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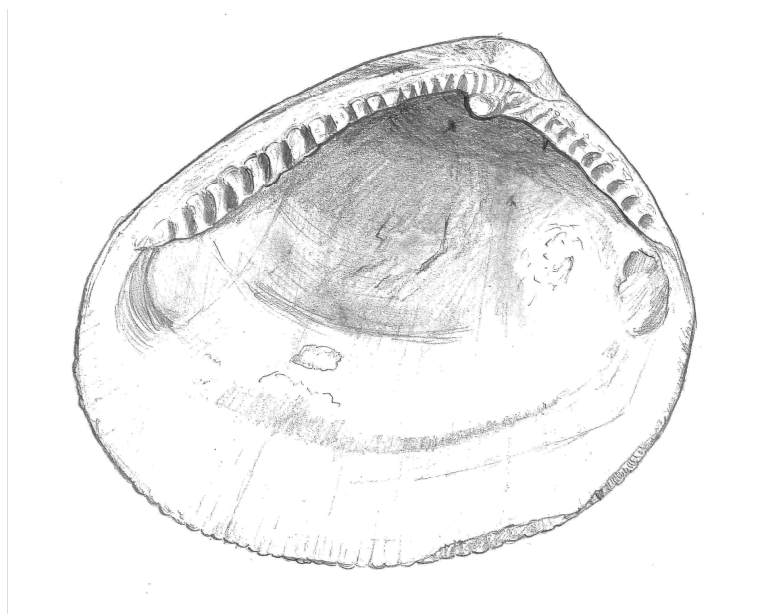
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PALEOENVIRONMENTAL RECONSTRUCTION OF THE GULF OF ELEFSINA
DURING HOLOCENE, BASED ON MACROFAUNAL ANALYSIS

MASTER THESIS

MSC 'APPLIED AND ENVIRONMENTAL GEOLOGY'

SPECIALIZATION FIELD: 'STRUCTURE AND EVOLUTION OF SEDIMENTARY BASINS'



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ΑΡΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ
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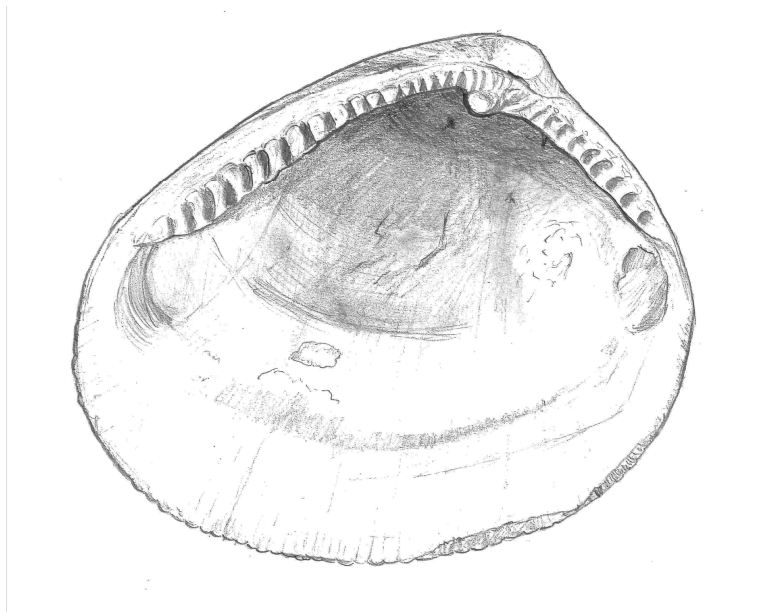


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PALEOENVIRONMENTAL RECONSTRUCTION OF THE GULF OF ELEFSINA DURING
HOLOCENE, BASED ON MACROFAUNAL ANALYSIS - *Master Thesis*

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Απαγορεύεται η αντιγραφή, αποθήκευση και διανομή της παρούσας εργασίας, εξ ολοκλήρου ή τμήματος αυτής, για εμπορικό σκοπό. Επιτρέπεται η ανατύπωση, αποθήκευση και διανομή για σκοπό μη κερδοσκοπικό, εκπαιδευτικής ή ερευνητικής φύσης, υπό την προϋπόθεση να αναφέρεται η πηγή προέλευσης και να διατηρείται το παρόν μήνυμα. Ερωτήματα που αφορούν τη χρήση της εργασίας για κερδοσκοπικό σκοπό πρέπει να απευθύνονται προς το συγγραφέα.

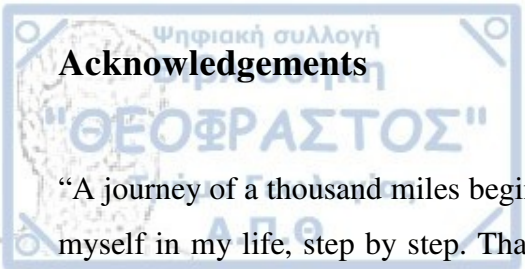
Οι απόψεις και τα συμπεράσματα που περιέχονται σε αυτό το έγγραφο εκφράζουν το συγγραφέα και δεν πρέπει να ερμηνευτεί ότι εκφράζουν τις επίσημες θέσεις του Α.Π.Θ.

Εικόνα Εξωφύλλου: *Nucula* species

The Gulf of Elefsina is a geomorphological embayment located in the northernmost part of the Saronic Gulf in central Greece. In order to assess the paleoenvironmental evolution of the area, an analysis was carried out using mollusk species retrieved from a locally drilled core sample named S2P. The methods used in this study included qualitative - quantitative - statistical analysis of the faunal specimens, macroscopic lithology description of the core sample, radiocarbon dating of core material and sand/mud percentages calculation. The collected specimens amounted to a total of 10500, from which 6661 individuals were observed, belonging to 44 mollusk genera. Four faunal assemblages were distinguished: the oldest Assemblage D ("fossil") consists of rounded and possibly calcified specimens; Assemblage C (freshwater - oligohaline environment) includes freshwater-brackish living species such as *Theodoxus* sp. and *Hydrobia* sp. and low values of faunal indices (Taxa (S), Shannon-Wiener H', Density); Assemblage B (open lagoon) consists of the brackish living species *Cerastoderma glaucum*, *Mytilaster marioni*, *Hydrobia* sp. and intermediate values of faunal indices; Assemblage A (marine) comprises marine living species (mainly *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata*, *Bittium reticulatum* and *Turritella communis*) and high values of faunal indices. The data showed that due to early Holocene sea level rise, Elefsina Gulf started to be affected by the sea (saline intrusions) and in a period of ~3000 years it turns from a freshwater environment to a closed lagoon, and in the end it connects with the sea to form an open lagoon. Before ~10,5 ka BP the environment became marine, with periodic anoxic episodes reflecting restricted communication with the open sea.

