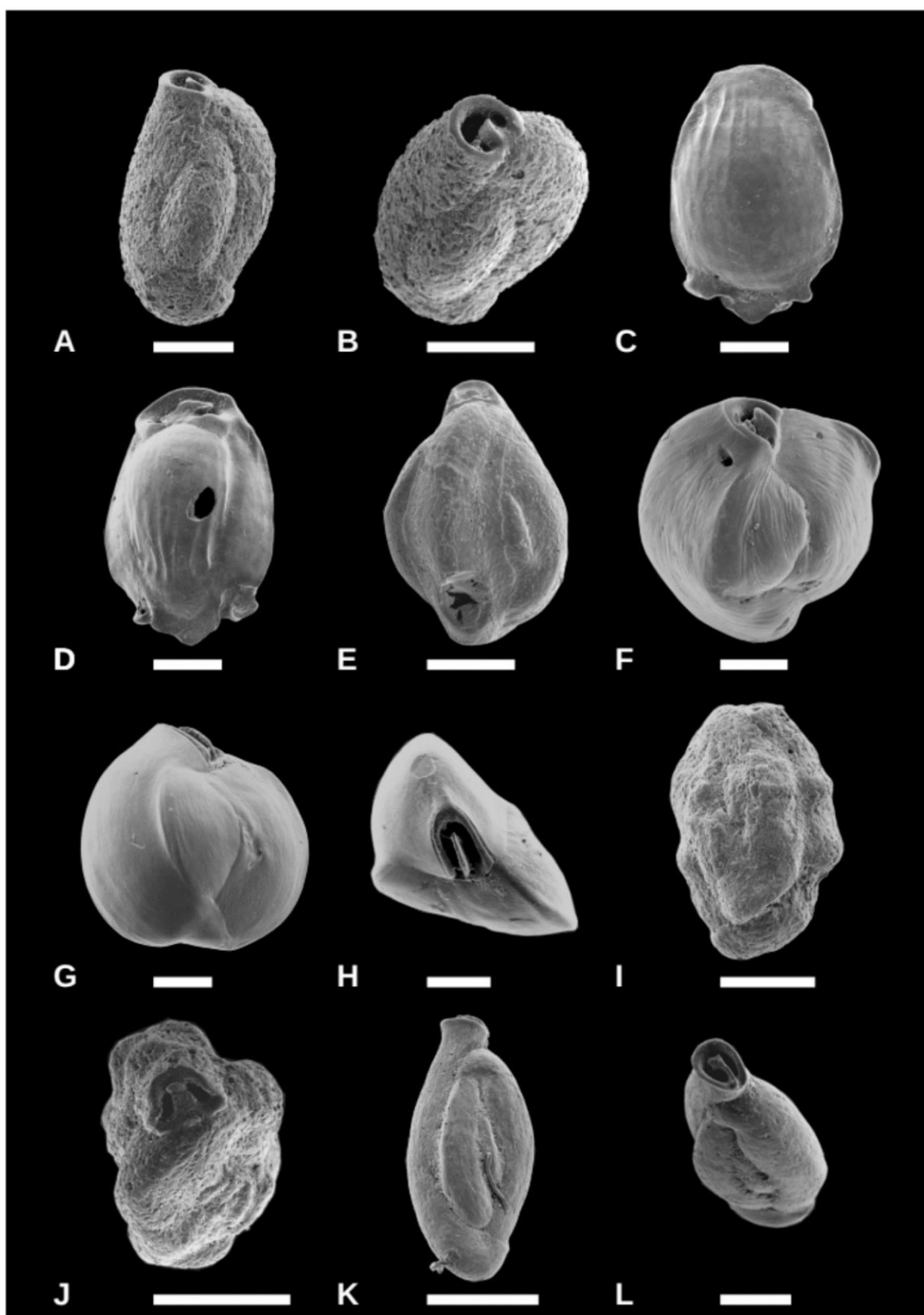
Plate 1



1A) *Textularia agglutinans*; 1B) *Textularia pala*; 1C) *Textularia* sp.1; 1D) *Borelis schlumbergeri**; 1E – F) *Affinetrina planciana*; 1G) *Articulina pacifica**; 1H) *Miliolinella subrotunda*; 1I) *Miliolinella labiosa*; 1J) *Pseudomassilina australis**; 1K – L) *Pseudoschlumbergerina ovata**

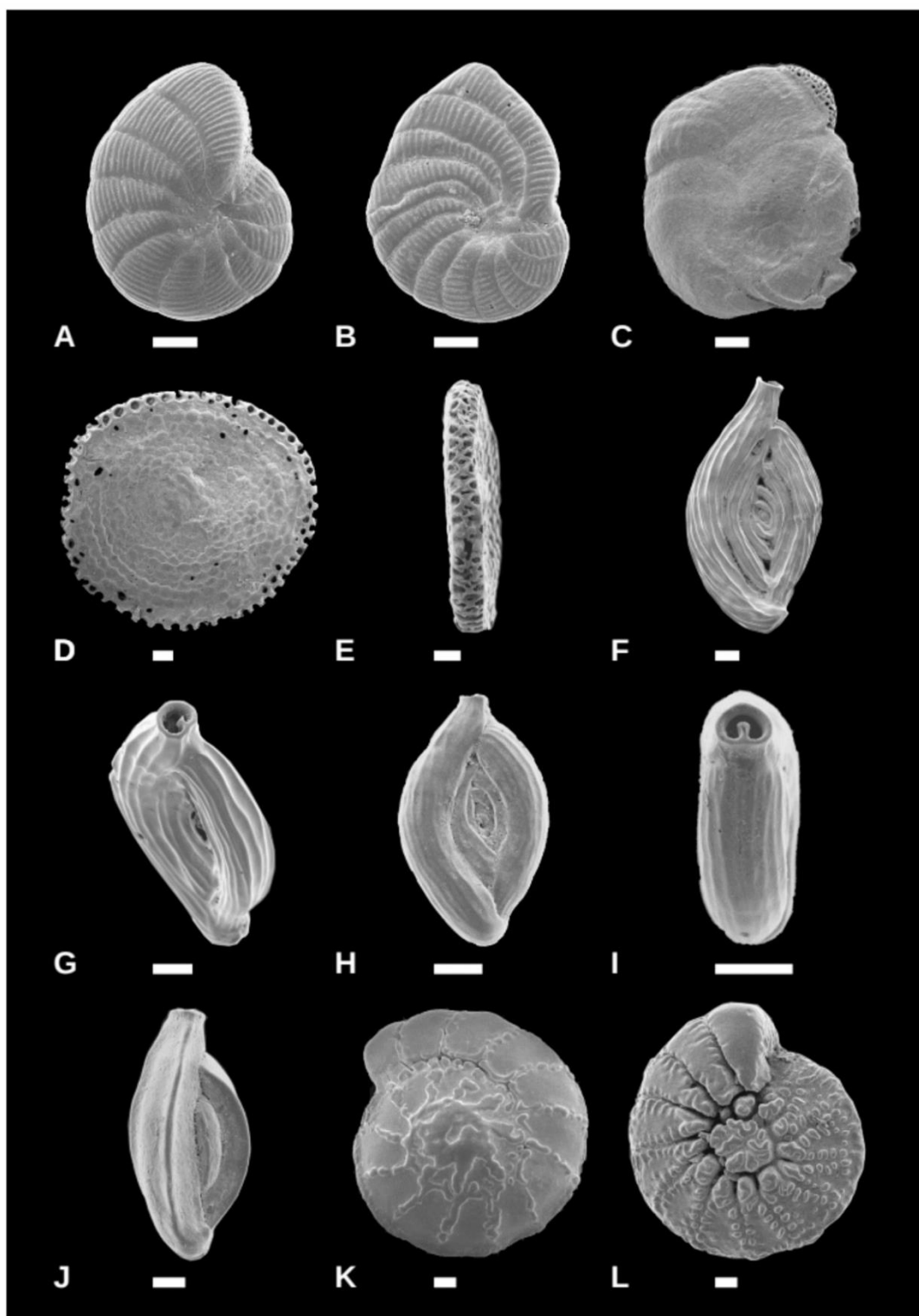
Scale: 100µm

Plate 2



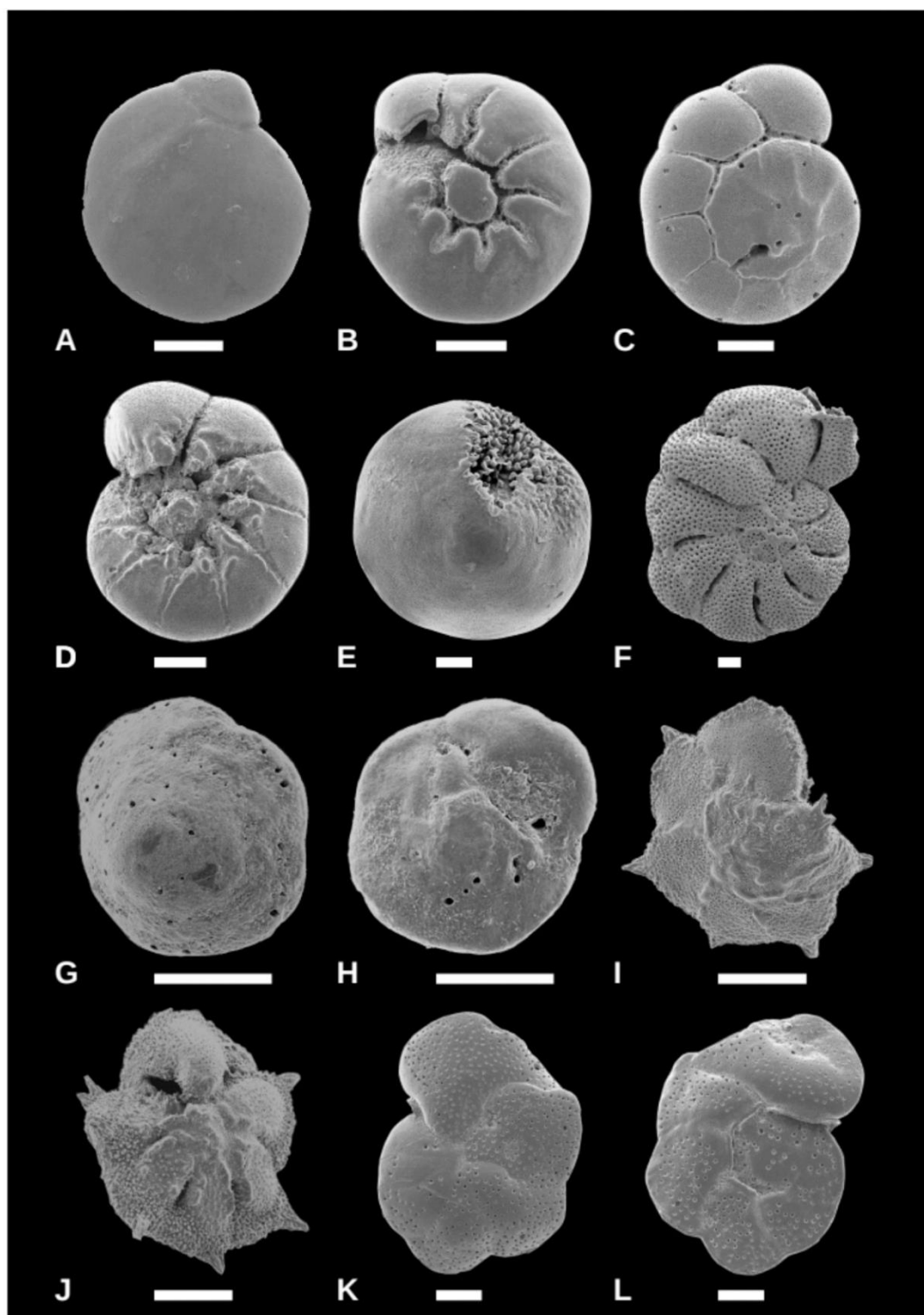
2A – B) *Pseudotriloculina subgranulata**; 2C – D) *Pyrgo striolata*; 2E) *Quinqueloculina* cf. *multimarginata**; 2F) *Quinqueloculina lamarckiana*; 2G – H) *Quinqueloculina pseudobuchiana*; 2I – J) *Quinqueloculina* sp.1; 2K – L) *Quinqueloculina* aff. *tropicalis*;
Scale: 100µm

Plate 3



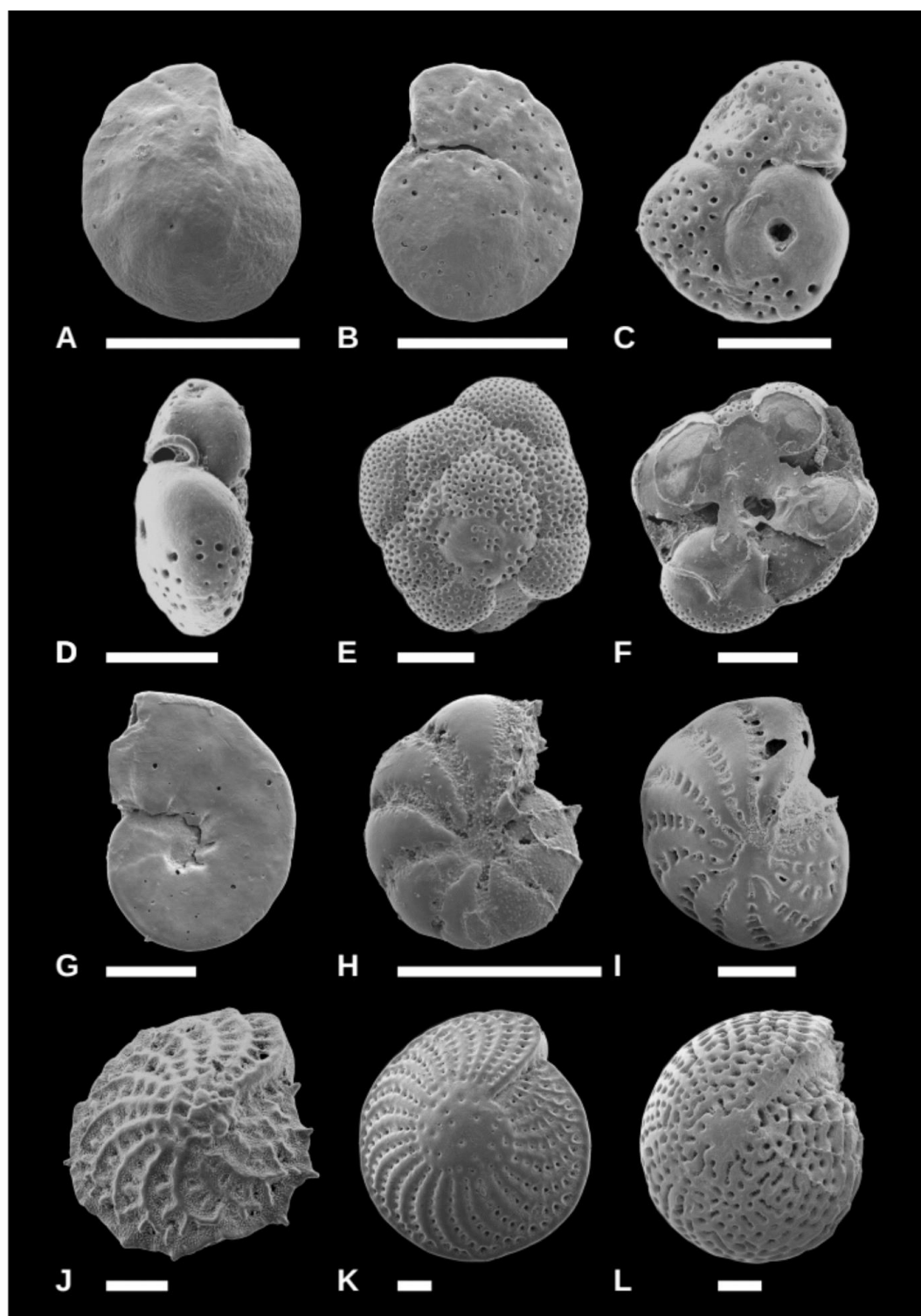
3A) *Peneroplis pertusus*; 3B) *Peneroplis planatus*; 3C) *Pseudohauerinella diversa**; 3D – E) *Sorites orbiculus**; 3F – G) *Spiroloculina angulata**; 3H – I) *Spiroloculina antillarum**; 3J) *Spiroloculina* sp.1; 3K – L) *Ammonia beccarii*;
Scale: 100µm

Plate 4



4A – B) *Ammonia* sp.2; 4C – D) *Ammonia* sp.1; 4E) *Amphistegina lobifera**; 4F) *Epistomaroides punctulata**; 4G – H) *Asterigerinata mamilla*; 4I – J) *Pararotalia calcariformata**; 4K – L) *Cibicidoides lobatulus*;
Scale: 100µm

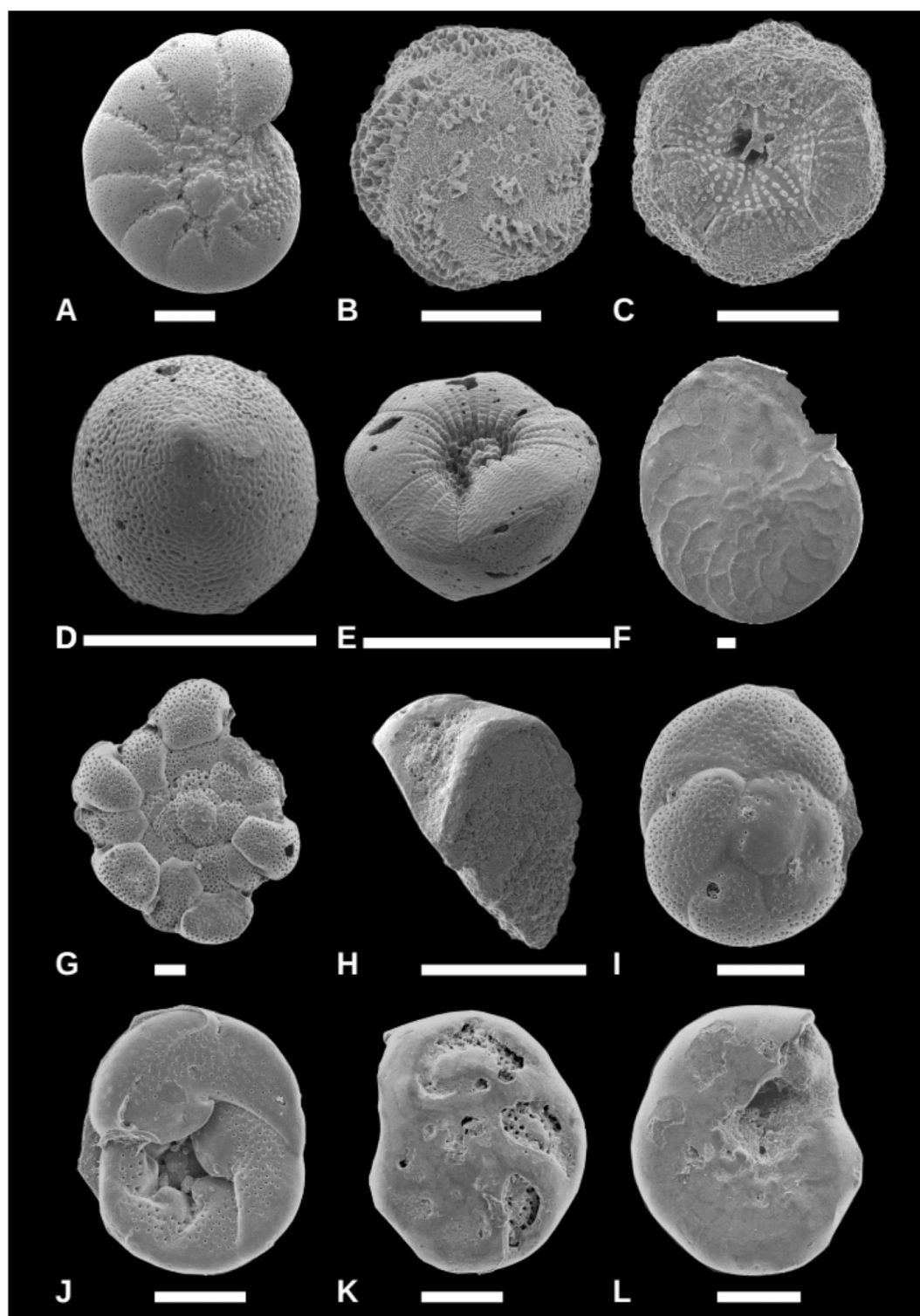
Plate 5



5A – B) *Cibicidoides pseudoungeriana*; 5C – D) *Cibicidoides variabilis*; 5E – F) *Cymbaloporella squamosa*; 5G) *Hanzawaia rhodiensis**; 5H) *Criboelphidium excavatum*; 5I) *Elphidium charlottense*; 5J) *Elphidium aculeatum*; 5K) *Elphidium crispum*; 5L) *Elphidium striatopunctatum**;

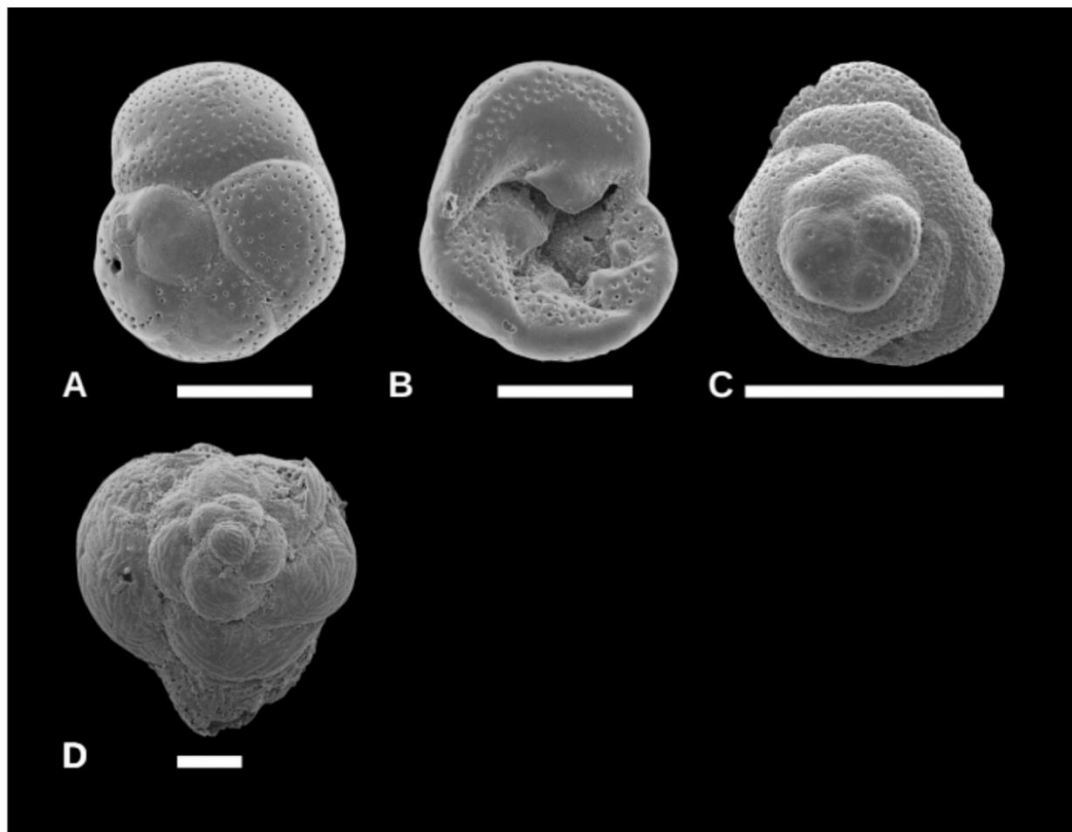
Scale: 100µm

Plate 6



6A) *Porosononion granosum*; 6B – C) *Glabratella hexacamerata*; 6D – E) *Pileolina patelliformis*; 6F) *Heterostegina depressa**; 6G) *Planorbulina mediterraneensis*; 6H) *Reussella spinulosa*; 6I – J) *Rosalina globularis*; 6K – L) *Rosalina macropora*;
Scale: 100 μ m

Plate 7



7A – B) *Rosalina* aff. *globularis*; 7C) *Tretomphalus bulloides*; 7D) *Carterina spiculotesta*;

Scale: 100 μ m

3.2 Non-indigenous species

In total 16 out of 128 species were observed and identified in the total assemblages as being non-indigenous to the Mediterranean Sea. At the southern stations six non-indigenous species were found, whereas the species *Pararotalia calcariformata** occurred in both seasons (Table 2). The other five non-indigenous species of the southern stations occurred either in spring or in autumn. *Elphidium striatopunctatum** was remarkably rare (Appendix 2) and only observed in the spring sample of S1. Fifteen non-indigenous species were identified in the samples of the northern stations. *Amphistegina lobifera**, *Epistomaroides punctulata**, *Heterostegina depressa** and *Pseudohauerinella diversa** were observed at all northern stations in both seasons. *Hanzawaia rhodiensis** was only observed in the spring sample of station N2, *Pseudomassilina australis** in the spring sample of station N3 and *Borelis schlumbergeri** in the autumn sample of N3. Following species were observed as well at southern stations as at northern stations during spring or autumn: *Pararotalia*

*calcariformata**, *Pseudohauerinella diversa**, *Pseudotriloculina subgranulata**, *Quinqueloculina cf. multimarginata** and *Spiroloculina antillarum**.

The most abundant non-indigenous species was the LBF *Amphistegina lobifera** which was observed in the live assemblages of the fraction size 500 μm – 1mm with values between 85% and 97% at northern stations.

Tab. 2. The table shows the occurrence of all non-indigenous species at all stations including both fraction sizes.

	S1 Spring	S1 Autumn	S2 Spring	S2 Autumn	N1 Spring	N1 Autumn	N2 Spring	N2 Autumn	N3 Spring	N3 Autumn
<i>Amphistegina lobifera</i>	-	-	-	-	x	x	x	x	x	x
<i>Articulina pacifica</i>	-	-	-	-	x	-	-	x	-	-
<i>Borelis schlumbergeri</i>	-	-	-	-	-	-	-	-	-	x
<i>Elphidium striatopunctatum</i>	x	-	-	-	-	-	-	-	-	-
<i>Epistomaroides punctulata</i>	-	-	-	-	x	x	x	x	x	x
<i>Hanzawaia rhodiensis</i>	-	-	-	-	-	-	x	-	-	-
<i>Heterostegina depressa</i>	-	-	-	-	x	x	x	x	x	x
<i>Pararotalia calcariformata</i>	x	x	-	-	-	x	x	x	x	x
<i>Pseudohauerinella diversa</i>	-	x	-	-	x	x	x	x	x	x
<i>Pseudomassilina australis</i>	-	-	-	-	-	-	-	-	x	-
<i>Pseudoschlumbergerina ovata</i>	-	-	-	-	x	x	x	-	x	x
<i>Pseudotriloculina subgranulat</i>	-	-	x	-	x	x	-	x	-	-
<i>Quinqueloculina cf multimargi</i>	-	x	-	-	-	-	-	-	x	-
<i>Sorites orbiculus</i>	-	-	-	-	x	x	-	x	-	x
<i>Spiroloculina angulata</i>	-	-	-	-	x	x	x	-	x	x
<i>Spiroloculina antillarum</i>	-	-	x	-	-	-	x	-	x	x

3.3 Faunal composition

The faunal composition and diversity indices of the benthic foraminiferal assemblages are described in the following chapter whereas samples are separated into the localities Akhziv, Nahariyya and Ashkelon. In addition, the samples are described within the two fraction size classes.

3.3.1 Akhziv

3.3.1.1 Fraction 500 μm – 1 mm

3.3.1.1.1 Total Assemblage

The total assemblages (live and dead) of both fraction sizes at stations N1 and N2 were mainly covered by benthic foraminifera with a hyaline test wall in both seasons. N2 included 390 individuals in spring and 371 in autumn, while N1 was covered by 310

in spring and 363 in autumn. Considering the triangular chart of Murray (1973), the foraminiferal assemblages of both stations represented an environment of a hyposaline area during both seasons (Figure 7a). The shallower station N2 was covered by 89% hyaline foraminifera in spring and by 79% in autumn. The abundance of agglutinated foraminifera increased from 8% in spring to 20% in autumn. The other part of Station N2 was covered by 3% miliolid foraminifera in spring and by 1% in autumn. The sample of the deeper station N1 was consisting of 87% hyaline, 8% agglutinated and 5% miliolid foraminifera in spring and of 84% hyaline, 12% agglutinated and 4% miliolid in autumn.

The calculation of the diversity indices for the total assemblage of the spring sample at station N2 showed a high dominance above 0.8, a low evenness below 0.3 and a low Shannon-Wiener Index of 0.43 (Table 3). The Chao-1 calculation estimated a diversity of nine species (six species were counted). The autumn sample at station N2 showed a dominance above 0.6, a low evenness below 0.4 and a low Shannon-Wiener Index of 0.56. The Chao-1 estimated a value of 5.5 species (five species were counted). At station N1 the diversity indices of the spring sample showed a high dominance above 0.7, a low evenness below 0.2 and a low Shannon-Wiener Index of 0.62. The Chao-1 calculation estimated a value of 18.5 (11 species were counted). The autumn sample of station N1 showed a dominance of 0.69, a low evenness below 0.2 and a Shannon-Wiener Index of 0.69. The estimated Chao-1 value was ten (ten species were counted).

3.3.1.1.2 Live Assemblage

The spring sample of station N2 (14 m and 11.8 m) consisted of 284 living specimens belonging to four species. The autumn sample was covered by 176 individuals, belonging to two species. At station N1 (20 m and 18.3 m) 71 living individuals were observed and assigned to two species in spring. In autumn 47 individuals were observed and split in two species.

All samples of the region Akhziv consisted mainly of living *Amphistegina lobifera** and *Textularia agglutinans* in both seasons (Figure 8a). The species *Amphistegina lobifera** covered up the sample of N2 with 91% in spring and 85% in autumn. At N1 it dominated the sample with 91% in spring and 93% in autumn. Only the spring sample of the station N2 included other living specimens belonging to the species *Pseudohauerinella diversa** and *Peneroplis planatus*.

At station N2 the diversity indices of the spring sample showed a high dominance above 0.8, a low evenness below 0.4 and a low Shannon-Wiener Index of 0.31 (Table 3). The Chao-1 calculation estimated five species (four species were counted). The calculation for the diversity indices of the autumn sample at station N2 resulted in a dominance above 0.7, an evenness above 0.7 and a Shannon-Wiener Index below 0.5. The estimated Chao-1 value was two (two species were counted). The calculated diversity indices for the live assemblages of the spring sample at station N1 showed a high dominance above 0.8, an average evenness above 0.6, and a low Shannon-Wiener Index of 0.29 (Table 3). The Chao-1 calculation estimated a diversity of two species (two species were counted). The autumn sample at station N1 was covered by a high dominance above 0.8, an average evenness above 0.6 and a low Shannon-Wiener Index of 0.24. The Chao-1 estimator calculated a diversity of two species (two species were counted).

3.3.1.1.3 Dead Assemblage

The sample of the station N2 was composed of 105 individuals defined in four species and one individual assigned to the order *Miliolida* in spring, and 190 individuals defined in five species and five individuals assigned to one genus in autumn. The deeper station N1 represented a spring sample made up of 235 individuals defined in eleven species and four individuals defined to one genus, and an autumn sample with 309 individuals which belonged to ten species. Five specimens could not be identified to the species level and were assigned to two genera. Two specimens were assigned to the order *Rotaliida*.

All samples were dominated by the species *Amphistegina lobifera** and *Textularia agglutinans* whereas the sample of station N2 included with *Adelosina mediterraneensis* another abundant species (Figure 8a). The abundance of *Amphistegina lobifera** varied between 72% and 83%.

3.3.1.2 Fraction 125 μ m – 500 μ m

3.3.1.2.1 Live Assemblage

At the shallower station N2 the live assemblage of this fraction size was covered by 278 individuals and 18 species in spring, and 494 individuals and 12 species in autumn. The deeper station N1 consisted of 131 living specimens identified as ten species and

one specimen identified to the genus level in spring, and of 288 specimens identified as 12 species and one specimen identified to the genus level in autumn.

In spring the most abundant species at N2 was *Textularia* sp.1 with 47% (Figure 9a). Other common species in this sample were *Pseudohauerinella diversa**, *Miliolinella subrotunda*, *Peneroplis pertusus*, *Rosalina* sp.1 and *Textularia agglutinans*. In autumn, the live assemblage mainly consisted of *Amphistegina lobifera** with 72%, *Pseudohauerinella diversa** with 11% and *Textularia* sp.1 with 10%. At N1 the most abundant species in spring were among the species *Amphistegina lobifera**, *Glabratella hexacamerata*, *Pseudohauerinella diversa** and *Textularia* sp.1. The autumn sample was mainly composed of *Amphistegina lobifera**, *Pseudohauerinella diversa** and *Textularia* sp.1.

The calculated diversity indices for the live assemblages of the spring sample at station N2 showed a low dominance below 0.3, a low evenness below 0.4, and a Shannon-Wiener Index of 1.81 (Table 3). The Chao-1 calculation estimated a diversity of 32 species (18 species were counted). The autumn sample at station N2 showed an average dominance above 0.5, a low evenness below 0.3 and a Shannon-Wiener Index of 0.98. The Chao-1 estimator calculated a diversity value of 19.5 (12 species were counted). At station N1 the diversity indices of the spring sample showed a low dominance below 0.3, an average evenness of 0.5 and a high Shannon-Wiener Index of 1.61. The Chao-1 calculation estimated a value of 10.75 (ten species were counted). The calculation for the diversity indices of the autumn sample at station N1 resulted in an average dominance above 0.4, a low evenness below 0.3 and a Shannon-Wiener Index above 1. The estimated Chao-1 value was 17 (12 species were counted).

3.3.1.2.2 Dead Assemblage

At station N2 147 individuals were observed and classified into 48 species in spring. Thirty-two individuals were assigned to eight genera, six individuals to the order *Rotaliida* and one individual to the order *Miliolida*. In autumn, the dead assemblage of the same station was covered by 53 individuals belonging to 23 species, ten individuals belonging to four genera, three specimens assigned to the order *Miliolida* and two specimens assigned to the order *Rotaliida*. The deeper station N1 consisted of 260 individuals defined as 62 species in spring. Thirty-nine individuals were classified into seven genera, 31 individuals into the order *Miliolida* and nine individuals into the order *Rotaliida*. In autumn 178 individuals were defined as 52 species, 28 individuals as eight genera and eleven specimens were assigned to the order *Miliolida*.

In spring at station N2 the assemblage was mainly covered by the species *Pseudohauerinella diversa**, *Pararotalia calcariformata**, *Peneroplis pertusus* and *Textularia* sp.1 (Figure 9a). *Amphistegina lobifera** and *Glabratella hexacamerata* were the most abundant at station N1. In autumn, the sample of N2 was primarily consisting of *Epistomaroides punctulata**, *Peneroplis pertusus*, *Sahulia conica* and *Textularia* sp.1 while the sample of N1 was mainly covered by two species of the genus *Peneroplis*.

3.3.2 Nahariyya

3.3.2.1 Fraction 500 μ m – 1 mm

3.3.2.1.1 Total Assemblage

In autumn, the total assemblage (live and dead) at station N3 was covered by 77% hyaline, 14% miliolid and 9% agglutinated foraminifera. The assemblage included 448 individuals. Considering the triangular chart of Murray (1973), the foraminiferal assemblage of the station N3 represented an environment of a hyposaline area during autumn (Figure 7a).

The calculation of the diversity indices for the total assemblage of the autumn sample at station N3 showed an average dominance of 0.57, a low evenness below 0.2 and a Shannon-Wiener Index above one (Table 3). The Chao-1 calculation estimated a diversity value of 16.5 (15 species were counted).

3.3.2.1.2 Live Assemblage

At this station 296 living specimens were observed in the autumn sample.

Ninety-seven% of the individuals were identified as *Amphistegina lobifera** and three percent as *Textularia agglutinans* (Figure 8b).

The diversity indices calculated for the live assemblage for the autumn sample of station N3 resulted in a high dominance with 0.96, an average evenness with 0.55 and a low Shannon-Wiener Index with 0.1 (Table 3). The Chao-1 calculation estimated a diversity of two species (two species were counted).

3.3.2.1.3 Dead Assemblage

The dead assemblage of this station was composed of 139 individuals belonging to 18 species, 12 individuals belonging to two genera and four individuals assigned to the order Miliolida.

The most abundant species were *Amphistegina lobifera**, *Heterostegina depressa**, *Peneroplis planatus*, *Quinqueloculina disparilis*, *Sorites orbiculus** and *Textularia agglutinans* (Figure 8b).

3.3.2.2 Fraction 125 μ m – 500 μ m

3.3.2.2.1 Live Assemblage

In spring the living assemblage of this fraction size was covered up by one specimen which belonged to the species *Pararotalia calcariformata** (Figure 9b). In autumn 183 living specimens were observed, identified into 16 species whereas the most abundant were among the species *Pseudohauerinella diversa** with 61% and *Amphistegina lobifera** with 15%.

Since the living assemblage of the spring sample at station N3 was covered by one specimen, the values of the Dominance, Evenness and Chao-1 were one. The value of the Shannon-Wiener Index was zero. The calculation for the diversity indices of the autumn sample at station N3 resulted in an average dominance above 0.4, a low evenness below 0.3 and a Shannon-Wiener Index of 1.47. The estimated Chao-1 value was 18.5 (16 species were counted).

3.3.2.2.2 Dead Assemblage

In spring 325 individuals were observed and defined into 47 species. 72 specimens could not be identified to the species level and were assigned to eight genera. Eleven specimens were assigned to the order *Rotaliida* and nine specimens to the order *Miliolida*. In autumn, the sample was covered by 260 individuals of 56 species and 36 individuals of 9 genera. Twenty-five specimens were assigned to the order *Miliolida*.

In spring the most abundant were among the species *Pseudohauerinella diversa**, *Pararotalia calcariformata**, *Peneroplis pertusus* and *Pseudoschlumbergerina ovata** (Figure 9b). *Heterostegina depressa**, *Pararotalia calcariformata** and *Peneroplis pertusus* were the most abundant species among the dead specimens in the autumn sample.

3.3.3 Ashkelon

3.3.3.1 Fraction 500 μm – 1 mm

3.3.3.1.1 Total Assemblage

The total assemblages (live and dead) of both southern stations were mainly covered by benthic foraminifera with a hyaline test wall in both seasons. S1 included 324 individuals in spring and 352 in autumn, while S2 included 491 individuals in spring and 316 in autumn. Considering the triangular chart of Murray (1973), the foraminiferal assemblages of the station S1 represent a hyposaline area and the assemblages of the station S2 a hypersaline area during both seasons (Figure 7b). While the values of the shallower station S1 (11.3 m and 11.8 m) were 83% in spring and 80% in autumn, station S2 (24.7 m and 28 m) was covered by 59% hyaline foraminifera in spring and 71% in autumn. The sample of the station S1 was additionally covered by 14% agglutinated and 3% miliolid in spring, and by 18% agglutinated and 2% miliolid in autumn. At the deeper station, the other part of the sample was covered by 40% miliolid and 1% agglutinated in spring, and by 28% miliolid and 1% agglutinated in autumn (Figure 7b). The calculation of the diversity indices for the total assemblage of the spring sample at station S1 resulted in a dominance of 0.72, a low evenness below 0.2 and a Shannon-Wiener Index of 0.6 (Table 3). The Chao-1 calculation estimated a diversity of 31 species (ten species were counted). The autumn sample at station S1 showed a dominance above 0.6, a low evenness below 0.3 and a Shannon-Wiener Index of 0.59. The Chao-1 estimated a diversity of ten species (seven species were counted). At station S2 the diversity indices of the spring sample showed a dominance below 0.5, an evenness below 0.3 and a Shannon-Wiener Index of 1.23. The Chao-1 calculation estimated a value of 16 species (13 were counted). The autumn sample of station S2 showed an average dominance of 0.62, a low evenness below 0.3 and a Shannon-Wiener Index of 0.89. The estimated Chao-1 value was 11 (ten species were counted).

3.3.3.1.2 Live assemblage

The number of individuals at the shallower sample S1 (11.3 m and 11.8 m) was 39 and consisted of seven species in spring. There were 32 individuals, belonging to three species in autumn. The deeper station (24.7 m and 28 m) consisted of eight living

specimens assigned to four species in spring and one specimen and thus one species in autumn.