Περίληψη

Ο κόλπος της Ελευσίνας αποτελεί μια γεωμορφολογική εμβάθυνση, η οποία βρίσκεται στο βορειότερο τμήμα του Σαρωνικού κόλπου, στην κεντρική Ελλάδα. Για να επιτευχθεί η αναπαράσταση της παλαιοπεριβαλλοντικής εξέλιξης της περιοχής, πραγματοποιήθηκε ανάλυση της μακροπανίδας μαλακίων που συλλέχθηκαν από πυρήνα γεώτρησης στον κόλπο της Ελευσίνας με ονομασία S2P. Οι μέθοδοι που χρησιμοποιήθηκαν σε αυτήν τη μελέτη περιλαμβάνουν ποιοτική - ποσοτική - στατιστική ανάλυση των πανιδικών δειγμάτων, μακροσκοπική περιγραφή της λιθολογίας, ραδιοχρονολόγηση υλικού του πυρήνα και υπολογισμό των ποσοστών άμμου/αργίλου-ιλύος. Από ένα σύνολο 10500 πανιδικών δειγμάτων, προσδιορίστηκαν 6661 μοναδικά άτομα, τα οποία ανήκουν σε 44 γένη μαλακίων. Διακρίθηκαν τέσσερις πανιδικές συναθροίσεις: η παλαιότερη συνάθροιση D («απολιθωμένη») αποτελείται από αποστρογγυλεμένα και περιασβεστωμένα δείγματα, η συνάθροιση C (γλυκών - υφάλμυρων υδάτων) περιλαμβάνει είδη γλυκών/υφάλμυρων υδάτων όπως τα *Theodoxus* sp. και *Hydrobia* sp. και χαμηλές τιμές πανιδικών δεικτών (Taxa (S), Shannon-Wiener H', Πυκνότητα) η συνάθροιση B (ανοιχτής λιμνοθάλασσας) αποτελείται από τα θαλάσσιας-υφάλμυρης διαβίωσης είδη *Cerastoderma glaucum*, *Mytilaster marioni*, *Hydrobia* sp. και ενδιάμεσες τιμές πανιδικών δεικτών, και τέλος η συνάθροιση A (θαλάσσια) συμπεριλαμβάνει θαλάσσια είδη (κυρίως *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata*, *Bittium reticulatum* και *Turritella communis*) και υψηλές τιμές πανιδικών δεικτών. Ο κόλπος της Ελευσίνας, επηρεάζεται από τη θάλασσα (θαλάσσιες υπερχειλίσεις), λόγω της Ολοκαινικής ανόδου της στάθμης της θάλασσας και μέσα σε ~3.000 χρόνια μετατρέπεται από γλυκού νερού περιβάλλον σε κλειστή λιμνοθάλασσα γλυκού – υφάλμυρου νερού ενώ τελικά συνδέεται με την θάλασσα και μετατρέπεται σε ανοικτή λιμνοθάλασσα. Περίπου στα 10,5 χιλιάδες χρόνια πριν από σήμερα το περιβάλλον έγινε θαλάσσιο, με περιοδικά ανοξικά επεισόδια που αντιστοιχούν σε περιορισμένη επικοινωνία με την ανοιχτή θάλασσα.



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“A journey of a thousand miles begins with a single step” – Lao. With this in mind I have always guided myself in my life, step by step. That also includes my journey into the academic world. By reaching a personal milestone with this Master thesis, I look back at what I have accomplished; I am glad of the present and look forward with confidence to the future that waits.

For this specialization thesis, I am thankful to many.

First and foremost, I would like to express my gratitude to my supervisor Professor George Syrides (AUTH), for the useful comments, remarks and generous engagement through the learning process of this master thesis. Furthermore, I would like to thank Professor Maria Triantaphyllou from the National and Kapodistrian University of Athens (NKUA) for suggesting the thesis topic, providing the studied samples as well as supporting and giving constructive feedback. I am also in deep thankfulness for the support from Dr. Olga Koukousioura who was my most precious guide during all the stages of my work.

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Nikolaos Mavrommatis

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The present Master Thesis deals with the use of invertebrate Macrofaunal (Mollusca) remnants as a tool for paleoenvironmental research.

A 342 cm long sediment core named S2-Perseus (S2P), from the Gulf of Elefsina in Athens, Attica, Greece, is analyzed. The core's macrofaunal content consists of remnants of mollusks, echinoderms and other invertebrates. Study of the fauna with qualitative and quantitative methods focuses on reconstructing the paleoenvironment of the area during several past millennia. This thesis is divided in chapters as described below.

To begin with, nomenclature and information are given within the first chapters *Introduction*, *Information of the study area* and *Materials and methods*. Specifically Chapter 1 deals with the terms paleoecology and paleoenvironmental reconstruction, as well as the concept of using macrofauna in scientific research. Subsequently, the various Phyla present in the core sample are studied and defined.

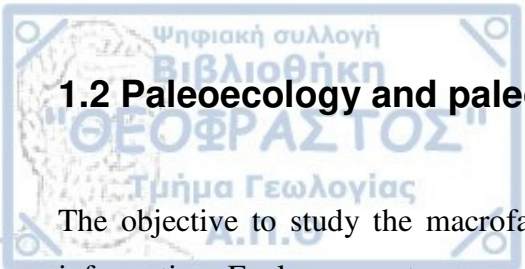
Chapter 2 has to do with general and geological information of the study area.

Chapter 3 concerns the material and methods applied, while the systematical classification of the taxa retrieved from the samples of the S2P is provided in Chapter 4, *Taxonomy*.

Chapter 5 and 6 (*Results* and *Discussion*). The results of the studied material are mentioned and followed by discussion in order to reconstruct the past of the study area and observe how it evolved ecologically and environmentally during the last thousands of years (ka).

Chapter 7 concludes the main results of the Master thesis. In fact, the suggested paleoenvironmental reconstruction and evolution of the Gulf of Elefsina are presented and explained.

Finally, the *Appendix* features tables of related working material.