At both stations, the spring live assemblage included individuals of the species *Ammonia beccarii*, *Spiroloculina communis* and *Textularia agglutinans* (Figure 8c). In addition, *Planorbulina mediterranensis* appeared at station S1 and *Triloculina trigonula* at station S2. At station S1 most of the living assemblage in autumn was covered by *Textularia agglutinans* with 73%. A small percentage belonged to the species *Ammonia beccarii* and *Miliolinella elongata*. The living specimen of the autumn sample at station S2 was identified as *Textularia agglutinans*.

The calculated diversity indices for the live assemblage of the spring sample at station S1 showed an average evenness above 0.5, a dominance of 0.57 and a Shannon-Wiener Index of 0.82 (Table 3). The Chao-1 calculation estimated a diversity of four species (four species were counted). In comparison, the autumn sample at station S1 showed a high dominance of 0.88, an average evenness below 0.5 and a low Shannon-Wiener Index of 0. The Chao-1 estimator calculated a diversity of four species (three species were counted). At station S2 the diversity indices of the spring sample showed a low dominance below 0.4, a high evenness above 0.8 and a Shannon-Wiener Index above 1. The Chao-1 calculation estimated five species (four species were counted). Since the autumn sample of station S2 consisted of one living specimen, the values for the dominance, evenness and Chao-1 were 1. The Shannon-Wiener Index was zero.

3.3.3.1.3 Dead Assemblage

In spring the sample of the station S1 consisted of 282 individuals whereas eight species were identified. Eleven specimens were identified only to the genus level and split in four genera. In autumn 312 individuals of six species were observed at station S1. Seven specimens were assigned to two genera and one to the order *Miliolida*. Station S2 showed a diversity of twelve species identified out of 423 specimens and two genera out of six specimens in spring. 54 specimens could neither be identified to the species or the genus level due to the decomposition of the test and were assigned to the order of *Miliolida*. In autumn, nine species out of 307 specimens and two genera out of eight specimens were identified. 24 specimens were assigned to the order of *Miliolida*.

The dead assemblage of the shallower station S1 was mainly covered by *Ammonia beccarii* with 88% in spring and 85% in autumn, and *Textularia agglutinans* in both

seasons (Figure 8c). The most abundant species at the deeper station S2 are *Ammonia beccarii* with 58% in spring and 70% in autumn, and three species of the genera *Adelosina* in both seasons.

3.3.3.2 Fraction 125 μm – 500 μm

3.3.3.2.1 Live assemblage

The samples of station S1 included 179 living specimens in spring. These were assigned to eight species. Two specimens could not be identified to the species level and were assigned to one genus. The autumn sample was covered by 302 living specimens, belonging to ten species. One specimen was identified only to the genus level. The deeper station S2 contained 58 specimens in spring and 31 in autumn. In both seasons nine species were found at station S2.

*Pararotalia calcariformata** was the dominant species at S1 which covered the live assemblage between 74% in spring and 91% in autumn (Figure 9c). Furthermore, *Rosalina* sp.1 and *Textularia* sp.1 belonged to the most abundant species in spring. At station S2 the most abundant species in spring were *Miliolinella subrotunda*, *Rosalina globularis*, *Textularia pala*, *Textularia* sp.1 and *Triloculina marioni*. In autumn, the sample mainly included *Ammoglobigerina globigeriformis*, *Cibicidoides lobatula*, *Cibicidoides variabilis*, *Planorbulina mediterraneensis*, *Rosalina* sp.1 and *Sahulina conica*.

The calculation of the diversity indices of the spring sample at station S1 resulted in an average dominance above 0.5, an evenness below 0.4 and a low Shannon-Wiener Index of 0.9 (Table 3). The Chao-1 calculation estimated a value of 8.33 (eight species were counted). The autumn sample at station S1 showed a high dominance of 0.84, a low evenness below 0.2 and a low Shannon-Wiener Index below 0.5. The Chao-1 estimator calculated a diversity of 15 species (ten species were counted). At station S2 the diversity indices of the spring sample showed a low dominance of 0.2, an evenness above 0.6 and a Shannon-Wiener Index of 1.81. The Chao-1 calculation estimated a value of 9.33 (nine species were counted). The autumn sample of station S2 showed a low dominance of 0.15, a high evenness above 0.8 and a Shannon-Wiener Index of 2. The estimated Chao-1 value was 12 (nine species were counted).

3.3.3.2.2 Dead Assemblage

All dead assemblages of this fraction size showed a high number of species at Ashkelon. The samples of S1 were composed of 142 individuals belonging to 32 species and 13 individuals belonging to five genera in spring. Eight specimens were assigned to the order *Miliolida*. In autumn, the assemblage of S1 included 133 individuals belonging to 30 species and 23 individuals belonging to six genera. Ten specimens were assigned to the order *Rotaliida* and three to the order *Miliolida*. In the spring sample of S2 193 dead specimens were counted and identified as 45 species. Twenty-four specimens could not be identified to the species level and were assigned to 6 different genera. Twenty-nine individuals were assigned to the order *Miliolida*. The autumn sample consisted of 249 dead specimens which were identified as 39 species. Thirty-four individuals were assigned to six genera, 27 to the order *Miliolida* and one to the order *Rotaliida*.

In spring the most abundant species were among *Ammonia beccarii*, *Ammonia parkinsoniana* and *Bolivina variabilis* at station S1, and among four species of the genus *Ammonia*, *Porosononion granosum* and *Rosalina globularis* at station S2 (Figure 9c). In autumn, the most abundant species were among *Adelosina cliarensis*, *Ammonia parkinsoniana*, *Pararotalia calcariformata**, *Porosononion granosum* and *Rosalina globularis* in the samples of the shallower station S1. The dead assemblage of the autumn sample of S2 was mainly covered by *Adelosina pulchella*, three species of the genus *Ammonia*, *Porosononion granosum* and *Triloculina marioni*.

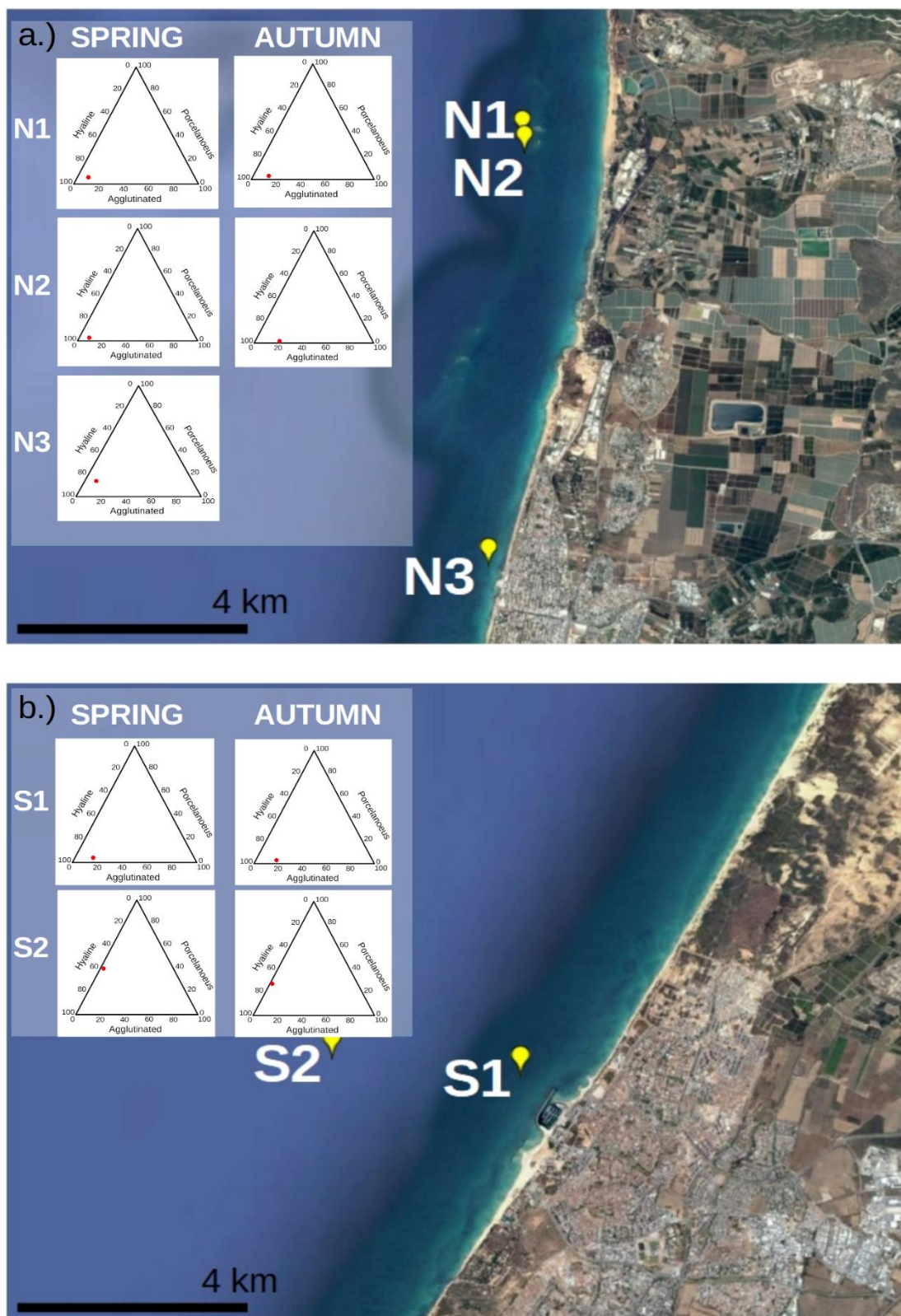
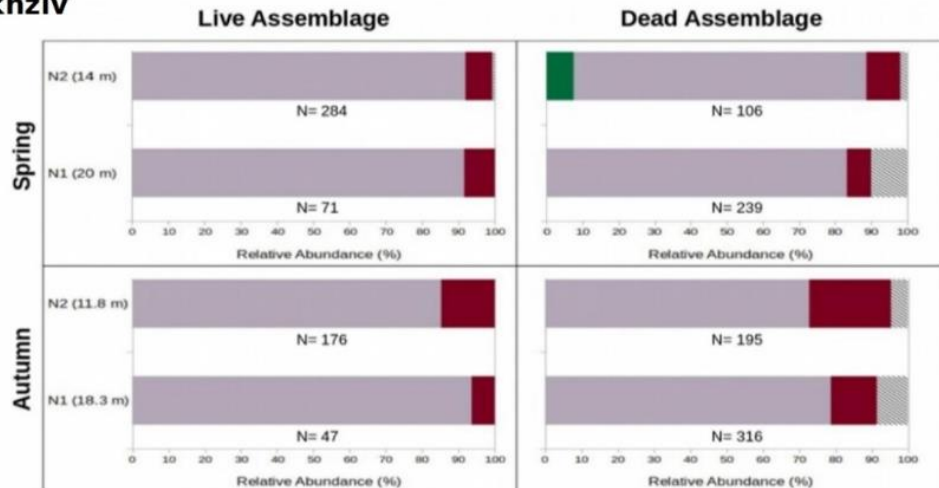
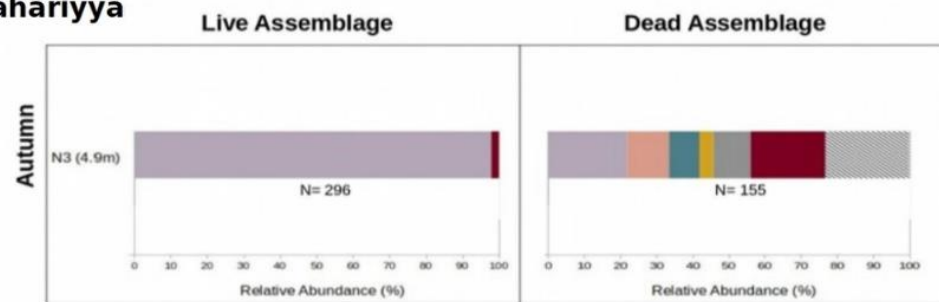


Fig. 7. The triangle charts show the percentage of hyaline, porcelaneous and agglutinated foraminifera of the total assemblages of the fraction size 500 μm – 1mm for **a.)** the northern stations at Akhziv and Nahariyya and **b.)** for the southern stations at Ashkelon. Triangle charts were modified after Murray (1973).

a.) Akhziv



b.) Nahariyya



c.) Ashkelon

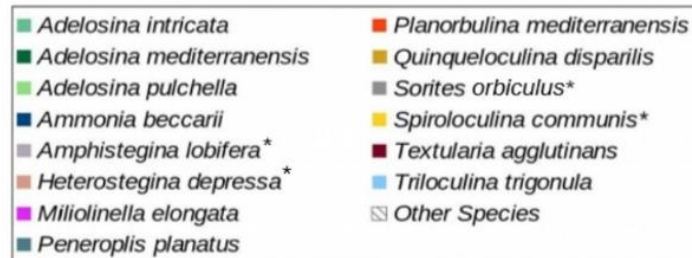
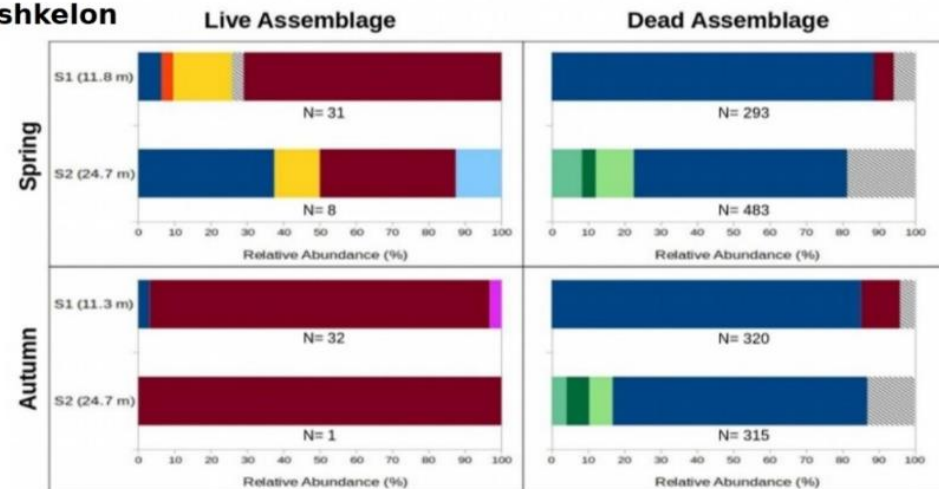
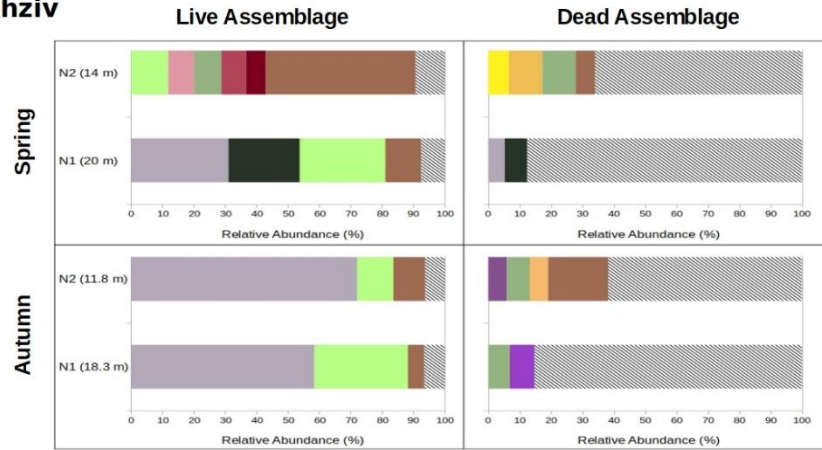
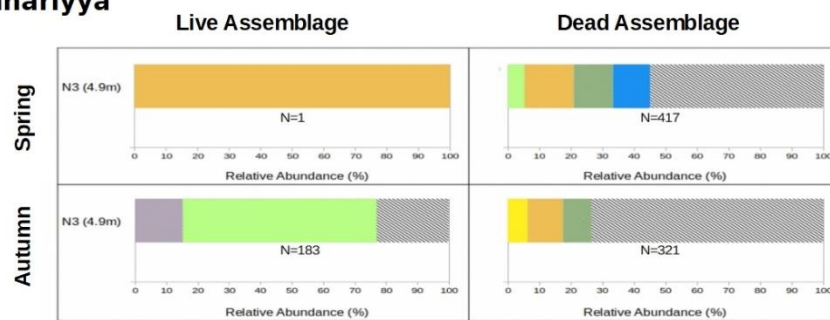


Fig. 8. The figures show the relative abundances of the most abundant species in all assemblages of the fractions size 500 μ m – 1mm at the three localities Akhziv (northern Israel) **(a)**, Nahariyya (northern Israel) **(b)** and Ashkelon (southern Israel) **(c)**.

a.) Akhziv



b.) Nahariyya



c.) Ashkelon

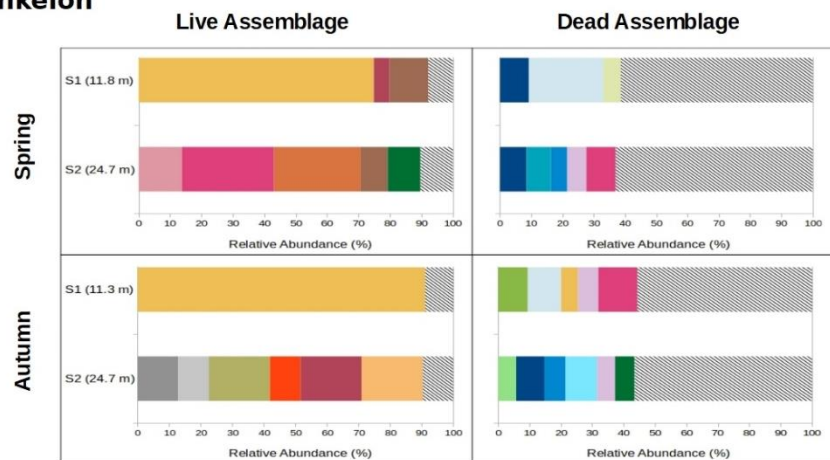


Fig. 9. The figures show the relative abundances of the most abundant species in all assemblages of the fractions size 125 μ m – 500 μ m at the three localities Akziv (northern Israel) **(a)**, Nahariyya (northern Israel) **(b)** and Ashkelon (southern Israel) **(c)**.

Tab.3. In this table the calculated indices for dominance, Shannon-Wiener Index, evenness, and Chao-1 are shown.

Total assemblage (0.5 mm – 1 mm)	Sample	Species	Non-indigenous Species	Individuals	Dominance_D	Shannon_H	Evenness	Chao-1
	N1 spring	11	4	306	0.75	0.62	0.17	18.5
	N1 autumn	10	5	356	0.69	0.69	0.20	10
	N2 spring	6	2	389	0.80	0.43	0.26	9
	N2 autumn	5	3	366	0.67	0.56	0.35	5.5
	N3 autumn	15	5	432	0.57	1.06	0.19	16.5
	S1 spring	10	1	312	0.72	0.6	0.18	31
	S1 autumn	7	0	344	0.67	0.59	0.26	10
	S2 spring	13	0	431	0.47	1.23	0.26	16
	S2 autumn	10	0	284	0.62	0.89	0.24	11
Live assemblage (0.5 mm – 1 mm)								
	N1 spring	2	1	71	0.85	0.29	0.67	2
	N1 autumn	2	1	47	0.88	0.24	0.63	2
	N2 spring	4	2	284	0.85	0.31	0.34	5
	N2 autumn	2	1	176	0.75	0.42	0.76	2
	N3 autumn	2	1	296	0.96	0.10	0.55	2
	S1 spring	4	0	30	0.57	0.82	0.57	4
	S1 autumn	3	0	32	0.88	0.28	0.44	4
	S2 spring	4	0	8	0.31	1.26	0.88	5
	S2 autumn	1	0	1	1	0	1	1
Live assemblage (125 µm – 500 µm)								
	N1 spring	10	2	131	0.24	1.61	0.5	10.75
	N1 autumn	12	2	288	0.44	1.11	0.25	17
	N2 spring	18	4	278	0.27	1.81	0.34	32
	N2 autumn	12	4	494	0.54	0.98	0.22	19.5
	N3 spring	1	1	1	1	0	1	1
	N3 autumn	16	5	183	0.41	1.47	0.27	18.5
	S1 spring	8	1	177	0.59	0.90	0.31	8.33
	S1 autumn	10	2	301	0.84	0.45	0.16	15
	S2 spring	9	0	58	0.20	1.81	0.68	9.33
	S2 autumn	9	0	31	0.15	2	0.82	12

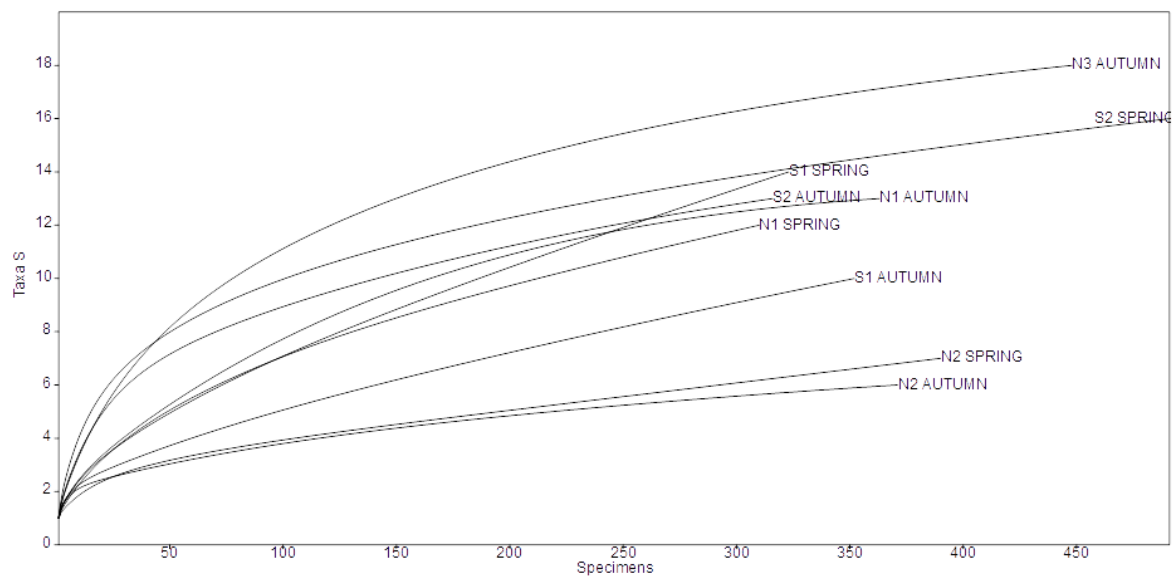
3.4 Individual Rarefaction

3.4.1 Fraction size 500 μm – 1mm

An individual rarefaction analysis was performed for the live and the total assemblages of the fraction size 500 μm – 1mm. Figure 10a shows the curves of the rarefaction for the total assemblage which all indicate a trend of flattening except of the spring sample of the station S1. The total assemblage of this sample shows an increasing gradient and indicates that not all species were recovered.

Figure 10b shows the curves of the rarefaction for the live assemblages. All northern samples indicate a flattening of the curves. The southern samples show an increasing gradient; therefore, the true species richness is higher than that of the collected data.

a) Total Assemblage



b.) Live Assemblage

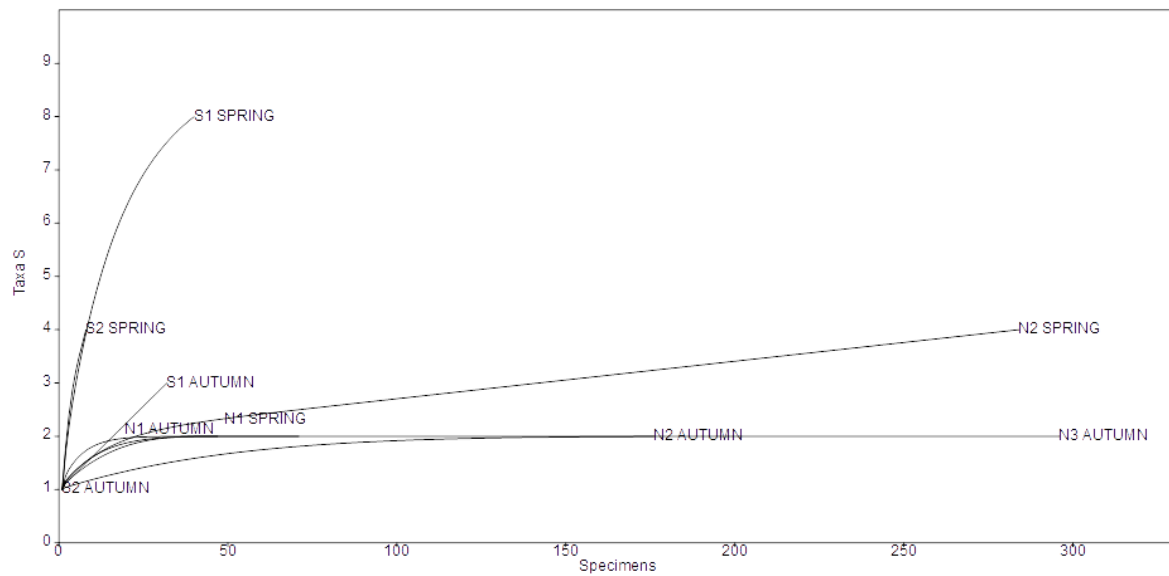


Fig. 10. All performed rarefaction curves for the total assemblages **(a)** and the live assemblages **(b)** of the fraction size 500 μm – 1mm are shown.

3.4.2 Fraction size 125 μm – 500 μm

For the fraction size 125 – 500 μm a rarefaction analysis was performed for the live assemblages of all samples (Figure 11). All samples show species accumulation curves which indicate a higher species richness than covered in the samples.

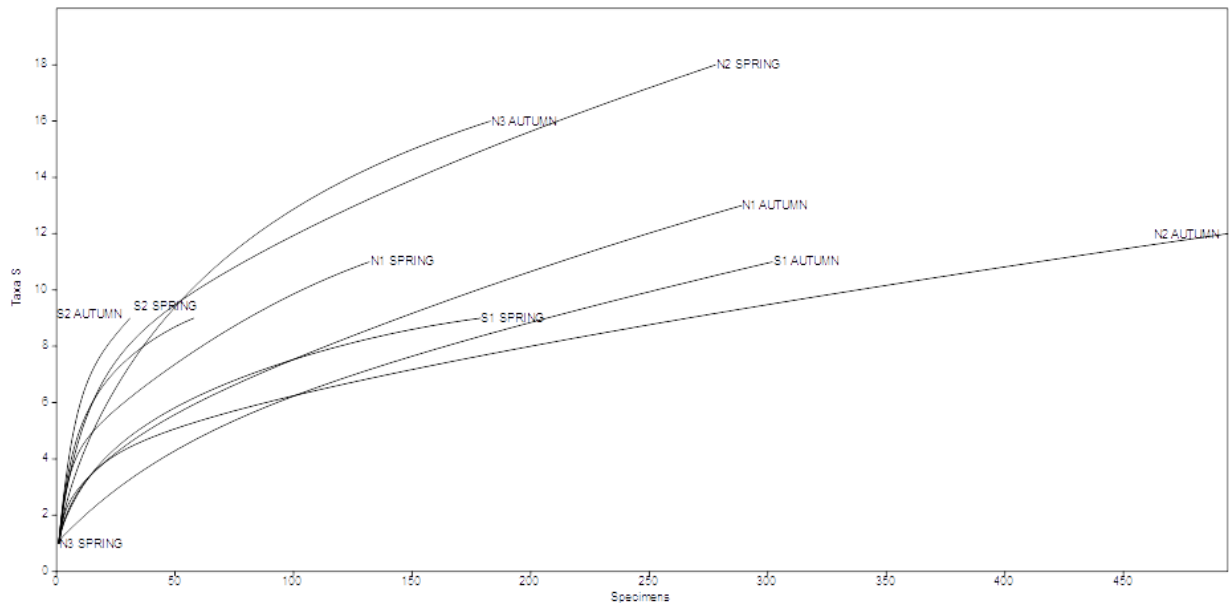


Fig. 11. The graph shows the rarefaction curves of all live assemblages of the fraction size 125 – 500 μm .

3.5 nMDS and ANOSIM

3.5.1 Fraction size 500 μm – 1mm

An nMDS plot and ANOSIM calculations were performed for the total and the living assemblage of the fraction size 500 μm – 1 mm. The nMDS plot of the total assemblage shows a similarity between the samples of the northern stations of both seasons and between the spring and autumn sample of station S2 (Figure 12a). The ANOSIM calculation using the locality as a factor resulted in a high statistic R value with 0.8611. The significance value calculated for the locality was 0.0031. Thus, the R value of the locality can be defined as being statistically significant which means that locality is likely to be the controlling factor giving a difference between these samples (Table 4a).

The ANOSIM calculation for the water depth and season showed significance values higher than 0.05 and thus the R values were defined as being statistically insignificant. The nMDS plot of the living assemblage shows a similarity between the northern samples of both seasons except of the spring sample of the Station N2 (Figure 12b). The spring samples of the station S1 and S2 show a higher similarity, as well as the autumn samples of the same stations. The ANOSIM calculation for the living assemblage using the locality as a factor resulted in a high statistic R value with 0.8056 and a significance value of 0.006 (Table 4b). The R value for the locality can be defined as being statistically significant and locality is likely to be the controlling factor for the differences between the samples. The ANOSIM calculation of the water depth resulted in a negative statistic R value and a significance value higher than 0.05. The ANOSIM using season as a factor showed a low statistic R value and a significance value higher than 0.05. Since both significance values were higher than 0.05, the R values of the water depth and season were classified as being statistically insignificant.

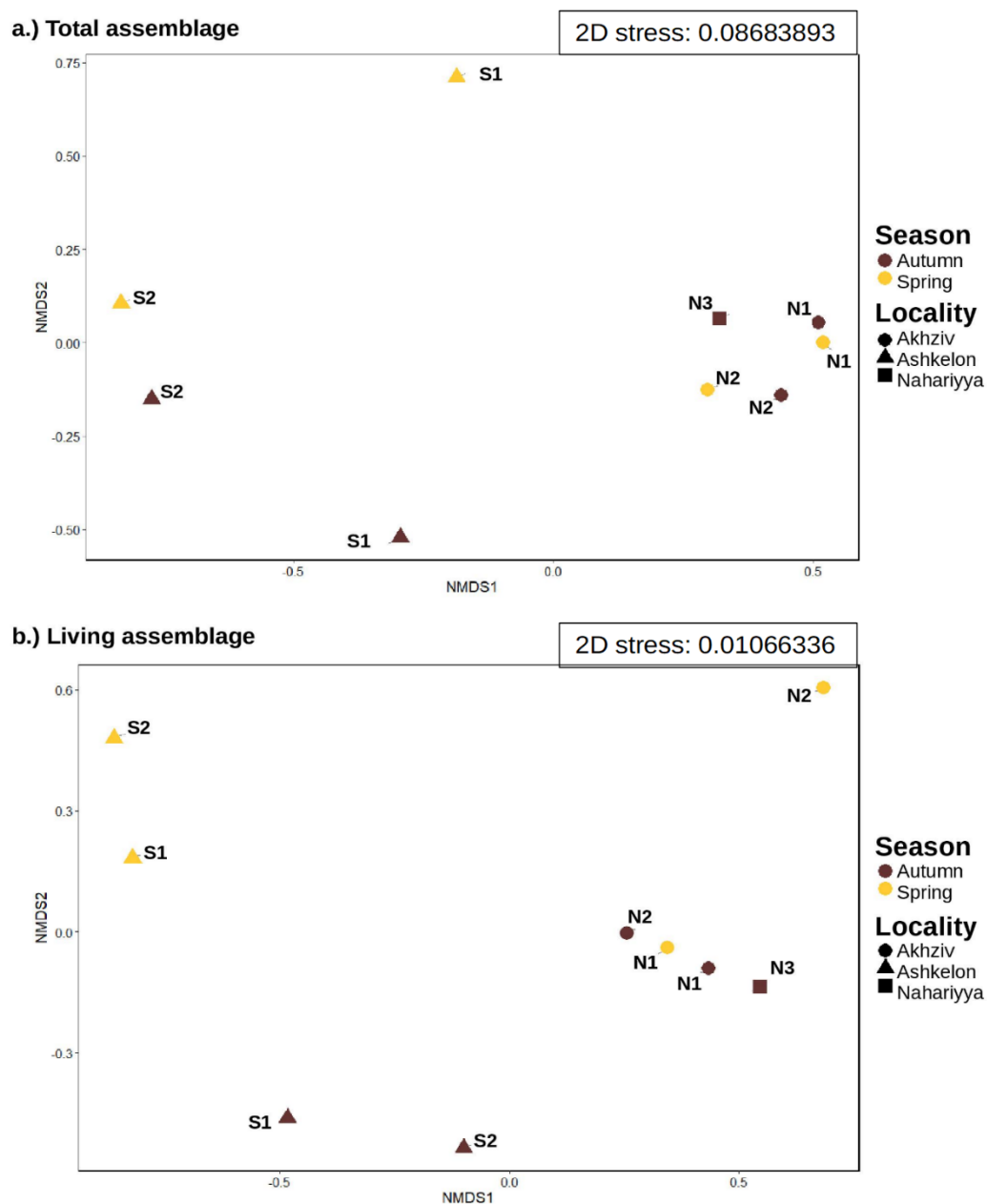


Fig. 12. The nMDS plots based on a Bray-Curtis similarity coefficient of the total assemblage **(a)** and the living assemblage **(b)** for the fraction size 500 μm – 1 mm. The total assemblages **(a)** show one cluster represented by all northern stations. Another cluster is shown by the station S2 including both seasons. S1 (spring and autumn) does not belong to any cluster. The living assemblage **(b)** shows one cluster including all northern stations except of the spring sample of N2. Southern stations show two clusters which are defined by seasonality.

Tab. 4. The statistical values of the ANOSIM test calculated for the total **(a)** and living **(b)** assemblage of the fraction size 500 μm – 1mm considering different localities, water depths and seasons.

a.) Total Assemblage	Statistical Values	Locality	Water Depth	Seasonality
	Statistic R	0.8611	-0.02857	-0.0125
	Significance	0.0031	0.5335	0.383
b.) Living Assemblage				
	Statistic R	0.8056	-0.02857	0.05625
	Significance	0.006	0.5359	0.2712

3.5.2 Fraction size 125 μm – 500 μm

An nMDS plot and ANOSIM test were performed for all samples of the living assemblage of the fraction size 125 μm – 500 μm . The nMDS plot shows a distribution of all spring samples in the upper part of the graph and of all autumn samples in the lower part (Figure 13). The ANOSIM calculation using the factors water depth and season included higher significance values than 0.05 and thus their R values were classified as being statistically insignificant (Table 5). The factor locality resulted in a significance value lower than 0.05, thus the R value can be classified as being statistically significant. The R value is not close to 1, thus considering locality as being the controlling factor all samples do not show a high dissimilarity to each other.

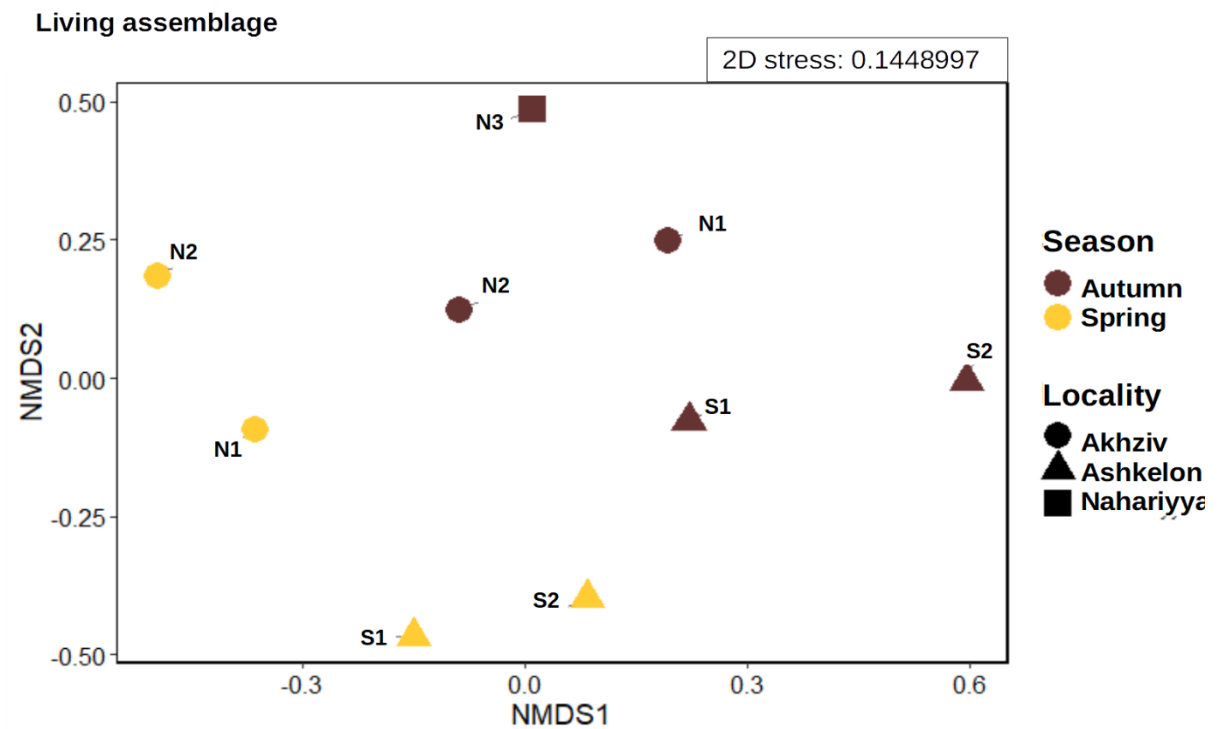


Fig. 13. The nMDS plot based on a Bray-Curtis similarity coefficient of the living assemblage of the fraction size 125 – 500 μm shows no clustering of the samples.

Tab. 5. The statistical values of the ANOSIM test calculated for the living assemblage of the fraction size 125 – 500 μm considering different localities, water depths and seasons.

Living Assemblage	Statistical Values	Locality	Water Depth	Seasonality
	Statistic R	0.375	-0.02857	0.1688
	Significance	0.034	0.5293	0.1408

4 Discussion

4.1 Non-indigenous species

Non-indigenous species in the Mediterranean Sea are the counterpart to species which have their origin in the Mediterranean Sea and are referred to as being native. Studies in the 20th and 21st century, e.g. Por (1971), or Hyams-Kaphzan et al. (2014), have shown the occurrence and abundance of non-indigenous, tropical species in this area whereas the artificial Suez Canal plays a major role for these migrating species. Transport occurs through ballast water of ship, digestion by fish or active migration. Recent studies on non-indigenous species, e.g. Schmidt et al. (2015), or Langer et al., (2012), expect a further increase and a higher distribution of certain non-indigenous species in the next years, thus it is important to monitor their occurrence and abundance in the Mediterranean Sea.

Many of these non-indigenous species were observed in this thesis and results show that the non-indigenous species *Amphistegina lobifera** was the most abundant non-indigenous species in general and the most abundant species in the northern samples, but was absent in the southern samples. Zenetos et al. (2010) classified *Amphistegina lobifera** as a non-indigenous species originating from the Red Sea. In contrast, Meriç et al. (2015) suggested that the genus *Amphistegina* spp. in the Mediterranean Sea originally emerges from a population in the Miocene which had evolved before the corridor of the Mediterranean-Indian Ocean closed, or from the Atlantic. However, a phylogenetic analysis of Schmidt et al. (2016) showed that specimens from the Gulf of Aquaba, Red Sea and specimens from the eastern Mediterranean have a genetic homogeneity which supports the classification to a non-indigenous species evolving from the Red Sea.

Langer et al. (2012) studied the possible biogeographical expansion of the genus *Amphistegina* spp. in the Mediterranean Sea in the future. Until 2012 the genus had been reported from the Nile Delta, the Levantine Basin, the Aegean Sea, northern Africa, Malta, Corfu and the Gulf of Evoikos (Langer et al., 2012, Yokes et al. 2007, Zenetos et al., 2010, Triantaphyllou et al., 2012). The applied species-distribution model by Langer et al. (2012) showed a possible biogeographical expansion of amphisteginid foraminifera to western parts of the Mediterranean Sea including the Adriatic and Tyrrhenian Sea in the 21st century. They suggested that the minimum sea-

surface temperature and the availability of calcite play a major role in the expansion of the genus *Amphistegina*. The occurrence of *Amphistegina lobifera** at the northern stations and the absence at the southern stations match with the different substrate types in both regions and thus confirm the suggestion of Langer et al. (2012). The northern stations Akhziv and Nahariyya were both north to Haifa Bay and represented assemblages of carbonate-rich sediments and ultra-oligotrophic conditions, while the southern stations at Ashkelon were situated in the Nile littoral cell which is mostly covered with siliciclastic material and thus more nutrients. In addition, researchers of the FWF project “Historical ecology of the Lessepsian Migration” reported about a higher turbidity at southern stations and a lower turbidity at northern stations. Considering a lower penetration of light due to turbidity and thus worse conditions for the photo-trophic symbionts inside the *Amphistegina lobifera**, turbidity of the sea water could be another factor explaining the absence of the species *Amphistegina lobifera** at southern stations.