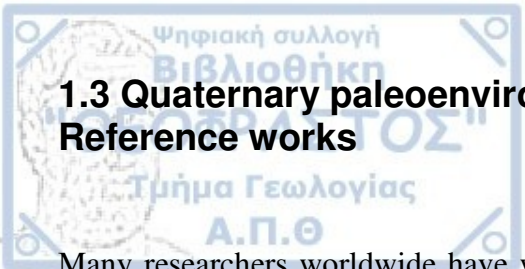
1.2 Paleoeecology and paleoenvironmental reconstruction

The objective to study the macrofauna, in the present work, was due to the provision of ecological information. Ecology as a term was firstly introduced by Haeckel (1866) and studies the interaction of organisms and their environment. As we go back in time, the data become less precise for experimental approach and direct measurement of environmental parameters. It is obvious we must rely on empirical data from fossils and their enclosing sedimentary rocks to make inferences about past conditions (Brett, 2008). This is considered Paleoeecology, in brief, the investigation of individuals, populations and communities of ancient organisms and their interactions with dynamic responses leading to a constantly changing environment (Gastaldo et al., 1996).

Generally, life has always great adaptability to environmental changes. The animal kingdom in particular, has shown from the very first moments on this planet that it has many mechanisms to cope with any possible changes to the climate, as well as geological processes, changing ecosystems and any various factors of biotic or abiotic origin possibly affecting on a local or global scale. These changes on the scale of geological time can be studied through fossil or sub fossil remains. The data gathered and its quality may vary. It sometimes depends on the research process and what we want to address. Since fossil records of any species are a valuable “view of the past”, we are given the chance to determine how the environment was, when those individuals were alive.

It is worth mentioning that the most successful organisms are those that are adapted to a particular environment (Breithaupt, 1992), and even more successful the ones which can react to any sort of disturbances and variations by attempting to getting used to environmental changes, or even migrating. Those interactions can derive from other organisms or be caused by the environment itself. Since there are a lot of species which have distinct living habits and environments the accumulated data of their (paleo)ecology is a valuable tool for applications to environmental research.

To conclude, we can form a model of the conditions of climate, morphology and ecosystems using fossil assemblages retrieved from fossiliferous sediments. It is known that Quaternary mollusk assemblages retain useful information about living habits and habitats of the marine benthos from which they come from (Aitken 1990 cited in Gordillo et al., 2014). They also provide direct evidence of biotic interactions, thus offering quantifiable data on predator-prey relationships (Gordillo et al., 2014 and references). Therefore the extended synthesis of the Quaternary macrofauna diversity provides the availability for analysis of the S2P core sample from the Gulf of Elefsina, offering certain data concerning the paleoenvironment of thousands of years.



1.3 Quaternary paleoenvironmental reconstruction using mollusks - Reference works

Many researchers worldwide have worked on Quaternary invertebrate macrofaunal assemblages - and particularly mollusks – for local paleoenvironmental reconstruction studies. Particularly in Europe, the molluscan species' paleoecological significance for such studies is well documented during recent times (e.g., Syrides, 1996; Syrides, 2008; Koskeridou and Ioakim, 2009; Poirer et al., 2009; Syrides et al., 2009a; Syrides et al., 2009b; Pavlopoulos et al., 2010; Di Rita et al., 2011; Pechlivanidou et al., 2014; Ivanova et al., 2015; Büyükmeriç, 2016; Büyükmeriç et al., 2016; Karadimou et al., 2016; Triantaphyllou et al., 2016). According to Poirer et al. (2009), the aim of these studies and research is to create paleoenvironmental evolution models while finding clues of the parameters, for instance sea level rise, climate, hydrodynamic processes or even anthropogenic impact, that triggered any possible changes to the environment. The same authors confirm that their analysis on Late Holocene molluscan assemblages of the Marennes–Oléron Bay on the Atlantic coasts of France provided relevant information regarding bathymetry, salinity, hydrodynamics, oxygen content and sediment supply. In the Western Mediterranean, Di Rita et al. (2011) accessed the paleoenvironmental evolution of the Palude Frattarolo–Lago Salso area (Tavoliere Plain, Apulia, Italy) using among other proxies the above mentioned method. In the Eastern Mediterranean, there has been a lot of interest in using molluscan assemblages, especially on the study of the sea connection changes between the Aegean Sea and the Black Sea (Ivanova et al., 2015; Büyükmeriç, 2016; Büyükmeriç et al., 2016). There are also Quaternary mollusk-related researches from localities of Greece: Syrides (1996) assessed the Holocene stratigraphy and paleoenvironment of the area of ancient Avdira (Thrace) through paleontological investigation; Syrides (2008) analyzed the mollusk fauna and stratigraphy of the Agia Paraskevi marsh (Lamia, Euboea); Syrides et al. (2009a) described the paleogeographical evolution and sea level changes at the prehistoric settlement of Mikro Vouni (Samothrace island) by also taking into account the presence of mollusks; Syrides et al. (2009b) reconstructed the paleogeographic changes of the northern margin of the Thessaloniki-Giannitsa plain, near the prehistoric settlement of Archontiko, by observing the molluscan faunas present in the Holocene sediments, among other methods; Koskeridou and Ioakim (2009) analyzed an Early Pleistocene molluscan fauna in the area of Arkitsa region in Atalanti Basin (Central Greece), to determine the paleoenvironmental conditions of those times; Pavlopoulos et al. (2010) used the presence of certain mollusks, as a tool for reconstructing the paleoenvironmental evolution of the embayment of Palamari (Skyros island), among other methods; Pechlivanidou et al. (2014) studied the Sperchios delta and its Holocene sediments that included mollusks to estimate the fluvio-deltaic depositional system; Karadimou et al. (2016), worked on the area of the Ismarida Lake (N. Greece), and pinpointed the environmental evolution during the Holocene including the study of the

molluscan faunal changes; Triantaphyllou et al. (2016) considered the presence and changes of mollusks for their multiproximal study of the paleoenvironmental evolution and sea level changes of Piraeus.

The above examples can picture and confirm that the method of determining the species of mollusks and their expansion during the most recent period of the Quaternary provides valuable data to present models of paleoenvironmental evolution of study areas, such as is the intention of the present work.

1.4 Mollusca

The phylum Mollusca Linnaeus (1758) is one of the largest and most diverse groups in the animal kingdom with a spawn range from the earliest moments of complex life forms (Cambrian) till present. There are thousands of described species in the phylum, most of which are marine species. The rest have adapted on different habitats, such as in brackish and fresh water or on the land (terrestrial). Generally, the group is characterized by a great diversity of form and habit (Gosling, 2003). Morton (1967 cited in Gosling 2003, p. 1) describes them effectively: *“Molluscs range from limpets clinging to rocks, to snails which crawl or dig or swim, to bivalves which anchor or burrow or bore, to cephalopods which torpedo through the water or lurk watchfully on the bottom. They penetrate all habitats: the abysses of the sea, coral reefs, mudflats, deserts, and forests, rivers, lakes and under ground. They may have become hidden as parasites in the interior of other animals. They feed on every possible food and vary in size from giant squids and claims to little snails a millimetre long”*.