On the other hand, *Pararotalia calcariformata** is the most abundant non-indigenous species in the southern samples and is classified among the tropical non-indigenous species which hosts various species of diatoms as photo-trophic symbionts (Schmidt et al., 2015). The species itself was reported in the Levantine Basin for the first time by Reinhardt et al. (1994) who suggested that the establishment and expansion of this species happened in the last two decades. Such a recent migration through the Suez Canal was probably due to widening of the Canal. A species distribution model by Schmidt et al. (2015) showed that this species will probably expand to the northern and western parts of the Mediterranean Sea, reaching the Ionian Sea by 2100 if considering the on-going global warming. Observations showed that specimens of this species had reproduced at 20°C and growth of young born individuals occurred between 24°C and 28°C (Schmidt et al., 2015). Schmidt et al. (2016) reported, that *Pararotalia calcariformata** did not show photochemical stress below 36 °C, which is much higher compared to *Amphistegina lobifera**. Photochemical stress was already observed at temperatures of 32 °C in this species. A possible explanation for the tolerance of higher temperatures in *Pararotalia calcariformata** could be the different symbiotic species. Schmidt et al. (2016) observed that this species hosts among other species, the diatom species *Minutocellus polymorphus*. This species has not been found in other foraminiferal species as symbionts by now. Schmidt et al. (2018) studied the symbionts

hosted by *Pararotalia calcariformata** and observed 17 different diatom species. Such a symbiont pool could be used by foraminifera for a better adaption to stress, e.g. heat. Hyams-Kaphzan et al. (2008) reported, that the non-indigenous *Pseudohauerinella diversa** appears together with *Heterostegina depressa** and *Amphistegina lobifera** at rocky reefs off Akhziv. All three species were also observed in the samples of this study whereas the stations N1 (Akhziv) and N3 (Nahariyya) represent total assemblages including all these three non-indigenous species.

These non-indigenous species prefer hard substrates enriched in calcium carbonate and overgrown with seagrass or macro algae (Langer & Hottinger, 2000). Additionally, these species include photo symbionts and thus these species are restricted to the photic zone (Briguglio & Hohenegger, 2011). Among the samples of the present study, only the rocks of the northern stations were overgrown with turf or seaweed and only within autumn. Spring samples were described as bare rocks. Occurrence of turf and seaweed in the northern samples fits to the restricted occurrence of e.g. *Amphistegina lobifera** at the northern stations.

4.2 Benthic foraminiferal assemblages

4.2.1 Fraction size 500 µm – 1mm

The triangular charts regarding the different shell composition resulted in two different environments: a hyposaline and hypersaline area. All stations except of the deepest station in the south S2 (24 – 28 m) were shown as a hyposaline area which means a lower salt concentration than 20 ‰ (Figure 7). These results do not fit with the actual salt concentration in this area, which is up to 40 ‰ in the Levantine Basin (Titelboim et al., 2019). Though the low salt concentration could be explained by the near coast and thus a possible freshwater influence. The foraminiferal assemblages of stations S2 represented a hypersaline area which means a higher salt concentration than 35 ‰ (Figure 7) and thus fits with the actual salt concentration.

Comparing the total assemblages of the fraction size 500 µm – 1mm at the stations off Ashkelon and Akhziv with soft bottom assemblages of the fraction size 149 µm – 2 mm of Hyams-Kaphzan et al. (2008), the foraminiferal assemblages and diversity indices showed a different pattern. Off Ashkelon Hyams-Kaphzan et al. (2008) observed *Ammonia parkinsoniana* as the most abundant species between 3 and 15 m. From 20 to 30 m they observed *Ammonia beccarii* as the most abundant species and *Ammonia*

parkinsoniana at water depths below 30 m. In this master thesis *Ammonia beccarii* was observed as the most abundant species off Ashkelon at water depths ~ 11 m and ~ 25 m during spring and autumn (Figure 8). While Hyams-Kaphzan et al. (2008) reported an increase of the dominance from 8 to 15 m, a following decrease until 20 m and another increase until 30 m at stations at Ashkelon, in this thesis the dominance showed a decreasing value of dominance from 11.8 to 24.7 m during both seasons (Table 3). Hyams-Kaphzan et al. (2008) observed the lowest evenness at 15 m and an increase until 25 m. The observed values of evenness in this thesis increased from the lower to the deeper station in spring and decreased in autumn. The nMDS plot, seen in Figure 12a, shows a similar trend as the diversity indices. Station S1 shows a high distance between the spring and the autumn sample, due to the low evenness and comparable high number of singletons, species with only one individual, of the spring sample (Table 3). In contrast, station S2 represents samples with a closer distance between spring and autumn due to similar evenness indices and a similar foraminiferal assemblage. Assemblages of Hyams-Kaphzan et al. (2008) were of collected data sets from 1996-1999 but specific dates were not given, thus a comparison of seasonal changes is not possible. At Akhziv, Hyams-Kaphzan et al. (2008) observed *Peneroplis* spp. and *Pseudoschlumbergerina ovata** as the most abundant species at shallow depths (3 – 9 m) and *Amphistegina lobifera** together with *Heterostegina depressa** and *Pseudohauerinella diversa** as the most abundant species between 15 and 25 m. In this thesis *Amphistegina lobifera** was observed as the most abundant species of the fraction size 500 µm – 1mm at water depths ~ 5 m, ~ 12 – 14 m and ~ 18 – 20 m off Ashkelon and Nahariyya during spring and autumn. It is observed that this species had already shown a higher abundance than in the past and it is expected that its distribution in the Mediterranean Sea will increase further. *Heterostegina depressa** and *Pseudohauerinella diversa** were observed but with lower abundances. Hyams-Kaphzan et al. (2008) reported about an increasing dominance from 8 to 15 m and a following decrease until 25 m off Akhziv. In this thesis, the dominance of the total assemblages decreased from the shallower station (14 m) to the deeper station (20 m) in spring and increased in autumn. They also reported about a decreasing evenness from 8 to 15 m and an increasing until 25 m. In this thesis, the evenness increased from 14 m to 20 m during both seasons (Table 3). Though the diversity indices of the different assemblages varied, the nMDS plot shows a cluster including all northern

samples due to a low shift in diversity indices and similar foraminiferal assemblages (Figure 12a).

The differences from the study of Hyams-Kaphzan et al. (2008) and this thesis might be due to the comparison of the different fraction size range. While Hyams-Kaphzan et al. (2008) studied the total assemblages of the fraction size 149 μm – 2 mm, their results were compared with the total assemblages of the fraction size 500 μm – 1 mm of this thesis.

The species *Textularia agglutinans* appeared in all assemblages at all stations and might be a non-indigenous species according to a phylogenetic analysis of Merkado et al., 2015. The study compared specimens from the Mediterranean Sea and the northern Red Sea and revealed, that all specimens belong to one population. This indicates that specimens of *Textularia agglutinans* which are found in the Levantin Sea originate from the Red Sea, and thus can be defined as being probably a non-indigenous species. The study also showed that the high abundance on hard bottom substrates might be due to the epiphytic life mode on macroalgae which tend to grow on hard substrates (Macreadie et al., 2017).

The high abundance of the species *Textularia agglutinans* might get reduced in the future, since the study of Merkado et al. (2015) shows that specimens do not tolerate a SST above 35°C and the future prediction for the Mediterranean Sea forecasts a yearly increase of 0.027 °C.

The high abundance of *Ammonia beccarii* together with miliolid species off Ashkelon was already observed by Hyams-Kaphzan et al. (2008). The genus *Ammonia* belongs to the most abundant species in the world and is typical for shallow environments (Murray, 1991). Observing the total assemblages including the total fraction size 125 μm – 1 mm of this thesis, the identifying of the different species of *Ammonia* unveiled difficulties in separating the species due to morphological differences. Hayward et al. (2004) reported about difficulties regarding the species identification due to the high variability in their morphology. Hayward et al. (2004) proposed that the recent genus *Ammonia* represents up to 40 genetically distinct species and subspecies, and not only one or two species as other propose. However the species *Ammonia beccarii* does show higher abundances in the dead assemblages of the fraction size 500 μm – 1mm at stations off Ashkelon but if the smaller fraction size 125 – 500 μm is included, the abundances of *Ammonia beccarii* is similar to those which were observed from Hyams-Kaphzan et al. (2008).

Hyams-Kaphzan et al. (2008) observed that the number of foraminiferal specimens increased from the southern to the northern coast of Israel and from the shallower to the deeper stations. They used the fraction size 149 – 2000 µm for their study. Since samples had a different weight in this master thesis, such a comparison is not possible. In addition, the occurrence of macro algae should be considered if observing such a pattern on hard substrates. However, a high number of miliolid species and a low number of agglutinated species was represented in the assemblages, which was already observed by Hyams-Kaphzan et al. (2014) Hyams-Kapzhan et al. (2008) and Arieli et al. (2011) along the coast of Israel.

An individual rarefaction analysis of the living assemblages led to the suggestion that not all species were observed at the southern stations but at the northern stations (Figure 10). Such a result could be explained by the higher amount of living individuals at northern stations and could have led to a different result if more sampling material had been used. The low number of living individuals could be explained by the absent non-indigenous species *Amphistegina lobifera**, which mostly covers the amount of living individuals at northern stations.

4.2.1.1 NMDS and ANOSIM

The nMDS plot of the total assemblages shows a separation of the northern stations (N1 and N2) from the southern stations (S1 and S2) during both seasons which agrees with the ANOSIM calculation for these samples (Figure 12, Table 4). Northern stations share a cluster due to the high abundance of *Amphistegina lobifera** in all samples. This is most likely related to the specific, carbonate-rich hard substrate as mentioned above. Spring and autumn samples of S2 cluster together, but samples of the station S1 are separated due to different assemblage compositions. Hyams-Kaphzan et al. (2014) observed living benthic foraminifera of rocky habitats in the northern part of the Israeli coast and identified three different depth categories regarding the different species composition of the assemblages: 2-6 m, 6-12 m, 12-20 m. In their samples the non-indigenous species *Amphistegina lobifera** was the most common species in all water depths, but only the deepest stations include values > 75%. The other two depth categories also showed abundances < 40%. In this master thesis two stations were observed at Akhziv, whereas both fit into the depth category 12-20 m defined by Hyams-Kaphzan et al. (2014). *Amphistegina lobifera** dominated at both stations during spring and autumn with an abundance of > 85%. The samples of the station at

Nahariyya which is located southern to Akhziv, showed the highest abundance of *Amphistegina lobifera**. At Akhziv the lowest stations in the study of Hyams-Kaphzan et al. (2014) represented a dominance of *Pararotalia calcariformata** and that *Textularia agglutinans* was mainly observed at these stations, which could not be confirmed in this master thesis due to missing stations at a water depth between 2 and 6 m in this area. Hyams-Kaphzan et al. (2014) reported that *Heterostegina depressa** showed a similar pattern as *Amphistegina lobifera** and occurred mostly between 6 and 20 m. In this thesis, no living individuals of *Heterostegina depressa** were observed off Akhziv but a few living individuals in the small fraction size 125 µm – 500 µm at the shallowest station (~ 5 m) off Nahariyya. Nobes et al. (2008) reported that the species *Heterostegina depressa** is preferably found at lower light intensities and hide in shadowed areas. This could be an explanation for missing living individuals of this species at stations off Akhziv.

Dead individuals of *Heterostegina depressa** were observed in all fraction sizes at both stations off Akhziv during spring and autumn whereas the highest number of dead individuals was reported at the shallowest station N3 off Nahariyya which might be due to the transport of dead shells from deeper to shallower areas.

Reiss and Hottinger (1984) observed that water depth is an important parameter, which influences the benthic foraminiferal distribution on hard bottom substrates. Especially LBF are affected by the water depth due to the limitation of light which can be explained by phototrophic symbionts as hosts. Considering this observation, more stations at various water depths could lead to similar water depth categories as observed in Hyams-Kaphzan et al. (2014).

The nMDS plot of the live assemblages shows a separation of the northern stations from the southern stations during both seasons except of the spring sample of station N2 (Figure 12). Only at this station other species than *Amphistegina lobifera** and *Textularia agglutinans* were found as living specimens. Though the ANOSIM calculation suggests, that the samples of the stations were separated because of different localities, the southern stations S1 and S2 do not cluster together. Both stations were separated due to the seasonality which might affect the diversity of species in the southern part of the Israeli coast, since spring samples of both stations included a higher number of species with living specimens than the autumn samples. This pattern fits with the results of Hyams-Kaphzan et al. (2009) who reported about a

significant decrease of species richness at Palmachim (north to Ashkelon) in summer and fall, 2003.

4.2.2 Fraction size 125 µm – 500µm

In this fraction size a remarkable number of individuals was only specified to a genus level due to uncompleted or deformed shells of foraminifera (Appendix 2). The occurrence of such shells could be explained by their transport through the water column and thus a following abrasion of the shell.

An individual rarefaction analysis of the live assemblages suggested that more sampling material would lead to the recovery of more species which were not yet observed in all samples (Figure 11).

4.2.2.1 NMDS and ANOSIM

The nMDS plot showed no clear clustering (Figure 13). The significance value of the ANOSIM calculations for locality showed a lower significance value and was classified as being statistically significant (Table 5). Other than in the ANOSIM calculation of the big fraction size, the statistic R value for the locality for the small fraction size was closer to zero than to one. Such result suggest that the stations does not share a high dissimilarity to each other depending on the locality.

This result might be explained by only including the living specimens for this calculation. Most of the living specimens belong to species which occur at several stations, while dead assemblages show definitely a different species composition between at least the southern and northern stations (Figure 9) but were not included in the ANOSIM calculation due to possible material loss and uncompleted samples.

4.3 Ongoing warming trend in the Mediterranean Sea

The introduction of non-indigenous species into the Mediterranean Sea was low until the middle of the 20th century, due to a different water temperature and salinity compared to the Red Sea (Zenetos et al., 2008, Galil, 2006). In this master thesis, a high abundance of non-indigenous species was observed in recent samples from the Mediterranean Sea (Tab. 2, Fig. 8, Fig. 9). Most likely, this is related with the increasing water temperature during the last decades, caused by climate change. Especially the occurrence and high abundance of *Amphistegina lobifera** might lead to major changes

regarding the ecosystem. They are key producers for carbonate and increase the stability of substrate and thus influence the reef structure (Langer et al., 2012).

Studies show that at tropical reefs amphisteginid foraminifera contribute more than one kg of calcium carbonate m^2y^{-1} to the sediment (Hallock, 1981; Langer et al., 1997; Langer, 2008). However, reef-structures composed of CaCO_3 do not exist in the Mediterranean Sea. Instead bioconstructions made mainly by coralline algae and dominated by invertebrates are present in the Mediterranean Sea (Pfannschmidt et al., 2002). It is suggested that the ongoing warming trend could lead to a further expansion of the genus *Amphistegina** and thus to CaCO_3 -rich bioconstructions in the future. To get a better knowledge of future expansions and the introduction of non-indigenous species like during the ongoing Lessepsian Migration, it is important to increase the focus on the study of non-indigenous species and their siblings. Titelboim et al., (2019) observed two species of the genus *Amphistegina* from the Red Sea: *Amphistegina lobifera* and *Amphistegina lessonii*. Both species show a different sensitivity to temperature. In the Red Sea the winter temperature is normally above 22°C , but in the Mediterranean Sea it is below 15°C . The minimum temperature seems to be a physical barrier for the species *Amphistegina lessonii*, limiting its migration from the Red Sea through the Suez Canal into the Mediterranean Sea. Additionally, the species *Amphistegina lobifera* tolerates higher and lower temperatures than the species *Amphistegina lessonii*. This will lead to a species shift in the Mediterranean Sea, affected by the ongoing warming trend. It is expected that this climate trend will lead to a higher abundance of tropical and subtropical species which tolerate higher water temperatures in summer and lower water temperatures in winter, e.g. *Pararotalia calcariformata**, and will change the composition of foraminiferal assemblages along the Israeli coast.

4.4 Limitations of the study

4.4.1 Sampling method

Though the samples of the airlift-suction did show a similar taxonomic pattern to previous studies, e.g. Hyams-Kaphzan et al. (2014), a net with a mesh width $< 500 \mu\text{m}$ would have led to a better resolution of the study, since the sampling material of the fraction size $125 - 500 \mu\text{m}$ could be incomplete due to the loss through the mesh.

In addition, it should be considered that the samples were not referred to a specific weight or sample size when comparing the samples. Thus, only relative abundances were used in this thesis and results should be compared carefully.

4.4.2 Classification of non-indigenous species

Since the number of existing studies regarding the non-indigenous species in the Mediterranean Sea is limited, not much is known about some species. Highly abundant species as *Amphistegina lobifera** or *Pararotalia calcariformata** play a mayor role in the migration topic, thus more studies are available, e.g. Schmidt et al., (2016). Non-indigenous species with low abundances, e.g. *Quinqueloculina cf. multimarginata**, are barely observed and discussed in previous studies. Thus, the classification of non-indigenous species is difficult due to missing studies and is mainly based on the classification of Zenetos et al. (2010) and Zenetos et al. (2012). On the other hand, species as the tropical foraminifera *Carterina spiculotesta* are classified as indigenous species in the Mediterranean Sea but only one study reported about this species in the Mediterranean Sea (Frontalini et al., 2015).

Along with missing reports about tropical foraminifera comes the unknown origin of some species. Several taxa, e.g. *Amphistegina lobifera**, were classified as Lessepsian migrants but were thought to have their origin from a population existing in the Mediterranean Sea in the Miocene (Meric et al., 2015). Only phylogenetic analysis of Schmidt et al. (2016) showed that this species originates from the Red Sea. Question on the origin of species could be relevant to all non-indigenous species including not only the possibility of an emergence of prior populations, but also the emergence through the Strait of Gibraltar or through the ballast water of ship.

More studies could reveal a better understanding of “new” species in the Mediterranean Sea and their origin.

5 Conclusion

The faunal and statistical analysis of benthic foraminiferal assemblages from the eastern Mediterranean Sea resulted in an overview of spring and autumn assemblages including the occurrence of non-indigenous species, mostly Lessepsian invaders.

In total 128 foraminiferal species were observed whereas 16 belonged to non-indigenous species. The living and total assemblages of the fraction size 500 µm – 1 mm showed a similar pattern to the living assemblage of the small fraction size. At

northern stations both assemblages of the big fraction size were dominated by the non-indigenous species *Amphistegina lobifera**. At southern stations, the living assemblages were dominated by *Textularia agglutinans* and the dead assemblages by *Ammonia beccarii*. In the living assemblage of the small fraction size (125 – 500 µm) the non-indigenous species *Pararotalia calcariformata** dominated at the shallower station S1 (~ 12 m). The deeper station S2 showed a higher evenness and species of the genera *Rosalina* spp. and *Textularia* spp. were the most abundant species. The northern stations were dominated by *Amphistegina lobifera**, *Pseudohauerinella diversa** and *Textularia* sp.1.

The high abundance of *Amphistegina lobifera** on hard-bottom substrates at northern stations fit with the carbonate-rich sediments occurring north to Haifa Bay which might play a key role considering the absence of this species at southern stations off Israel. In general, the Mediterranean Sea has been shown a warming trend in the past which is expected to continue in the future and thus supports the migration and distribution of non-indigenous species with an origin in the Indo-Pacific. Besides *Amphistegina lobifera**, the species *Pararotalia calcariformata** had been observed as a dominant species, especially at southern stations. Both tropical species bear a photo-trophic symbiont inside and tolerate higher temperatures whereas studies revealed that the species *Pararotalia calcariformata** did not show photochemical stress below 36 °C and represents a species with a high tolerance towards heat. Such strategies might lead to a higher distribution of these species in the Mediterranean Sea and to higher latitudes.

Considering the ongoing warming trend and the possibilities of migration into the Mediterranean Sea, a constant monitoring of the Levantine Basin regarding the occurrence and abundance of non-indigenous species is recommended, since their dispersal can disrupt ecosystems. In addition, more studies might lead to a better identification of non-indigenous species and their actual origin.

6 References

- Abu Tair, N. K.**, 2011. Der Impakt invasiver Foraminiferen aus dem Roten Meer auf das mediterrane Ökosystem von Zypern. Unpublished Diplomarbeit, Rheinische Friedrich-Wilhelms-Universität, Bonn, 73 pp.
- Almagor, G.**; Gill, D. & Perath, I., 2000. Marine sand resources offshore Israel. *Marine Georesources and Geotechnology*, 18, 1-42.
- Almagor, G.** & Hall, J., 1984. Morphology and bathymetry of the Mediterranean continental margin of Israel. *Israel Geological Survey Bulletin*, 77, 31 pp.
- Almogi-Labin, A.** & Hyams-Kaphzan, O., 2012. *Epistomaroides punctatus* (Said, 1949) - a new alien foraminifera found at Akhziv-Rosh HaNikra, northern Israel, eastern Mediterranean Sea. *Mediterranean Marine Science*, 13, 294-296.
- Anderson, M. J.** & Walsh, D. C., 2013. PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: what null hypothesis are you testing? *Ecological monographs*, 83(4), 557-574.
- Arieli, R.N.**; Almogi-Labin, A.; Abramovich, S. & Herut, B., 2011. The effect of thermal pollution on benthic foraminiferal assemblages in the Mediterranean shoreface adjacent to Hadera power plant (Israel). *Marine Pollution Bulletin*, 62, 1002-1012.
- Avnaim-Katav, S.**; Almogi-Labin, A.; Sandler, A. & Sivan, D., 2013. Benthic foraminifera as palaeoenvironmental indicators during the last million years in the eastern Mediterranean inner shelf. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 386, 512-530.
- Berman, T.**; Townsend, D. W.; El-Sayed, S. Z.; Trees, C. C. & Azov, Y., 1984. Optical transparency, chlorophyll and primary productivity in the Eastern Mediterranean near the Israeli coast. – *Oceanologica Acta*, 7, 367-372.
- Benson, B. L.**, 1989. Airlift sampler: applications for hard substrata. *Bulletin of Marine Science*, 44(2), 752-756.
- Bianchi C. N.**; Pronzato, R.; Cattaneo-Vietti, R.; Benedetti Cecchi, L.; Morri, C.; Pansini, M.; Chemello, R.; Milazzo, M.; Frascchetti, S.; Terlizzi, A.; Peirano, A.; Salvati, E.; Benzoni, F.; Calcinai, B.; Cerrano, C. & Bavestrello, G., 2004. Hard bottoms. *Biol. Mar. Mediter.* 11, 185-215.
- Boudaughier-Fadel, M. K.**, 2018. Evolution and geological significance of larger benthic foraminifera. UCL Press.
- Briguglio, A.**, & Hohenegger, J., 2011. How to react to shallow water hydrodynamics: the larger benthic foraminifera solution. *Marine Micropaleontology*, 81(1-2), 63-76.

- Chao, A.;** 1984. Nonparametric estimation of the number of classes in a population. *Scandinavian Journal of statistics*, 265-270.
- Chapman, F.;** 1901. Foraminifera from the lagoon at Funafuti. *Zoological Journal of the Linnean Society*, 28(181), 161-210.
- Cimerman, F. & Langer, M.R.,** 1991. Mediterranean Foraminifera. *Academia Scientarium et Arithum Slovenica, Dela, Opera* 30, Classis IV: Historia Naturalis.
- Emery, K. O. & Neev, D.,** 1960. Mediterranean beaches of Israel. *Geological Survey of Israel Bulletin*, 26, 1-23.
- Frontalini, F.;** Kaminski, M. A.; Mikellidou, I., & du Châtelet, E. A. 2015. Checklist of benthic foraminifera (class Foraminifera: d'Orbigny 1826; phylum Granuloreticulosa) from Saros Bay, northern Aegean Sea: a biodiversity hotspot. *Marine Biodiversity*, 45(3), 549-567.
- Galil, B. S.;** 2006. Shipwrecked—shipping impacts on the biota of the Mediterranean Sea. In *The ecology of transportation: managing mobility for the environment*. Springer, Dordrecht. 39-69.
- Gruber, L.;** 2006. Population dynamics of two larger foraminifera as environmental indicators of the HaCarmel coast. MSc thesis (in Hebrew), Haifa University, Israel, 91 pp.
- Gruber, L.;** Lazar, S.; Hyams, O.; Herut, B. & Almogi-Labin, A., 2007. *Amphistegina lobifera*, a larger symbiont-bearing foraminiferal migrant from the Red Sea, now dominates rocky coasts of the Israeli Mediterranean. *Geophysical Research Abstracts*, 9, A-01407.
- Golik, A.;** 1993. Indirect evidence for sediment transport on the continental shelf off Israel. *Geo-Marine Letters*, 13, 159-164.
- Golik, A.;** 1997. Dynamics and management of sand along the Israeli coastline. *Bulletin de l'Institut Oceanographique, Monaco, CIESM Science Series*, 3, 97-110.
- Guy-Haim, T.;** Hyams-Kaphzan, O.; Yeruham, E.; Almogi-Labin, A. & Carlton, J. T., 2017. A novel marine bioinvasion vector: Ichthyochory, live passage through fish. *Limnology and Oceanography Letters*, 2(3), 81-90.
- Hallock, P.;** 1981. Light dependence in *Amphistegina*. *Journal of Foraminiferal Research*, v. 11, 40–46.
- Hayward, B. W.;** Holzmann, M.; Grenfell, H. R.; Pawlowski, J. & Triggs, C. M., 2004. Morphological distinction of molecular types in *Ammonia*—towards a taxonomic revision

of the world's most commonly misidentified foraminifera. *Marine Micropaleontology*, 50(3-4), 237-271.

Herut, B.; Almogi-Labin, A.; Jannink, N. & Gertman, I., 2000. The seasonal dynamics of nutrient and chlorophyll a concentrations on the SE Mediterranean shelf-slope. *Oceanologica Acta* 23, 771–782.

Hottinger, L.; Halicz, E. & Reiss, Z., 1991. The foraminiferal genera *Pararotalia*, *Neorotalia*, and *Calcarina*: taxonomic revision. *Journal of Paleontology*, 65(1), 18-33.

Hottinger, L.; Halicz, E. & Reiss, Z., 1993. Recent Foraminiferida from the Gulf of Aqaba, Red Sea (No. 563.12 HOT).

Hyams, O.; Almogi-Labin, A. & Benjamini, C., 2002. Larger foraminifera of the southeastern Mediterranean shallow continental shelf off Israel. *Israel Journal of Earth Sciences*, 51, 169–179.

Hyams-Kaphzan, O.; Almogi-Labin, A.; Benjamini, C. & Herut, B., 2009. Natural oligotrophy vs. pollution-induced eutrophy on the SE Mediterranean shallow shelf (Israel): environmental parameters and benthic foraminifera. *Marine Pollution Bulletin*, 58, 1888–1902.

Hyams-Kaphzan, O.; Almogi-Labin, A.; Sivan, D. & Benjamini, C., 2008. Benthic foraminifera assemblage change along the southeastern Mediterranean inner shelf due to fall-off of Nile-derived siliciclastics. *Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen*, 248(3), 315-344.

Hyams-Kaphzan, O.; Grossowicz, L. P. & Almogi-Labin, A., 2014. Characteristics of benthic foraminifera inhabiting rocky reefs in northern Israeli Mediterranean shelf. *Geological Survey of Israel Report GSI*,36.

IPCC (Intergovernmental Panel on Climate Change), 2007. *Climate Change 2007: The Physical Science Basis* WMO/UNEP.

Itam, A. E.; Emeka, V. & Emeka, C., 2019. Foraminiferal study of Nkporo shale exposures, Calabar flank (SE Nigeria): age and depositional environment. *Journal of Sedimentary Environments*, 4, 369-378.

Jones, R.W., 1994. *The Challenger Foraminifera*. Oxford University Press.

Jorissen, F.J.; de Stigter, H.C. & Widmark, J.G.V., 1995. A conceptual model explaining benthic foraminiferal microhabitats. *Marine Micropaleontology* 26, 3–26.

Krebs, C.J., 2014. *Ecological methodology*. 3rd ed. Addison Wesley Educational Publishers, Inc. 745pp.

- Krom, M. D.;** Kress, N.; Brenner S. & Gordon, L. I., 1991. Phosphorus limitation of primary productivity in the eastern Mediterranean Sea. *Limnology and Oceanography*, 36, 424-432.
- Langer, M.R.;** 2008. Assessing the contribution of foraminiferal protists to global ocean carbonate production. *Journal of Eukaryotic Microbiology*. 55. 163–169.
- Langer, M. R. & Lipps, J. H.** 1997. Global ocean carbonate production of foraminifera. Abstract. Proc. Int. Symp. on Foraminifera, FORAMS '98, Soc. Mexicana de Paleont., Spec. Publ.:61.
- Langer, M. R., & Hottinger, L.,** 2000. Biogeography of selected" larger" foraminifera. *Micropaleontology*, 46, 105-126.
- Langer, M. R.;** Weinmann, A. E.; Lötters, S. & Rödder, D., 2012. "Strangers" in paradise: modeling the biogeographic range expansion of the foraminifera *Amphistegina* in the Mediterranean Sea. *The Journal of Foraminiferal Research*, 42(3), 234-244.
- Lei, Y. & Li, T.,** 2016. Atlas of Benthic Foraminifera from China Seas: The Bohai Sea and the Yellow Sea. Springer.
- Loeblich, A.R. & Tappan, H.,** 1994. Foraminifera of the Sahul shelf and Timor Sea. Cushman Foundation for Foraminiferal Research. Special Publication 31.
- Macias, D.;** Garcia-Gorriz, E. & Stips, A., 2013. Understanding the causes of recent warming of Mediterranean waters. How much could be attributed to climate change? *PLoS One*, 8(11), e81591.
- Macreadie, P. I.,** Jarvis, J., Trevathan-Tackett, S. M., & Bellgrove, A., 2017. Seagrasses and macroalgae: Importance, vulnerability and impacts. *Climate Change Impacts on Fisheries and Aquaculture: A Global Analysis* (Wiley-Blackwell), 729-770.
- Makled, W. A., & Langer, M. R.,** 2011. Benthic Foraminifera from the Chuuk Lagoon Atoll System (Caroline Islands, Pacific Ocean). *Neues Jahrbuch für Geologie und Paläontologie-Abhandlungen*, 259(2), 231-249.
- Mckee, E. D.;** Chronic, J., & Leopold, E. B., 1959. Sedimentary belts in lagoon of Kapingamaringi Atoll: Bulletin of the American Association of Petroleum Geologists, v. 43, 501–562.
- Merkado, G.;** Titelboim, D.; Hyams-Kaphzan, O.; Holzmann, M.; Pawlowski, J.; Almogi-Labin, A.; ... & Abramovich, S., 2015. Molecular Phylogeny and Ecology of *Textularia agglutinans* d'Orbigny from the Mediterranean Coast of Israel: A Case of a Successful New Incumbent. *Plos one*, 10(11), e0142263.

- Meric, E.;** Avşar, N.; Yokeş, M. B., & Dincer, F., 2014. Atlas of recent benthic foraminifera from Turkey. *Micropaleontology*, 60(3-4), 211-398.
- Meriç, E., Yokeş, M. B.,** Avşar, N., & Dinçer, F. 2015. New Observations of Alien Foraminifera on the Turkish Coasts of the Aegean Sea (2008-2011). *International Journal of Environment and Geoinformatics*, 2(2), 77-87.
- Meriç, E.;** Yokes, M.B.; Avsar, K.N.; Kirki-Elmas, E.; Dinçer, F.; Karhan, S.U.; Kalkan, E. & Demir, V., 2013. First report of *Pararotalia calcariformata* from the Hatay coastline (Turkey—north-eastern Mediterranean). *Marine Biodiversity Records*, 6, 31.
- Meyer Viol, S. L.** 2015. A box model of Mediterranean deep-water formation applied to sapropels (Master's thesis).
- Mikhalevich V.I.** 2014. Post-Cambrian testate foraminifera as a system in its evolution. *Nova Sci. Publ.*, New York, 426 pp.
- Milker, Y. & Schmiedl, G.,** 2012. A taxonomic guide to modern benthic shelf foraminifera of the western Mediterranean Sea. *Palaeontologia Electronica* 15, 16A, 134 pp.
- Murray, J.W.,** 1973. *Distribution and Ecology of Living Benthic Foraminiferids*. Heinemann Educational Books, 274 pp.
- Murray, J.W.,** 1991. *Ecology and Palaeoecology of Benthic Foraminifera*. Longman, Harlow, 397 pp.
- Neev, D.,** 1965. Submarine geological studies in the continental shelf and slope off the Mediterranean coast of Israel. Geological Survey of Israel.
- Nir, Y.,** 1984. Recent sediments of the Israel Mediterranean continental shelf and slope. Ph. D. Dissertation, Göteborg University, Sweden, 149 pp.
- Nobes K.,** Uthicke S. & Henderson R., (2008). Is light the limiting factor for the distribution of benthic symbiont bearing foraminifera on the Great Barrier Reef? *Journal of Experimental Marine Biology and Ecology*. 363, 48-57.
- Oksanen, J.,** 2015. *Vegan: an introduction to ordination*. URL <http://cran.r-project.org/eb/packages/vegan/vignettes/introvegan.pdf>, 8, 19.
- Oksanen, J.;** Blanchet, F. G.; Friendly, M.; Kindt, R.; Legendre, P.; McGlinn, D.; Peter R. Minchin, P. R.; O'Hara, R. B.; Simpson, G. L; Solymos, P.; Stevens, M. H. H.; Szoecs, E.; Wagner, H., 2019. *vegan: Community Ecology Package*. R package version 2.5-6. <https://CRAN.R-project.org/package=vegan>

- Panchang, R.,** & Nigam, R. A. J. I. V., 2014. Benthic ecological mapping of the Ayeyarwady delta shelf off Myanmar, using foraminiferal assemblages. *J Palaeontol Soc India*, 59(2), 121-168.
- Pawlowski, J.;** Holzmänn, M. & Debenay, J. P., 2014. Molecular phylogeny of *Carterina spiculotesta* and related species from New Caledonia. *The Journal of Foraminiferal Research*, 44(4), 440-450.
- Pfannschmidt, S.;** Heß, M.; Melzer, R.; Hofrichter, R.; Wilke, M.; Türkay, M., & Herzer, K., 2002. Lebensräume und Lebensgemeinschaften, in Hofrichter, R. (ed.), *Das Mittelmeer: Fauna, Flora, Ökologie. Band. I: Spektrum Akademischer Verlag*, Heidelberg, 288–423.
- Por, F. D.,** 1971. One hundred years of Suez Canal—a century of Lessepsian migration: retrospect and viewpoints. *Systematic Zoology*, 20(2), 138-159.
- Por, F.D.,** 1978. Lessepsian Migration: The Influx of Red Sea biota into the Mediterranean by Way of the Suez Canal. Springer-Verlag,
- Por, F. D.,** 2012. Lessepsian migration: the influx of Red Sea biota into the Mediterranean by way of the Suez Canal (Vol. 23). Springer Science & Business Media,
- R Core Team** 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.
- Razak, A.;** Al-Sayigh, A.; Muhanna, M.; Jahdhami, A. & Muftah, A., 2015. Recent Foraminifers from Oman Coast. *Journal of Environmental Science and Engineering A*, 4, 137-142.
- Reinhardt E.G;** Patterson R.T. & Schroeder-Adams C.J, 1994. Geoarchaeology of the ancient harbor site of Caesarea Maritima, Israel; evidence from sedimentology and paleoecology of benthic foraminifera. *J Foraminifer Res.* 24(1):37–48.
- Reiss, Z. &** Hottinger, L., 1984. *The Gulf of Aqaba: Ecological Micropaleontology*: Springer-Verlag, 354 pp.
- Samir, A. M.;** Abdou, H. F.; Zazou, S. M. & El-Menhawey, W. H., 2003. Cluster analysis of recent benthic foraminifera from the northwestern Mediterranean coast of Egypt. *Revue de micropaleontologie*, 46(2), 111-130.
- Schattner, U.;** Gurevich, M.; Kanari, M. & Lazar, M., 2015. Levant jet system—effect of post LGM seafloor currents on Nile sediment transport in the eastern Mediterranean. *Sedimentary Geology*, 329, 28-39.

- Schmidt, C.;** Morard, R.; Almogi-Labin, A.; Weinmann, A. E.; Titelboim, D.; Abramovich, S. & Kucera, M., 2015. Recent invasion of the symbiont-bearing foraminifera *Pararotalia* into the eastern Mediterranean facilitated by the ongoing warming trend. *PLoS One*, 10(8), e0132917.
- Schmidt, C.,** Morard, R., Romero, O., & Kucera, M., 2018. Diverse internal symbiont community in the endosymbiotic Foraminifera *Pararotalia calcariformata*: implications for symbiont shuffling under thermal stress. *Frontiers in Microbiology*, 9.
- Schmidt, C.,** Titelboim, D., Brandt, J., Herut, B., Abramovich, S., Almogi-Labin, A., & Kucera, M., 2016. Extremely heat tolerant photo-symbiosis in a shallow marine benthic foraminifera. *Scientific reports*, 6(1), 1-9.
- Schönfeld, J.;** Alve, E.; Geslin, E.; Jorissen, F.; Korsun, S.; Spezzaferri, S. & members of the FOBIMO group (Abramovich, S., Almogi-Labin, A., Armynot du Chatelet, E., Barras, Bergamin, C.L., Bicchi, E., Bouchet, V., Cearreta, A., Di Bella, L., Dijkstra, N., Disaro, S.T., Luciana Ferraro, Frontalini, F., Gennari, G., Golikova, E., Haynert, K., Hess, S., Husum, K., Martins, V., McGann, M., Oron, S., Romano, E., Sousa S.M. and Tsujimoto, A., 2012. The FOBIMO (FOraminiferal BloMOnitoring) initiative - Towards a standardized protocol for soft-bottom benthic foraminiferal monitoring studies. *Marine Micropaleontology*, 94–95, 1–13.
- Sen Gupta, B.,** 2003. Introduction to modern foraminifera. *Modern foraminifera*, 3-6.
- Streftaris, N. & Zenetos, A.,** 2006. Alien marine species in the Mediterranean-the 100 'Worst Invasives' and their impact. *Mediterranean Marine Science*, 7(1), 87-118.
- Symphonia, T. & Nathan, S.,** 2019. Taxonomic notes on Recent Foraminifera from the Continental Shelf-Slope Region of Southwestern Bay of Bengal, East Coast of India. *Palaeontologia Electronica*, 10, 26879/811.
- Temelkov B.K.;** Golemansky V.G. & Todorov M.T., 2006. Updated Check-List of the Recent 390 Foraminifera from the Bulgarian Black Sea Coast. *Acta Zoologica Bulgarica*, 58, 17-36.
- Titelboim, D.;** Almogi-Labin, A.; Herut, B.; Kucera, M.; Asckenazi-Polivoda, S. & Abramovich, S., 2019. Thermal tolerance and range expansion of invasive foraminifera under climate changes. *Scientific reports*, 9(1), 1-5.
- Triantaphyllou, M. V.;** Dimiza, M. D., Koukousioura, O., & Hallock, P., 2012. Observations on the life cycle of the symbiont-bearing foraminifer *Amphistegina lobifera* Larsen, an invasive species in coastal ecosystems of the Aegean Sea (Greece, E. Mediterranean): *Journal of Foraminiferal Research*, v. 42, 143–150.