Anatomically speaking they are, according to Riedl (1991), bilateral and square-built, articulated on the head and body, usually provided of a mantle that excretes cuticle and/or calcium carbonate and a ventral foot. The mantle encloses the internal organs (Gosling, 2003).

This richly diverse group of animals is divided into 8 living Classes (Bivalvia, Caudofoveata, Cephalopoda, Gastropoda, Monoplacophora, Polyplacophora, Scaphopoda, Solenogastres) and 1 extinct (Rostroconchia Cox, 1960), according to the latest accepted classification of Margulis and Schwarz (1998). Many researchers (e.g., Morton, 1967; Willmer, 1990; Gosling, 2003) hypothesize that all mollusks derive from a single ancestor (Fig. 1.4.A, 1.4.B), from which the diversification started, depending on local or global factors, or simply due to the mechanism of evolution itself.

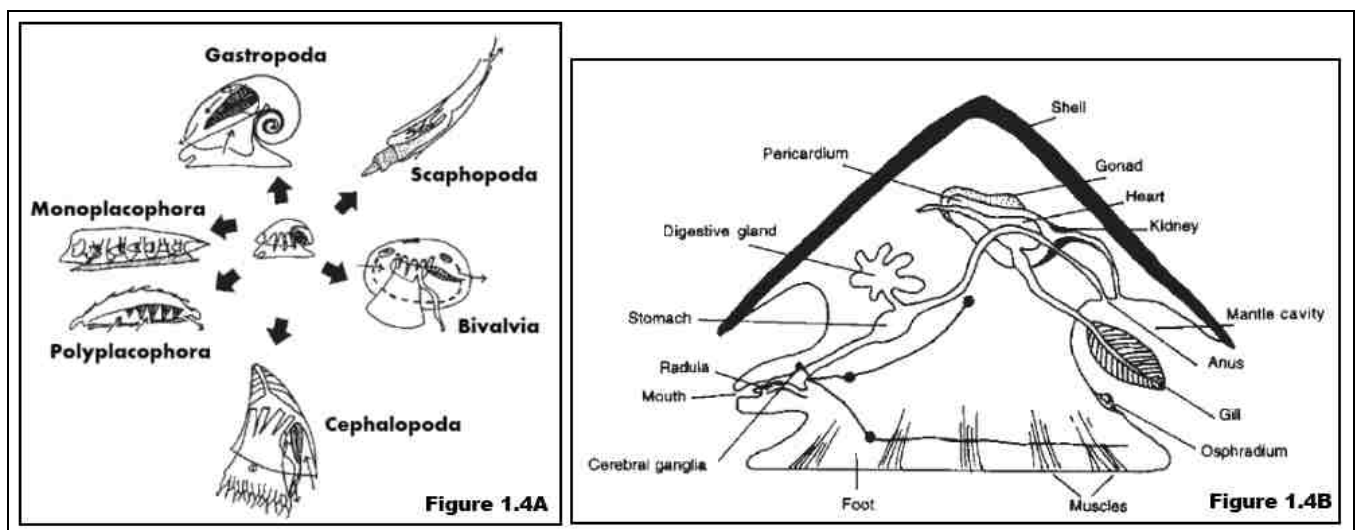


Figure 1.4.A Radiation of six classes of mollusks from a hypothetical ancestor. Modified after Gosling (2003), **1.4.B** The hypothetical common ancestor of the mollusks (from Willmer, 1990 cited in Gosling, 2003).



1.4.1 Bivalvia

Morphological features

The Class Bivalvia Linnaeus (1758) or Bivalves is a taxonomic class within the phylum Mollusca, with a presence spanning from the Lower Cambrian till present (though the taxonomic and ecological diversification blooms in the Lower Ordovician). It includes animals enclosed in two shell valves, and their classification and species determination is based on the shell's architecture; however, for the differentiation of larger systematic groups, the soft body anatomy (ex., gills shape) must also be taken into consideration, as stated by Riedl (1991). The same author describes the Bivalves as Mollusks with a soft body compressed laterally, and a shell divided longitudinally and centrally on the dorsal area, formed by two valves with an articulation region (hinge), with a surface that often has glossy sculptures, varied colours and designs. Characteristic of this Class, aside of the shell forms themselves, are the absence of a head, the presence of a foot often used as a digging organ, the lack of a radula or jaws in the pharyngeal area and the organs enclosed in the mantle.

As it is frequently observed in the nomenclature of the Mollusca, the Bivalvia are under continuous debate and difficulties in their classification. The Class itself has had alternatively proposed names during the centuries. In the 19th century literature Acephala Cuvier (1795) and Conchifera Lamarck (1818) appear, while in the 20th century the names Lamellibranchiata de Blainville (1816) and Pelecypoda Goldfuss (1820) have been extensively used. The latter was quite preferred, due to the presence of other animal groups with bivalved shells (e.g., Brachiopods, Ostracods and some Gastropods) and non-bivalved animals within the Class (e.g., Rostroconchia Cox, 1960).

Recent studies (e.g., Bieler et al., 2014) have stated that the Bivalvia consist of two major clades, Protobranchia Pelseneer (1889) and Autobranchia Grobelen (1894), with the second one dividing into Pteriomorpha Beurlen (1944) and Heteroconchia Cox (1960). Heteroconchia in turn consist of Palaeoheterodonta Newell (1965) and Heterodonta Neumayr (1884) with the latter dividing into Archiheterodonta Giribet in Taylor, Williams, Glover and Dyal (2007) and Euheterodonta. Since this thesis follows the suggestions of the World Register of Marine Species checklist (WoRMS), the Bivalvia are split into the following Subclasses: Heterodonta, Palaeoheterodonta, Protobranchia, Pteriomorpha.

The specimens of Bivalves found in the studied material belong to 3 Subclasses of the above stated, namely Heterodonta, Protobranchia and Pteriomorpha. This thesis focuses on the taxonomic rank of the Families and Genera. A total of 16 Families and 22 Genera of bivalves are present in the S2P. All described taxa are shown in Chapter *Taxonomy*.

Shell morphology

A simplified bivalve shell is shown and described in Figure 1.4.1.A. Generally, a Bivalve's shell is composed of two calcareous valves. Each valve forms thanks to the secretion of various substances (mainly calcium carbonate) from the mantle. On the first stages of growth, an embryonic protoconch precedes the creation of the complete shell. The protoconch is conserved in the umbo of the hinge (top part of the valve). The mantle is attached on the valves with retractor muscles, and forms a sometimes visible line on the edge of each valve's interior, the pallial line. The pallial line usually ends on the adductor muscle scars on the valves, which are the remaining marks where such muscles reside, and they are used to tightly close the shell. In some groups the mantle forms siphons, which are used for the water expelling and suspension feeding. The deeper some species live buried in the sediment, the longer the siphons, which need to be retracted in case of necessity in a pocket-like feature, called the pallial sinus. Lastly, the valves are articulated with hinge teeth of various forms, and joined together with the ligament, a flexible and elastic organic material.

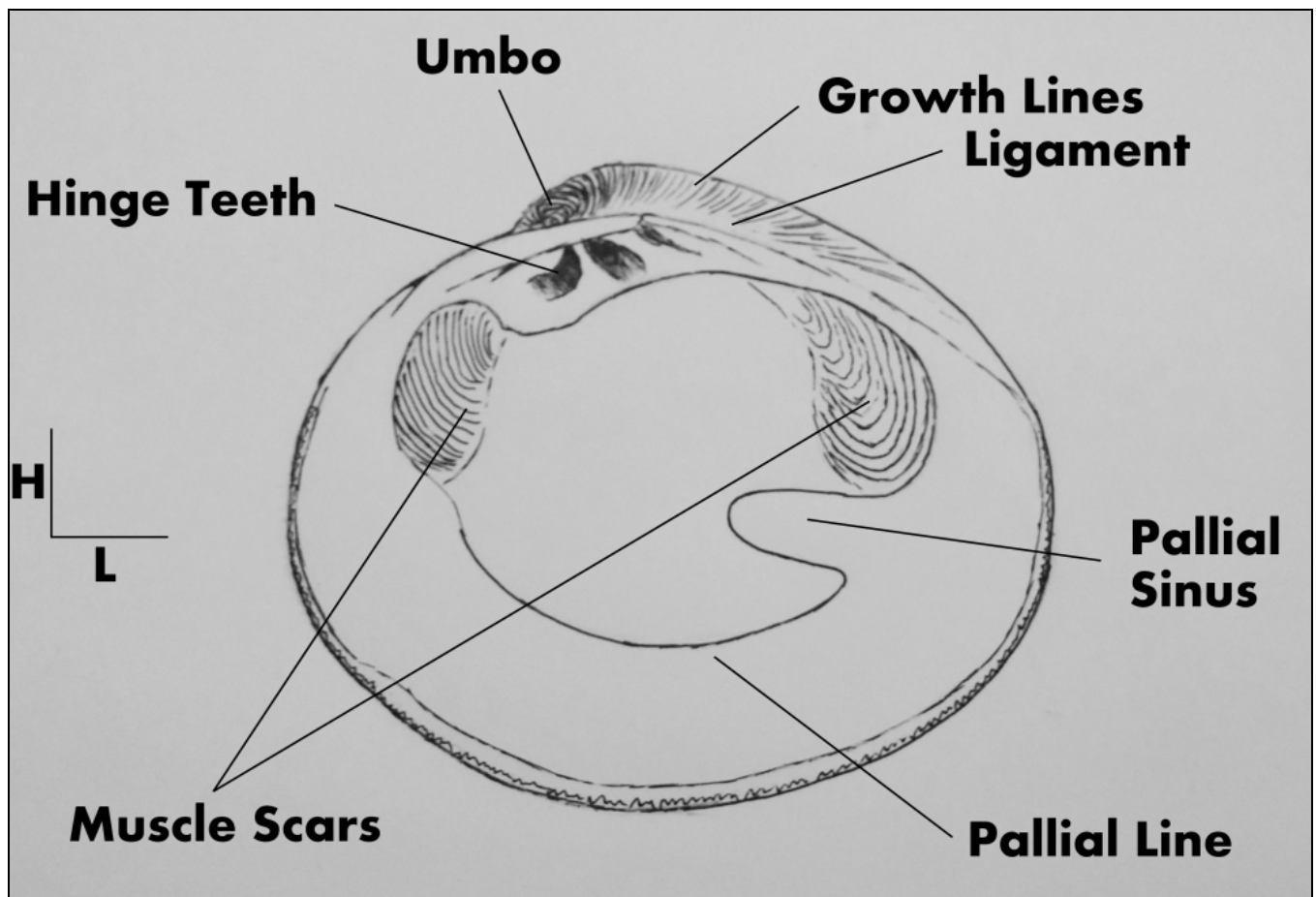


Figure 1.4.1A Simplified sketch of a valve of *Venus verrucosa* Linnaeus, 1758. Such species have a good example of fully featured shells, with all the characteristics mentioned above.

Distribution and Ecology

Riedl (1991) mentions the existence of about 8000 known bivalve species. Bivalve species are mostly marine, but there are also individuals prone to living on lower salinities (brackish). Some families live in fresh water environments. Bivalves are benthic forms, present from the intertidal zone to deep depths, and particularly on soft-bottom (sand, mud) benthic environments. Generally, only larval (early-life stage) individuals have a pelagic life, for a period of time varying from species to species (Riedl, 1991). The streaks of the shell also indicate the approximate age of the animal. Most of Bivalves enter the substrate using the foot, which can be stretched for digging. Some Bivalves move jump by flexing their feet; other species open and close the valves, swimming with a wavy motion. There are forms that live anchored on hard surfaces or sandy bottoms with byssus filaments or are fixed to the substrate with slurry. Moreover, some species are able to pierce stone or wood by mechanical or chemical means. According to Riedl (1991), they feed exclusively by filtering the food (suspension feeders). Even the species that corrode and enter the stone (ex., *Lithophaga*) are filters. The food consists of tiny plankton, small benthonic organisms and suspended particles of detritus. Only the Teredinae eat almost exclusively pieces of wood, hemp and jute fibers, while plankton feed has only a secondary role. Bivalves are prey to seastars, crustaceans, fishes, coastal birds and predatory gastropods. For the latter, it is very common to find shells perforated by Muricids and Naticoid species (Fig. 1.4.1B).