- Yacobi, Y. Z.;** Zohary, T.; Kress, N.; Hecht, A.; Robarts, R. D.; Waiser, M.; Wood, A. M. & Li, W. K. W., 1995. Chlorophyll distribution throughout the southeastern Mediterranean in relation to the physical structure of the water mass. *Journal of Marine Systems*, 6, 179-190.
- Yanko, V.;** Ahmad, M. & Kaminski, M., 1998. Morphological deformities of benthic foraminiferal tests in response to pollution by heavy metals: implications for pollution monitoring. *Journal of Foraminiferal Research*, 23, 177–200.
- Yokes, M. B.,** Meric, E., and Avsar, N., 2007. On the presence of alien foraminifera *Amphistegina lobifera* Larsen on the coasts of the Maltese Islands: *Aquatic Invasions*, v. 2, 439– 441.
- Zavattarelli, M. & Mellor, G. L.,** 1995. A Numerical Study of the Mediterranean Sea Circulation, American Meteorological Society.
- Zenetos, A.;** Gofas, S.; Verlaque, M.; Cinar, M.E.; Garcia, J.E.; Bianchi, C.N.; Morri, C.; Azzurro, E.; Bilecenoglu, M.; Frogia, C.; Siokou, I.; Violanti, D.; Sfriso, A.; San Martin, G. et al., 2010. Alien species in the Mediterranean Sea by 2010. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part I . Spatial distribution: *Mediterranean Marine Science*, 11, 381-493.
- Zenetos, A.;** Gofas, S.; Morri, C.; Rosso, A.; Violanti, D.; Raso, J. G.; ... & Ballesteros, E., 2012. Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean marine science*, 13(2), 328-352.
- Zviely, D.;** Kit, E., & Klein, M., 2007. Longshore sand transport estimates along the Mediterranean coast of Israel in the Holocene. *Marine Geology*, 238(1-4), 61-73.

7 Appendix

7.1 Abstract

7.1.1 English Version

The Levantine Basin, in the eastern Mediterranean Sea, has been facing changes lately regarding the occurrence and abundance of non-indigenous species. In this area, especially ship traffic and the artificial Suez Canal enabled a migration of such species, mostly of a tropical origin, into the Mediterranean Sea.

In this thesis, benthic foraminiferal assemblages were sampled from hard-bottom substrates at the southern and northern coast of Israel by airlift suction. Stations were located at different water depths and were sampled during spring and autumn 2018. In total 128 benthic foraminifera species were identified whereas 16 belonged to non-indigenous species. Six of them occurred at southern stations, 15 at northern stations. The number of species varied between one and fifteen in the total assemblages of the big fraction size (500 μm – 1mm), and one and eighteen in the living assemblages of the small fraction size (125 – 500 μm). An nMDS plot and ANOSIM calculation using benthic foraminifera abundance of the big fraction size (total assemblage and living assemblage) showed, that assemblages differed due to the different sampling sites, separating the samples into a southern and northern cluster. An nMDS plot and ANOSIM calculation for the living small fraction size did not show any clustering. The most abundant species at northern sites was the non-indigenous species *Amphistegina lobifera** with values up to 97% in the big fraction size during both seasons. At southern stations the most abundant species were *Textularia agglutinans* in the living assemblages and *Ammonia beccarii* in the total assemblages in the same fraction size during both seasons. The most abundant species in the living assemblages of the small fraction size were among the genera *Rosalina* spp. and *Textularia* spp., and the non-indigenous species *Pararotalia calcariformata** at the southern stations. Northern stations were mainly covered by the non-indigenous species *Amphistegina lobifera**, *Pseudohauerinella diversa** and the indigenous species *Textularia agglutinans*.

Results of this thesis show a high abundance of non-indigenous species on the Israeli coast in the Mediterranean Sea. Since most of them were among tropical species and

rising sea surface temperatures are expected due to global warming, a continuous monitoring of this area is recommended to observe future faunal developments.

7.1.2 German Version

In letzter Zeit fanden Veränderungen im Levantischen Meer, im Osten des Mittelmeers gelegen, bezüglich des Auftretens und der Häufigkeit von nicht indigenen Arten statt. In diesem Bereich des Meeres ermöglichen insbesondere der Schiffsverkehr und der künstliche Suez Kanal die Migration solcher Arten, welche meist aus tropischen Gewässern stammen.

In dieser Arbeit wurden benthische Foraminiferen-Vergesellschaftungen von Hartsubstraten untersucht, wobei die Proben von der nördlichen und südlichen Küste Israels stammen. Die Proben wurden mittels eines sogenannten „airlift sampler“ genommen. Die Standorte befanden sich an unterschiedlichen Wassertiefen, die Probennahme erfolgte saisonal – einmal im Frühling und einmal im Herbst 2018.

Insgesamt konnten 128 benthische Arten bestimmt werden, wobei 16 Arten als nicht indigen bezeichnet werden können. An den südlichen Standorten konnten sechs nicht indigene Arten identifiziert werden, an den nördlichen fünfzehn. Die Anzahl der Arten variierte zwischen eins und fünfzehn in den gesamten Vergesellschaftungen der großen Fraktion (500 μm – 1mm), und zwischen eins und achtzehn in den Lebend-Vergesellschaftungen der kleinen Fraktion (125 – 500 μm). Anhand der Häufigkeit der Arten wurde ein nMDS Plot und eine ANOSIM Berechnung erstellt. Der nMDS Plot und die ANOSIM Berechnung wurden in der großen Fraktion für die Lebend-Vergesellschaftung und für die gesamte Vergesellschaftung erstellt. Dabei zeigten die Ergebnisse, dass die Vergesellschaftungen der unterschiedlichen Proben eine Ungleichheit bezüglich der Lage des Standortes aufweisen, genauer eine Trennung südlicher und nördlicher Standorte. Für die kleine Fraktion wurde ein nMDS Plot und eine ANOSIM Berechnung für die Lebend-Vergesellschaftung erstellt, dabei konnte kein Cluster festgestellt werden. Die am häufigsten auftretende Art in der großen Fraktion war an allen nördlichen Standorten die nicht indigene Art *Amphistegina lobifera** mit relativen Häufigkeiten bis zu 97%, sowohl im Frühling als auch im Herbst. An den südlichen Standorten waren die häufigsten Arten *Textularia agglutinans* in der Lebend-Vergesellschaftung und *Ammonia beccarii* in der gesamten Vergesellschaftung während beider Jahreszeiten. Die häufigsten Arten in der Lebend-Vergesellschaftung der kleinen Fraktion gehörten an den südlichen Standorten zu den

Gattungen *Rosalina* spp., *Textularia* spp. oder zu *Pararotalia calcariformata**. An den nördlichen Standorten dominierten die nicht indigenen Arten *Amphistegina lobifera**, *Pseudohauerinella diversa** und die indigene Art *Textularia agglutinans*.

Die Ergebnisse dieser Arbeit zeigen ein hohes Vorkommen nicht indigener Arten an der israelischen Mittelmeer-Küste. Da die meisten dieser Arten ursprünglich aus tropischen Gewässern stammen und steigende Meerestemperaturen aufgrund der Klimaerwärmung zu erwarten sind, sollte eine kontinuierliche Beobachtung in diesem Gebiet erfolgen, und die faunale Entwicklung weiter zu verfolgen.

7.2 Species list of the big fraction size (500 µm - 1mm)

7.2.1 Total assemblages

Species	S1 s	S1 a	S2 s	S2 a	N1 s	N1 a	N2 s	N2 a	N3
<i>Adelosina cliarensis</i>	0	1	0	0	0	0	0	0	0
<i>Adelosina colomi</i>	0	0	0	0	1	0	0	0	0
<i>Adelosina dubia</i>	0	0	13	0	0	0	0	0	0
<i>Adelosina intricata</i>	0	0	40	13	0	0	0	0	1
<i>Adelosina mediterraneensis</i>	0	2	19	20	0	0	8	0	0
<i>Adelosina pulchella</i>	0	0	50	20	0	0	0	0	0
<i>Adelosina aff. pulchella</i>	1	0	0	0	0	0	0	0	0
<i>Adelosina spp.</i>	0	0	5	7	0	0	0	0	0
<i>Ammonia beccarii</i>	262	274	287	221	1	2	0	0	0
<i>Ammonia batava subs. compacta</i>	0	0	1	1	0	0	0	0	0
<i>Ammonia spp.</i>	1	6	0	0	0	0	0	0	0
<i>Amphistegina lobifera</i>	0	0	0	0	264	243	347	292	324
<i>Cycloforina aff. contorta</i>	1	0	0	0	0	0	0	0	0
<i>Elphidium crispum</i>	0	0	0	0	1	0	0	0	0
<i>Elphidium macellum</i>	0	0	1	0	0	0	0	0	1
<i>Elphidium striatopunctatum</i>	1	0	0	0	0	0	0	0	0
<i>Elphidium spp.</i>	2	0	0	0	0	0	0	0	0
<i>Epistomaroides punctatum</i>	0	0	0	0	1	2	0	1	0
<i>Eponides repandus</i>	0	0	3	3	0	0	0	0	0
<i>Heterostegina depressa</i>	0	0	0	0	2	4	0	2	18
<i>Hyalin spp.</i>	0	0	0	0	0	2	0	0	0
<i>Massilina secans</i>	0	1	0	2	0	0	0	0	3
<i>Miliolide spp.</i>	0	1	54	24	0	0	1	0	4

<i>Miliolinella elongata</i>	0	1	0	0	0	0	0	0	0
<i>Miliolinella subrotunda</i>	0	0	1	0	0	0	0	0	0
<i>Peneroplis pertusus</i>	0	0	0	0	5	4	0	0	0
<i>Peneroplis planatus</i>	0	0	0	0	7	0	1	1	13
<i>Planorbulina mediterranensis</i>	1	0	0	0	1	3	1	0	0
<i>Polymorphina</i> sp.1	0	0	0	1	0	0	0	0	0
<i>Pseudohauerinella diversa</i>	0	0	0	0	0	2	1	0	4
<i>Quinqueloculina berthelotiana</i>	0	0	0	0	0	1	0	0	0
<i>Quinqueloculina disparilis</i>	0	0	0	0	0	0	0	0	6
<i>Quinqueloculina limbata</i>	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina schlumbergeri</i>	0	1	0	0	0	0	0	0	0
<i>Quinqueloculina variolata</i>	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina viennensis</i>	0	0	0	0	0	0	0	0	2
<i>Quinqueloculina vulgaris</i>	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina</i> spp.	0	0	0	1	0	0	0	0	0
<i>Siphonaperta</i> spp.	1	0	1	0	0	0	0	0	0
<i>Sorites orbiculus</i>	0	0	0	0	1	2	0	0	16
<i>Sorites</i> spp.	0	0	0	0	0	4	0	0	8
<i>Spiroloculina angulata</i>	0	0	0	0	0	0	0	0	1
<i>Spiroloculina communis</i>	5	0	1	0	0	0	0	0	0
<i>Spiroloculina excavata</i>	1	0	0	0	0	0	0	0	2
<i>Spiroloculina excisa</i>	0	0	0	2	0	0	0	0	0
<i>Spiroloculina</i> sp.2	0	0	2	0	0	0	0	0	2
<i>Spiroloculina</i> spp.	0	0	0	0	0	1	0	0	0
<i>Textularia agglutinans</i>	38	64	4	1	22	43	31	70	38
<i>Textularia truncata</i>	1	0	0	0	0	0	0	0	0
<i>Textularia</i> spp.	7	1	0	0	4	0	0	5	4
<i>Triloculina trigonula</i>	1	0	9	0	0	0	0	0	1

7.2.2 Living and dead assemblages

	S1 spring		S1 autumn		S2 spring		S2 autumn		N1 spring		N1 autumn		N2 spring		N2 autumn		N3 autumn	
	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead
<i>Adelosina cliarensis</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina colomi</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Adelosina dubia</i>	0	0	0	0	0	13	0	0	0	0	0	0	0	0		0	0	0
<i>Adelosina intricata</i>	0	0	0	0	0	40	0	13	0	0	0	0	0	0	0	0	0	1
<i>Adelosina mediterraneanensis</i>	0	0	0	2	0	19	0	20	0	0	0	0	0	8	0	0	0	0
<i>Adelosina pulchella</i>	0	0	0	0	0	50	0	20	0	0	0	0	0	0	0	0	0	0
<i>Adelosina aff pulchella</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina spp.</i>	0	0	0	0	0	5	0	7	0	0	0	0	0	0	0	0	0	0
<i>Ammonia beccarii</i>	2	260	1	273	3	284	0	221	0	1	0	2	0	0	0	0	0	0
<i>Ammonia batava subs. compacta</i>	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
<i>Ammonia spp.</i>	0	1	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amphistegina lobifera</i>	0	0	0	0	0	0	0	0	65	199	44	199	261	86	150	142	290	34
<i>Cycloforina aff contorta</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium crispum</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Elphidium macellum</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1

<i>Elphidium striatopunctatum</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> spp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epistomaroides punctatum</i>	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	0
<i>Eponides repandus</i>	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	0
<i>Heterostegina depressa</i>	0	0	0	0	0	0	0	0	0	2	0	8	0	0	0	2	0	18
<i>Hyalin</i> spp.	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
<i>Massilina secans</i>	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	3
<i>Miliolinella elongata</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Miliolinella subrotunda</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Miliolide</i> spp.	0	0	0	1	0	54	0	24	0	0	0	0	0	1	0	0	0	4
<i>Peneroplis pertusus</i>	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
<i>Peneroplis planatus</i>	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	1	0	13
<i>Planorbulina mediterraneensis</i>	1	0	0	0	0	0	0	0	0	1	0	3	0	1	0	0	0	0
<i>Polymorphina</i> sp.1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Pseudohauerinella diversa</i>	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	4
<i>Quinqueloculina berthelotiana</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Quinqueloculina disparilis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
<i>Quinqueloculina limbata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina schlumbergeri</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

<i>Quinqueloculina variolata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina viennensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Quinqueloculina vulgaris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Quinqueloculina spp.</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Siphonaperta spp.</i>	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorites orbiculus</i>	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	16
<i>Sorites spp.</i>	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	8
<i>Spiroloculina angulata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Spiroloculina communis</i>	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina excavata</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Spiroloculina excisa</i>	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina sp.2</i>	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
<i>Spiroloculina spp</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Textularia agglutinans</i>	22	16	30	34	3	1	1	0	6	16	3	40	21	10	26	44	6	32
<i>Textularia truncata</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Textularia spp.</i>	0	7	0	1	0	0	0	0	0	4	0	0	0	0	0	5	0	4
<i>Triloculina trigonula</i>	0	1	0	0	1	8	0	0	0	0	0	0	0	0	0	0	0	1

7.3 Species list of the small fraction size (125 - 500 µm)

7.3.1 Total assemblages

Species	S1 s	S1 a	S2 s	S2 a	N1 s	N1 a	N2 s	N2 a	N3 s	N3 a
<i>Adelosina cliarensis</i>	4	16	3	11	1	2	0	0	4	2
<i>Adelosina colomi</i>	0	0	0	0	0	0	0	0	0	0
<i>Adelosina dubia</i>	0	0	1	0	7	0	0	0	0	0
<i>Adelosina intricata</i>	0	0	3	7	0	0	0	0	0	0
<i>Adelosina mediterrane-sis</i>	0	0	2	14	0	0	0	0	0	0
<i>Adelosina cf. mediterrane-sis</i>	0	0	1	1	0	0	0	0	0	0
<i>Adelosina partschi</i>	0	1	3	0	0	0	0	0	1	0
<i>Adelosina pulchella</i>	0	0	5	18	5	2	0	0	4	0
<i>Adelosina aff. pulchella</i>	0	0	0	0	0	0	0	0	0	0
<i>Adelosina sp.1</i>	0	0	2	5	0	0	0	0	0	0
<i>Adelosina spp</i>	0	0	8	9	0	0	2	0	0	3
<i>Affinetrina planciana</i>	0	0	0	0	2	2	3	1	0	5
<i>Ammoglobigerina globigeriniformis</i>	1	0	1	8	0	0	1	0	0	0
<i>Ammonia batava subs. compacta</i>	1	1	19	5	1	2	0	0	0	0

<i>Ammonia beccarii</i>	15	6	21	28	0	0	0	0	0	0
<i>Ammonia tepida</i>	6	5	6	31	1	0	2	0	0	2
<i>Ammonia</i> sp.1	8	6	13	21	5	0	2	0	0	2
<i>Ammonia</i> sp.2	39	18	6	9	0	0	1	1	5	3
<i>Ammonia</i> spp.	3	13	9	16	0	0	1	0	7	0
<i>Amphistegina lobifera</i>	0	0	0	0	59	179	11	358	2	35
<i>Amphistegina</i> spp	0	0	0	0	0	0	1	0	0	0
<i>Articulina pacifica</i>	0	0	0	0	1	0	0	1	0	0
<i>Articulina</i> spp.	0	0	0	0	0	0	0	0	0	1
<i>Asterigerinata mamilla</i>	1	0	3	4	13	4	1	0	18	13
<i>Astrononion stelligerum</i>	0	0	1	1	0	1	0	0	0	0
<i>Bolivina variabilis</i>	9	3	1	0	1	0	1	0	0	3
<i>Borelis schlumbergeri</i>	0	0	0	0	0	0	0	0	0	2
<i>Buccella granulata</i>	2	1	2	0	1	0	0	0	3	0
<i>Bulimina elongata</i>	0	0	0	3	0	0	0	0	0	0
<i>Cancris auriculus</i>	0	0	0	0	1	0	0	0	0	0
<i>Carterina spiculotesta</i>	0	0	0	0	0	1	0	0	0	0
<i>Cibicides pseudobatululus</i>	1	0	2	0	2	0	0	1	0	1
<i>Cibicides pseudoungeriana</i>	0	0	0	0	0	0	1	0	0	0
<i>Cibicides refulgens</i>	0	0	0	0	1	0	0	0	1	0
<i>Cibicides</i> sp.1	0	0	0	1	0	2	0	1	0	1

<i>Cibicides</i> spp.	0	2	1	3	0	5	0	0	0	0
<i>Cibicoides lobatula</i>	1	0	0	7	5	0	2	0	1	3
<i>Cibicoides variabilis</i>	1	3	0	3	9	7	4	7	1	1
<i>Conorbella pulvinata</i>	0	0	0	1	0	0	0	0	0	0
<i>Criboelphidium excavatum</i>	0	0	1	0	0	0	0	0	0	0
<i>Cycloforina</i> sp.1	0	0	0	0	1	1	0	0	3	3
<i>Cycloforina</i> spp.	0	0	0	0	0	1	0	0	1	0
<i>Cymbaloporella squamosa</i>	0	0	0	0	1	3	2	1	1	1
<i>Discorbinella bertheloti</i>	0	0	1	0	0	0	0	0	1	0
<i>Elphidium aculeatum</i>	0	0	0	0	1	0	0	0	0	0
<i>Elphidium charlottense</i>	0	2	0	2	0	0	0	0	1	2
<i>Elphidium crispum</i>	0	1	1	0	5	0	1	0	2	1
<i>Elphidium macellum</i>	0	0	0	0	0	0	0	0	1	2
<i>Elphidium striatopunctatum</i>	0	0	0	0	0	0	0	0	0	0
<i>Elphidium</i> spp.	0	0	1	2	0	0	0	0	0	0
<i>Epistomaroides punctatum</i>	0	0	0	0	0	6	1	5	0	1
<i>Eponides repandus</i>	0	0	1	6	2	1	0	0	0	0
<i>Flintinoides labiosa</i>	0	0	3	2	2	1	3	0	0	0
<i>Gavelinopsis praegei</i>	0	0	0	0	2	0	1	0	3	5
<i>Glabratella hexacamerata</i>	0	0	0	0	54	6	0	3	1	2

<i>Gyroidinoides</i> spp.	1	0	0	0	0	0	0	0	0	0
<i>Hanzawaia rhodiensis</i>	0	0	0	0	0	0	1	0	0	0
<i>Haynesina depressula</i>	0	0	0	1	2	0	0	0	0	1
<i>Heterostegina depressa</i>	0	0	0	0	5	5	13	1	7	23
<i>Hyalin</i> spp.	0	10	0	1	9	0	6	2	11	0
<i>Massilina secans</i>	0	1	0	0	0	0	0	1	0	5
<i>Miliolinella elongata</i>	0	0	0	0	0	0	4	0	0	7
<i>Miliolinella subrotunda</i>	9	3	10	3	6	2	27	1	0	7
<i>Miliolinella</i> spp.	0	1	0	0	1	0	0	3	1	0
<i>Miliolide</i> spp.	8	3	29	27	31	11	12	3	9	25
<i>Neoconorbina terquemi</i>	0	0	0	0	0	1	1	0	0	0
<i>Neorotalia calcar</i>	0	0	0	0	0	0	1	0	0	2
<i>Nubeculina</i> sp.1	2	1	3	0	0	0	0	0	0	0
<i>Pararotalia calcariformata</i>	138	284	0	0	0	2	22	2	66	37
<i>Pararotalia</i> spp.	0	0	0	0	0	0	0	0	7	0
<i>Peneroplis pertusus</i>	0	0	0	0	17	15	45	7	52	29
<i>Peneroplis planatus</i>	0	0	0	0	14	17	5	0	4	4
<i>Peneroplis</i> spp.	0	0	0	0	3	6	2	0	0	4
<i>Pileolina patelliformis</i>	0	0	0	0	4	3	1	2	2	2
<i>Planoglabratella opercularis</i>	0	0	0	0	2	0	1	0	0	0
<i>Planogypsina</i> sp.1	0	1	0	0	0	0	0	0	0	0

<i>Planorbulina mediterraneensis</i>	2	6	3	6	8	9	2	1	0	4
<i>Polymorphina</i> sp.1	2	0	1	1	1	0	0	0	0	0
<i>Polymorphina</i> sp.2	0	0	0	1	0	0	0	0	0	0
<i>Porosononion granosum</i>	6	11	15	19	0	1	0	0	0	1
<i>Pseudohaueriella diversa</i>	0	1	0	0	42	93	36	57	22	126
<i>Pseudohaueriella</i> spp.	0	0	0	0	6	0	12	1	48	17
<i>Pseudomassilina australis</i>	0	0	0	0	0	0	0	0	1	0
<i>Pseudoschlumbergerina ovata</i>	0	0	0	0	8	3	4	0	49	16
<i>Pseudotriloculina subgranulata</i>	0	0	1	0	3	1	0	2	0	0
<i>Pyrgo oblonga</i>	0	0	0	0	0	0	1	0	1	0
<i>Pyrgo striolata</i>	0	0	0	0	0	0	1	0	0	1
<i>Quinqueloculina agglutinans</i>	0	1	0	0	3	3	1	0	1	2
<i>Quinqueloculina berthelotiana</i>	0	0	0	0	0	8	4	0	0	14
<i>Quinqueloculina bicarinata</i>	0	0	0	0	0	0	0	0	1	0
<i>Quinqueloculina bosciana</i>	1	0	0	0	1	0	0	0	0	0
<i>Quinqueloculina disparilis</i>	0	0	2	0	3	0	1	0	8	1
<i>Quinqueloculina irregularis</i>	0	0	0	0	0	0	0	0	2	1
<i>Quinqueloculina laevigata</i>	0	0	0	0	0	0	0	1	0	0

<i>Quinqueloculina lamarckiana</i>	0	1	0	0	6	4	0	0	12	3
<i>Quinqueloculina</i> cf. <i>multimarginata</i>	0	1	0	0	0	0	0	0	1	0
<i>Quinqueloculina pseudobuchiana</i>	2	0	0	0	0	0	7	0	0	0
<i>Quinqueloculina seminula</i>	4	3	6	3	1	0	2	0	2	2
<i>Quinqueloculina schlumbergeri</i>	0	0	1	0	7	2	2	0	3	1
<i>Quinqueloculina</i> aff. <i>tropicalis</i>	0	0	1	0	0	0	0	0	0	0
<i>Quinqueloculina ungeriana</i>	0	0	0	0	0	0	0	0	1	0
<i>Quinqueloculina</i> sp.1	0	0	2	0	1	0	1	1	1	6
<i>Quinqueloculina</i> spp.	0	5	3	0	0	4	9	0	0	1
<i>Reusella spinulosa</i>	1	0	0	0	0	1	0	0	3	0
<i>Rosalina bradyi</i>	0	0	0	1	0	2	0	0	0	0
<i>Rosalina floridensis</i>	0	0	0	3	0	0	0	0	0	0
<i>Rosalina globularis</i>	9	27	40	2	6	1	4	0	1	9
<i>Rosalina</i> aff. <i>globularis</i>	12	2	5	7	0	2	24	1	0	0
<i>Rosalina macropora</i>	0	0	0	0	5	1	3	1	5	6
<i>Rosalina williamsoni</i>	0	0	0	0	1	0	0	0	0	0
<i>Rosalina</i> spp.	3	0	0	0	3	0	0	1	0	0

<i>Sahulia conica</i>	0	10	0	7	1	13	0	4	0	4
<i>Sigmoilina costata</i>	0	0	0	0	2	1	0	0	0	0
<i>Siphonaperta horrida</i>	0	0	5	2	0	0	0	0	0	0
<i>Siphonaperta</i> spp.	0	0	0	0	0	0	0	0	0	0
<i>Sorites orbiculus</i>	0	0	0	0	3	10	0	1	0	2
<i>Sorites</i> spp.	7	0	0	0	8	3	0	0	0	2
<i>Sphaerogypsina globulus</i>	0	0	0	0	1	1	0	0	0	0
<i>Spirillina limbata</i>	0	0	0	0	1	1	0	0	0	0
<i>Spiroloculina angulata</i>	0	0	0	0	5	3	3	0	1	0
<i>Spiroloculina angulosa</i>	0	0	0	0	1	0	0	0	0	3
<i>Spiroloculina antillarum</i>	0	0	1	0	0	0	1	0	1	1
<i>Spiroloculina communis</i>	1	0	2	1	2	1	0	0	0	1
<i>Spiroloculina excavata</i>	0	0	1	0	1	0	0	0	0	0
<i>Spiroloculina subimpressa</i>	0	0	0	0	0	0	0	0	0	1
<i>Spiroloculina</i> sp.1	0	2	0	0	0	0	0	0	0	0
<i>Spiroloculina</i> sp.2	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina</i> sp.3	0	0	0	0	0	1	0	0	0	0
<i>Spiroloculina</i> spp.	0	1	0	1	0	3	2	0	1	4
<i>Textularia agglutinans</i>	2	3	4	6	4	6	18	20	5	11
<i>Textularia pala</i>	3	0	16	2	6	1	2	0	3	1

<i>Textularia truncata</i>	0	0	0	0	0	0	0	0	0	0	5
<i>Textularia</i> sp.1	26	4	6	8	27	22	145	63	12	10	
<i>Textularia</i> spp.	1	0	2	0	18	5	0	5	4	2	
<i>Tretomphalus bulloides</i>	0	0	1	0	0	0	1	1	1	0	
<i>Triloculina marioni</i>	7	6	11	19	0	0	0	0	0	0	
<i>Triloculina oblonga</i>	1	2	0	0	0	1	0	0	0	1	
<i>Triloculina plicata</i>	0	0	0	0	1	0	1	0	0	1	
<i>Triloculina schreiberiana</i>	1	1	0	0	0	0	0	0	0	0	
<i>Triloculina trigonula</i>	1	0	9	0	3	1	3	1	5	2	
<i>Triloculina</i> spp.	0	2	3	3	0	2	3	0	3	2	
<i>Valvulineria</i> spp.	0	0	0	0	1	0	0	0	0	0	
<i>Vertebralina striata</i>	0	0	0	0	4	7	0	0	0	0	
<i>Wiesnerella auriculata</i>	0	0	0	0	0	1	0	0	0	0	

7.3.2 Living and dead assemblages

Species	S1 spring		S1 autumn		S2 spring		S2 autumn		N1 spring		N1 autumn		N2 spring		N2 autumn		N3 spring		N3 autumn	
	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead	Living	Dead
<i>Adelosina cliarensis</i>	0	4	0	16	0	3	0	11	0	1	0	2	0	0	0	0	0	4	0	2
<i>Adelosina colomi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina dubia</i>	0	0	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0
<i>Adelosina intricata</i>	0	0	0	0	0	3	0	7	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina mediterraneensis</i>	0	0	0	0	0	2	0	14	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina</i> cf. <i>mediterraneensis</i>	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina partschi</i>	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0

<i>Adelosina pulchella</i>	0	0	0	0	0	5	0	18	0	5	0	2	0	0	0	0	0	4	0	0
<i>Adelosina aff. pulchella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina sp.1</i>	0	0	0	0	0	2	0	5	0	0	0	0	0	0	0	0	0	0	0	0
<i>Adelosina spp.</i>	0	0	0	0	0	8	0	9	0	0	0	0	0	2	0	0	0	0	0	3
<i>Affinetrina planciana</i>	0	0	0	0	0	0	0	0	0	2	0	2	1	2	0	1	0	0	0	5
<i>Ammoglobigerina globigeriniformis</i>	0	1	0	0	0	1	4	4	0	0	0	0	0	1	0	0	0	0	0	0
<i>Ammonia batava subs. compacta</i>	0	1	0	1	0	19	0	5	0	1	0	2	0	0	0	0	0	0	0	0
<i>Ammonia beccarii</i>	0	15	0	6	0	21	0	28	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ammonia tepida</i>	0	6	0	5	0	6	0	31	0	1	0	0	0	2	0	0	0	0	0	2
<i>Ammonia sp.1</i>	0	8	0	6	0	13	0	21	0	5	0	0	0	2	0	0	0	0	0	2
<i>Ammonia sp.2</i>	0	39	0	18	0	6	0	9	0	0	0	0	0	1	0	1	0	5	0	3
<i>Ammonia spp.</i>	0	3	0	13	0	9	0	16	0	0	0	0	0	1	0	0	0	7	0	0
<i>Amphistegina lobifera</i>	0	0	0	0	0	0	0	0	41	18	169	10	10	1	356	2	0	2	28	7
<i>Amphistegina spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Articulina pacifica</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
<i>Articulina spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Asterigerinata mamilla</i>	0	1	0	0	0	3	0	4	2	11	0	4	0	1	0	0	0	18	0	13
<i>Astrononion stelligerum</i>	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
<i>Bolivina variabilis</i>	0	9	0	3	0	1	0	0	0	1	0	0	0	1	0	0	0	0	2	1
<i>Borelis schlumbergeri</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
<i>Buccella granulata</i>	0	2	0	1	0	2	0	0	0	1	0	0	0	0	0	0	0	3	0	0
<i>Bulimina elongata</i>	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cancris auriculus</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Carterina spiculotesta</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Cibicides pseudolobatus</i>	0	1	0	0	2	0	0	0	0	2	0	0	0	0	1	0	0	0	0	1
<i>Cibicides pseudoungeriana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Cibicides refulgens</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
<i>Cibicides sp.1</i>	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	1
<i>Cibicides spp.</i>	0	0	1	1	0	1	0	3	0	0	1	4	0	0	0	0	0	0	0	0
<i>Cibicoides lobatula</i>	0	1	0	0	0	0	6	1	0	5	0	0	0	2	0	0	0	1	0	3
<i>Cibicoides variabilis</i>	0	1	0	3	0	0	3	0	0	9	2	5	1	3	5	2	0	1	1	0
<i>Conorbella pulvinata</i>	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Criboelphidium excavatum</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cycloforina sp.1</i>	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	3	0	3
<i>Cycloforina spp.</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0

<i>Cymbaloporetta squam- mosa</i>	0	0	0	0	0	0	0	0	0	1	1	2	1	1	0	1	0	1	0	1
<i>Discorbinella bertheloti</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Elphidium aculeatum</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Elphidium charlottense</i>	0	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	2
<i>Elphidium crispum</i>	0	0	0	1	0	1	0	0	0	5	0	0	0	1	0	0	0	2	0	1
<i>elphidium macellum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
<i>Elphidium striatopunctatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium spp.</i>	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epistomaroides punctatum</i>	0	0	0	0	0	0	0	0	0	0	0	6	1	0	1	4	0	0	0	1
<i>Eponides repandus</i>	0	0	0	0	0	1	0	6	0	2	0	1	0	0	0	0	0	0	0	0
<i>Flintinoides labiosa</i>	0	0	0	0	0	3	0	2	0	2	0	1	1	2	0	0	0	0	0	0
<i>Gavelinopsis praegeri</i>	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	3	0	5
<i>Glabratella hexacamerata</i>	0	0	0	0	0	0	0	0	30	24	1	5	0	0	0	3	0	1	0	2
<i>Gyroidinoides spp.</i>	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hanzawaia rhodiensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
<i>Haynesina depressula</i>	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	1
<i>Heterostegina depressa</i>	0	0	0	0	0	0	0	0	0	5	0	5	0	13	0	1	0	7	3	20
<i>Hyalin spp.</i>	0	0	0	10	0	0	0	1	0	9	0	0	0	6	0	2	0	11	0	0
<i>Massilina secans</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	3
<i>Miliolinella elongata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	3	4
<i>Miliolinella subrotunda</i>	6	3	1	2	8	2	0	3	1	5	0	2	23	4	0	1	0	0	4	3
<i>Miliolinella spp.</i>	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	3	0	1	0	0
<i>Miliolid spp.</i>	0	8	0	3	0	29	0	27	0	31	0	11	0	12	0	3	0	9	0	25
<i>Neoconorbina terquemi</i>	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
<i>Neorotalia calcar</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0
<i>Nubeculina sp.1</i>	0	2	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pararotalia calcariformata</i>	134	4	275	9	0	0	0	0	0	0	0	2	1	21	0	2	1	65	1	36
<i>Pararotalia spp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0
<i>Peneroplis pertusus</i>	0	0	0	0	0	0	0	0	1	16	0	15	24	21	2	5	0	52	0	29
<i>Peneroplis planatus</i>	0	0	0	0	0	0	0	0	0	14	0	17	2	3	0	0	0	4	0	4
<i>Peneroplis spp.</i>	0	0	0	0	0	0	0	0	0	3	0	6	0	2	0	0	0	0	0	4
<i>Pileolina patelliformis</i>	0	0	0	0	0	0	0	0	0	4	0	3	0	1	0	2	0	2	0	2
<i>Planoglabratella opercularis</i>	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
<i>Planogypsina sp.1</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Planorbulina mediterraneensis</i>	0	2	1	5	0	3	3	3	0	8	1	8	0	2	0	1	0	0	0	4

<i>Polymorphina</i> sp.1	0	2	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
<i>Polymorphina</i> sp.2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Porosonion granosum</i>	0	6	0	11	0	15	1	18	0	0	0	1	0	0	0	0	0	0	0	1
<i>Pseudohauerinella diversa</i>	0	0	1	0	0	0	0	0	36	6	86	7	33	3	57	0	0	22	113	13
<i>Pseudohauerinella</i> spp.	0	0	0	0	0	0	0	0	0	6	0	0	0	12	0	1	0	48	0	17
<i>Pseudomassilina australis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Pseudoschlumbergerina ovata</i>	0	0	0	0	0	0	0	0	0	8	0	3	0	4	0	0	0	49	0	16
<i>Pseudotriloculina subgranulata</i>	0	0	0	0	0	1	0	0	0	3	0	1	0	0	0	2	0	0	0	0
<i>Pyrgo oblonga</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
<i>Pyrgo striolata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
<i>Quinqueloculina agglutinans</i>	0	0	0	1	0	0	0	0	0	3	0	3	0	1	0	0	0	1	0	2
<i>Quinqueloculina berthelotiana</i>	0	0	0	0	0	0	0	0	0	0	0	8	0	4	0	0	0	0	0	14
<i>Quinqueloculina bicarinata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Quinqueloculina bosciana</i>	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina disparilis</i>	0	0	0	0	0	2	0	0	0	3	0	0	0	1	0	0	0	8	0	1
<i>Quinqueloculina irregularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
<i>Quinqueloculina laevigata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Quinqueloculina lamarckiana</i>	0	0	0	1	0	0	0	0	0	6	0	4	0	0	0	0	0	12	1	2
<i>Quinqueloculina</i> cf. <i>multimarginata</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Quinqueloculina pseudobuchiana</i>	0	2	0	0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0
<i>Quinqueloculina seminula</i>	0	4	0	3	0	6	0	3	0	1	0	0	0	2	0	0	0	2	0	2
<i>Quinqueloculina schlumbergeri</i>	0	0	0	0	0	1	0	0	0	7	0	2	0	2	0	0	0	3	0	1
<i>Quinqueloculina</i> aff. <i>tropicalis</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Quinqueloculina ungeriana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
<i>Quinqueloculina</i> sp.1	0	0	0	0	0	2	0	0	0	1	0	0	1	0	1	0	0	1	1	5
<i>Quinqueloculina</i> spp.	0	0	0	5	0	3	0	0	0	0	0	4	0	9	0	0	0	0	0	1
<i>Reusella spinulosa</i>	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0
<i>Rosalina bradyi</i>	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0

<i>Rosalina floridensis</i>	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rosalina globularis</i>	2	7	6	21	17	23	0	2	1	5	0	1	3	1	0	0	0	1	9	0
<i>Rosalina aff. globularis</i>	9	3	2	0	1	4	6	1	0	0	1	1	22	2	1	0	0	0	0	0
<i>Rosalina macropora</i>	0	0	0	0	0	0	0	0	2	3	0	1	1	2	0	1	0	5	0	6
<i>Rosalina williamsoni</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Rosalina</i> spp.	2	1	0	0	0	0	0	0	1	2	0	0	0	0	0	1	0	0	0	0
<i>Sahulia conica</i>	0	0	9	1	0	0	6	1	0	1	8	5	0	0	0	4	0	0	1	3
<i>Sigmoilinita costata</i>	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0
<i>Siphonaperta horrida</i>	0	0	0	0	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Siphonaperta</i> spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorites orbiculus</i>	0	0	0	0	0	0	0	0	0	3	0	10	0	0	0	1	0	0	0	2
<i>Sorites</i> spp.	0	7	0	0	0	0	0	0	0	8	0	3	0	0	0	0	0	0	0	2
<i>Sphaerogypsina globula</i>	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
<i>Spirillina limbata</i>	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
<i>Spiroloculina angulata</i>	0	0	0	0	0	0	0	0	0	5	0	3	0	3	0	0	0	1	0	0
<i>Spiroloculina angulosa</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
<i>Spiroloculina antillarum</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	1
<i>Spiroloculina communis</i>	0	1	0	0	1	1	0	1	0	2	0	1	0	0	0	0	0	0	0	1
<i>Spiroloculina excavata</i>	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina subimpressa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
<i>Spiroloculina</i> sp.1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina</i> sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spiroloculina</i> sp.3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
<i>Spiroloculina</i> spp.	0	0	0	1	0	0	0	1	0	0	0	3	0	2	0	0	0	1	0	4
<i>Textularia agglutinans</i>	0	2	1	2	2	2	1	5	0	4	2	4	17	1	18	2	0	5	7	4
<i>Textularia pala</i>	1	2	0	0	16	0	1	1	2	4	0	1	0	2	0	0	0	3	0	1
<i>Textularia truncata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
<i>Textularia</i> sp.1	22	4	4	0	5	1	0	8	15	12	15	7	133	12	50	13	0	12	5	5
<i>Textularia</i> spp.	0	1	0	0	0	2	0	0	0	18	0	5	0	0	0	5	0	4	0	2
<i>Tretomphalus bulloides</i>	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	1	0	0
<i>Triloculina marioni</i>	2	5	0	6	6	5	0	19	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triloculina oblonga</i>	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
<i>Triloculina plicata</i>	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1
<i>Triloculina schreiberiana</i>	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Triloculina trigonula</i>	0	1	0	0	0	9	0	0	0	3	0	1	0	3	1	0	0	5	0	2
<i>Triloculina</i> spp.	0	0	0	2	0	3	0	3	0	0	0	2	0	3	0	0	0	3	0	2
<i>Valvulineria</i> spp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Vertebralina striata</i>	0	0	0	0	0	0	0	0	0	4	0	7	0	0	0	0	0	0	0	0

<i>Wiesnerella auriculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
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7.4 List of used splits

7.4.1 Big fraction size (500 µm - 1 mm)

	Split (weight of split)	Number of individuals
S1 spring	1/16 (5.825 g)	323
S1 autumn	1/32 (6.52 g)	352
S2 spring	1/32 (0.8 g)	491
S2 autumn	1/32 (1.2 g)	316
N1 spring	1/64 (0.84 g)	310
N1 autumn	1/32 (0.94 g)	313
N2 spring	1/64 (0.60 g)	390
N2 autumn	1/32 (0.84 g)	371
N3 autumn	Split 1/32 (0.96 g)	451

7.4.2 Small fraction size (125 - 500 µm)

	Split (weight of split)	Number of individuals
S1 spring	1/32 (0.41 g)	342
S1 autumn	1/8 (0.34 g)	471
S2 spring	1/256 (0.26 g)	304
S2 autumn	1/16 (0.88 g)	342
N1 spring	1/128 (0.18 g)	471
N1 autumn	1/128 (0.17 g)	506
N2 spring	1/64 (0.14 g)	475
N2 autumn	1/64 (0.14 g)	562
N3 spring	1/256 (0.25 g)	418
N3 autumn	1/32 (0.33 g)	504