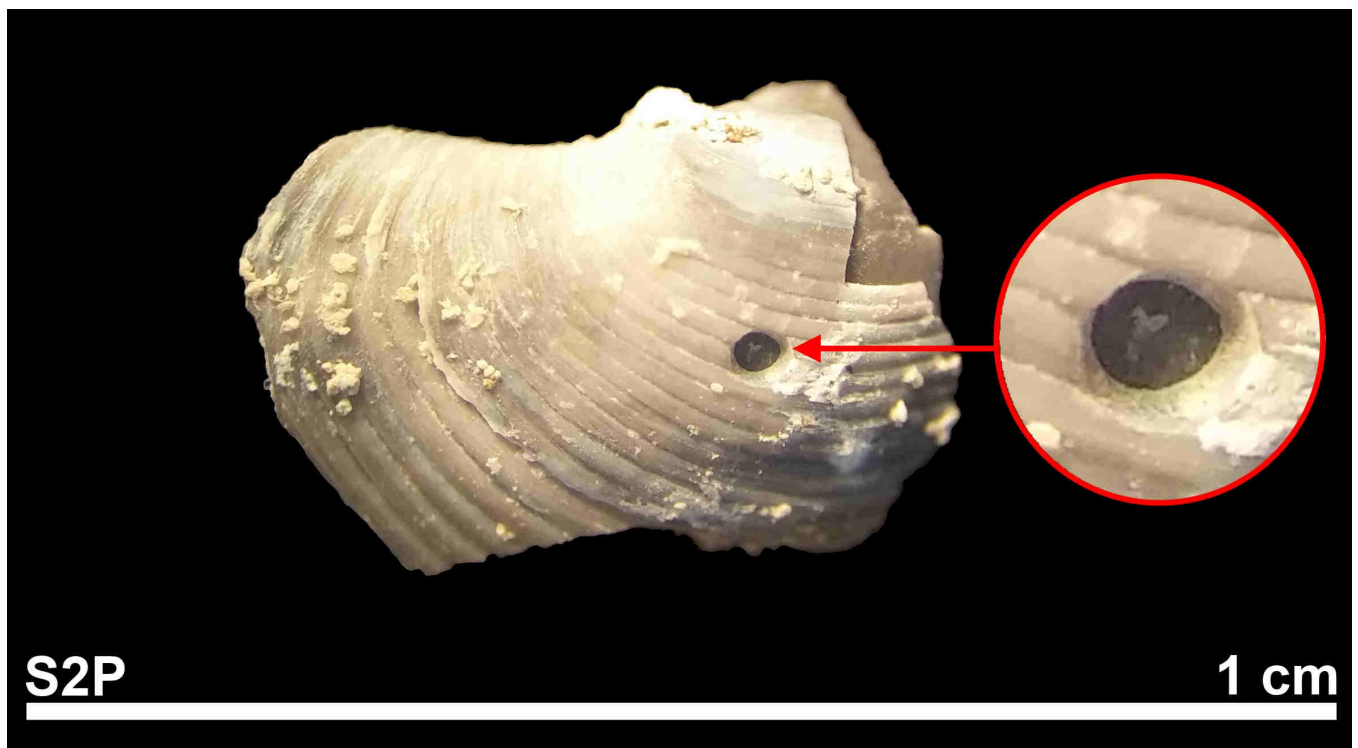


Figure 1.4.1B Boring on a bivalve shell (*Corbula gibba*) from the S2P core. Geometry of the hole is typical of a Naticoid gastropod. Note the incomplete boring, predator failed to eat its prey.

1.4.2 Gastropoda

Morphological features

The Class Gastropoda Cuvier (1795), or Gastropods, is a large taxonomic class within the phylum Mollusca, with a presence spawning from the Late Cambrian till present, and it includes shell-bearing animals with an asymmetric body architecture that takes many forms. All gastropods have a single shell, but the shape varies considerably among major groups (Pyron and Brown, 2015) and in general it has a patelliform, spiral or shortened form (Riedl, 1991). There are exceptions within the Class, where some gastropods, also named slugs, may have or not have a shell, or the shell might not be large enough that the animal can fully retract its soft parts into it. For the actual gastropod organism and its soft parts, the most important features to note are a well defined head that usually has a mouth with a radula (scraping organ with teeth for feeding), a developed foot used for crawling, visceral mass and a mantle, whose epidermis secretes proteins, calcium salts, mucus and contains sensory elements (Ruppert et al., 2004). As stated by Riedl (1991), a profound cavity (sinus) in the mantle (present on the anterior or on the right of the organ) and how it is organized within is the distinctive feature from which the Class Gastropoda is subdivided. The same author noted in his work the presence of 4 Subclasses: Prosobranchia Milne Edwards (1848), Opisthobranchia Milne Edwards (1848), Gymnomorpha and Pulmonata Cuvier (1814). Originally and for the majority of the 20th century the subclasses were 3 (Prosobranchia, Opisthobranchia, Pulmonata), suggested by Thiele (1929-1931). Such systematics is still present in major textbooks (e.g., Brusca and Brusca, 2003). However, nowadays the continuous reorganization of the Class has lead to different suggestions for a correct subdivision in the attempt to bring it as close as possible to a changing phylogenetic hypothesis of the class. The most recent and the one that is accepted and followed by many researchers is the classification of Bouchet and Rocroi (2005). It includes the following subclasses:

- Caenogastropoda Cox, 1960
- Cocculiniformia Haszprunar, 1987
- Heterobranchia Burmeister, 1837
- Neomphalina Mclean, 1981
- Neritimorpha Golikov and Starobogatov, 1975
- Patellogastropoda Lindberg, 1986
- Vetigastropoda Salvini-Plawen, 1980

The individuals found in this research belong to 4 of the stated subclasses. Those are Caenogastropoda, Heterobranchia, Neritimorpha and Vetigastropoda. In total there are 22 Genera of gastropods present in

the S2P (Chapter *Taxonomy*). Some of them, as it will be noted further on, also have opercula (a “lid” with various shapes attached to their foot that is used to protect themselves when retiring into the shell) and they can be useful for systematic classification.

Shell morphology

Generally, the basic morphology of a gastropod shell and the variety of forms that it can take are shown in Figure 1.4.2.A. An important feature of the shell, not visible in the sketch, is the columella, a pillar-like structure in the inside that is also the axis of the shell’s coiling. Moreover, exceptions aside, the gastropods have a dextral coiling. While there is a rich variety of forms and shapes, the shell starts from the embryonic whorls of the protoconch, often distinct from the shell. From the apex/protoconch the shell whorls gradually increase in size, till the body whorl. The aperture may be simple or modified, with a usual presence of inner and outer lips. These may be continuous with each other, or may be divided by the siphonal notch, where in some cases it is elongated to form a siphonal canal. Some species might have more notches. Additionally, if the axis of coiling is hollow, the opening on the anterior is called umbilicus. The umbilicus varies in size, and may be partially or completely covered by a callus of the inner lip (ex., present in the genus *Natica*).

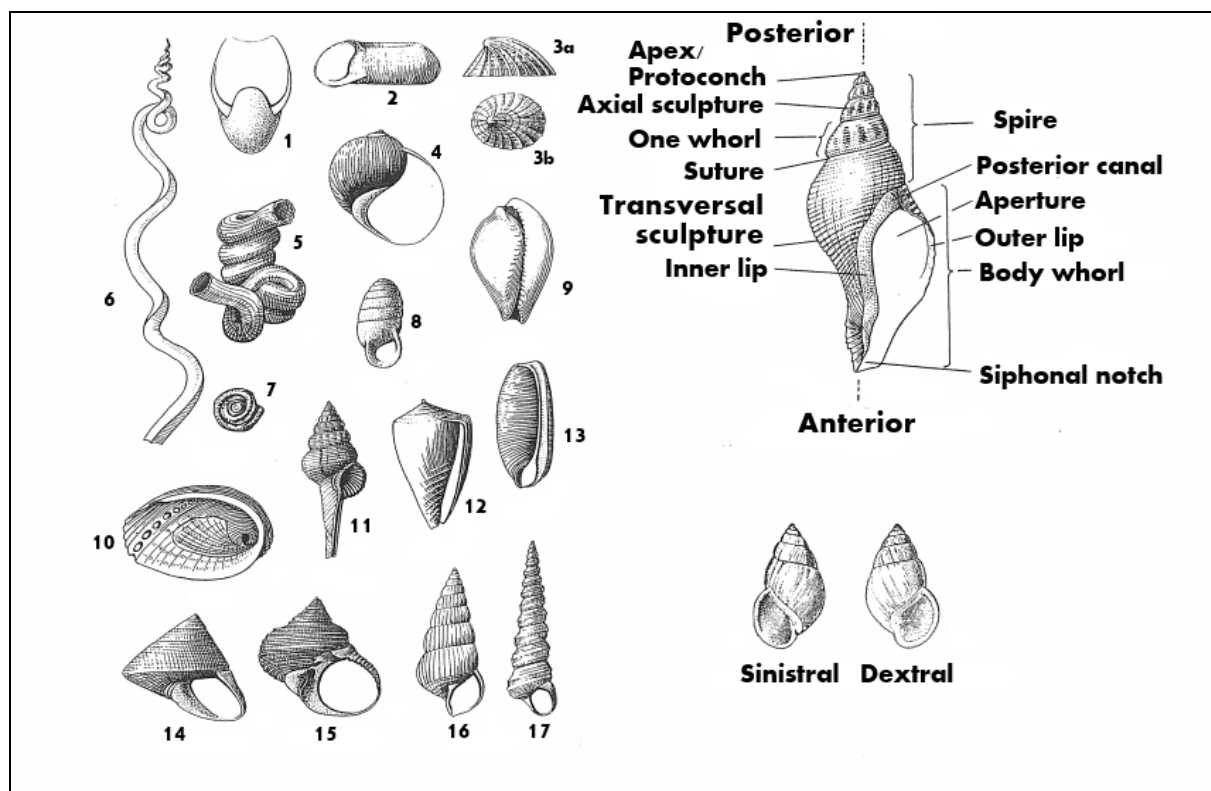
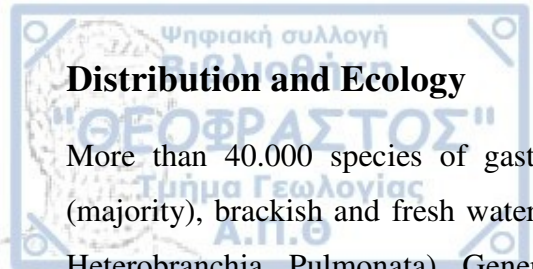


Figure 1.4.2.A A Generic gastropod shell anatomy and nomenclature (right) and shell forms (left). 1. Globose, 2. Discoidal, 3a, 3b. Patelliform, 4. Naticoid, 5, 6, 7. Vermiform, 8. Pupaeform, 9. Cypraeform, 10. Auriform, 11. Fusiform, 12. Obconical, 13. Obovate, 14. Trochiform, 15. Turbiniiform, 16, 17. Turriiform (modified after Easton, 1960 and references).



Distribution and Ecology

More than 40.000 species of gastropods are known (Riedl, 1991). Most of them live in marine (majority), brackish and fresh water environments, but there are also terrestrial living individuals (ex., Heterobranchia, Pulmonata). Generally, the taxa are predominantly benthonic (except the pelagic Pteropods) and their habitat ranges from the littoral area to great depths. The preferred sediments of the benthos depends on the species, from hard to soft bottoms, while some others live inside floral assemblages (algae) or interstitially between rocks. Depending on their feeding habits, they are herbivore, carnivore, filtrating feeders, specialized and parasites (Riedl, 1991). Specialized (those who feed on specific organisms, ex. sponges), as well as parasite gastropods have interactions with certain groups of animals to access food. Herbivore and filtrating gastropods seek for floral organisms and particles of their environment respectively. Finally, carnivores feed on other animals. Worth noting is the drilling predation by gastropods, a hunting habit which involves mechanical rasping with the radula, as well as secretions from the accessory boring organ (Carriker 1981, cited in Gordillo et al., 2014). The process creates a bore on the shell of the prey and it can be a valuable clue for the presence of such species (found in Mollusca and Vermes in this thesis). Although it is known within several families of gastropods, most cases reported are produced by naticoid and muricid gastropods (Gordillo et al., 2014).

1.4.3 Scaphopoda

Morphological features

The Scaphopoda Bronn (1862), also known as tusk shells or tooth shells, are benthic shelled marine mollusks with worldwide distribution and a spawn range from the Devonian till present. According to Riedl (1991), the class comprises organisms with a tubular shell (Fig. 1.4.3A), slightly curved and with an opening on both of its extremities, just like the cavity of the mantle. Important biologic features are the presence of a head (although not very conspicuous), grabbing tentacles called captacula and a radula. They move within the substrate by excavating with their foot and doing stretching and retracting movements. The Mediterranean species size range from 2,5mm to 70mm. The most important characteristics used for their taxonomy are the form of the foot and the size and sculpture of the shell.

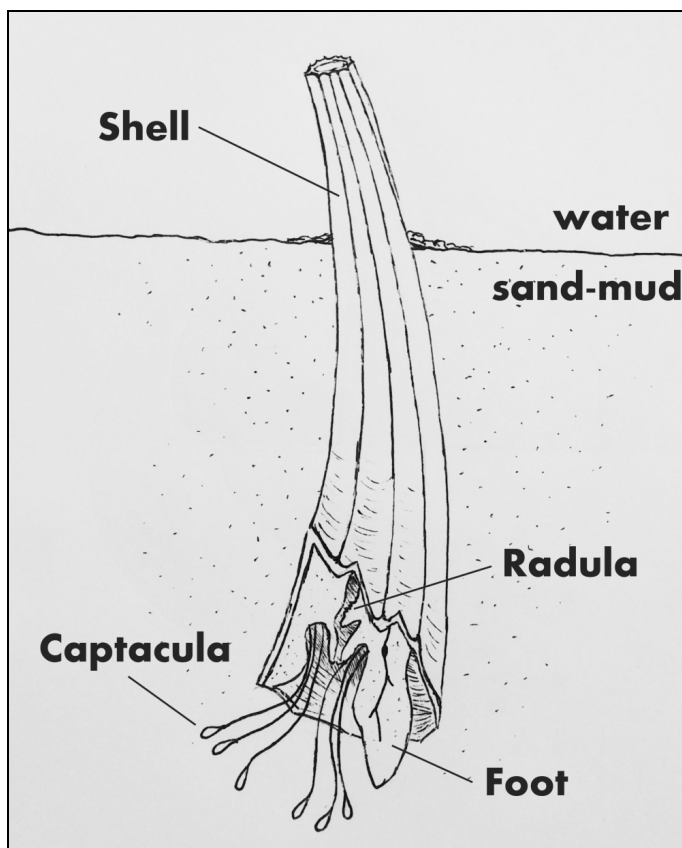
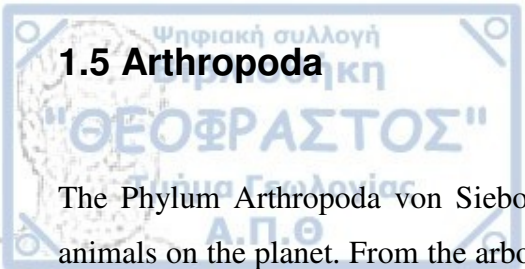


Figure 1.4.3A Life position of a scaphopod. The bottom part of the shell is imaginarily removed to reveal features of the animal's anatomy.

Distribution and Ecology

More than 350 species of scaphopods are known, with 20 species being found in the Mediterranean (Riedl, 1991). They live on all the sedimentary basins, from the coast to deep depths and are exclusively of marine living. They feed mostly on foraminifera, detritus and occasionally bivalves, while they are in turn prey to predating gastropods (ex., Naticoids) as well as Asteroids and benthonic fishes. The shells can be transported with the sediment flow.



1.5 Arthropoda

The Phylum Arthropoda von Siebold (1848) includes the oldest, richly varied and adapted group of animals on the planet. From the arboreal life in the Cambrian, the arthropods have conquered land, sea and air, with millions of species and many more undocumented/undiscovered. Arthropods' most characteristic feature is the presence of an exoskeleton made of a tough compound, called chitin. This shell has multiple uses and its utility and forms differentiate among the taxa. To be able to move inside such a rigid armour, the chitin is divided into plates, with joints between them (Arthropoda="jointed legs"). The segmented bodies have patterns of segment fusion (tagmosis) from which integrated units are formed (head, abdomen, etc.). Their habitat depends on the species and ranges from marine and brackish/fresh water to terrestrial. Only small fragments are present in the S2P samples and belong to Malacostracans (Malacostraca Latreille, 1802), following the classification of Brusca and Brusca (1990) and Regier et al. (2010). The specimens are remnants of exoskeleton and pincers, probably of crabs and possibly shrimps, but due to the lack of distinct morphological features, they are undeterminable. The Malacostracans are present in freshwater and terrestrial habitats, while they are abundant in all marine ecosystems, where most species are scavengers, some filter feeders (porcelain crab) and some carnivores (mantis shrimps) (Hayward et al., 1995).

1.6 Echinodermata

The Phylum Echinodermata Bruguière (1791) [ex Klein, 1734] is a large group of marine-exclusive benthonic animals with a definitive first appearance dating back to the Cambrian. Echinoderms have adapted to all depths, from the intertidal zone to the abyssal plains of the seas. This Phylum includes commonly known animals such as the sea stars (Asteroidea), sand dollars and sea urchins (Echinoidea) and the brittle stars (Ophiuroidea). They are headless and radially symmetric (pentaradial symmetry or bilateral). Aside of having a common skeleton of interlocking calcium carbonate plates and spines, all taxa share the same, unique to the animal kingdom feature, the water vascular system. It is a hydraulic system of thin tubes from which water circulates after passing through a filter-like plate (Madreporite) and it has multiple uses (locomotion, feeding, waste transportation, respiration). Such features, much like in every other Phylum, mutate in each Class and other sub classifications and are important to distinguish the various taxa. The direct child taxa of the Echinodermata are the Subphyla Asterozoa, Crinozoa and Echinozoa (Margulis and Schwartz, 1998). Due to the presence of Echinoid remnants in many studied samples of the present work, it is appropriate to make next a short description of the Class Echinoidea, of the Subphylum Echinozoa.

1.6.1 Echinoidea

Identification - Anatomy

The Class Echinoidea Leske (1778), includes Echinoderms with a spherical or disc-like form and skeletal plates usually welded with each other to form rigid armour and always provided with mobile aculei (Riedl, 1991). Characteristic features are the described below water vascular system with its components and the Aristotle's lantern, an organ made of five calcium carbonate teeth or jaws and flesh parts used for feeding (Fig. 1.6.1A).

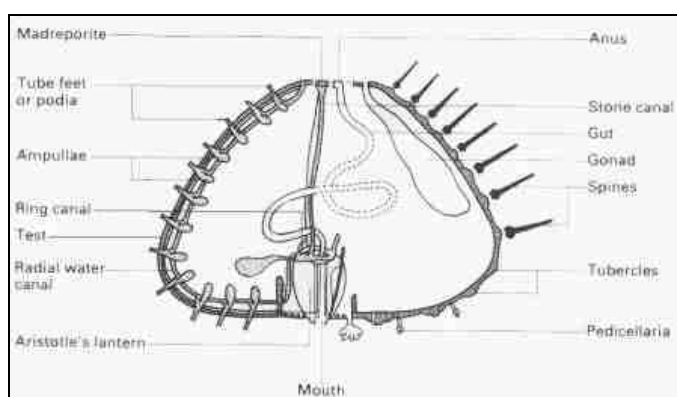
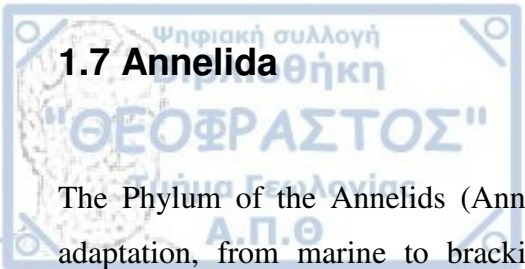


Figure 1.6.1A Cross section of an Echinoid. The water vascular system (left) has on the opposite side an alignment of spines (right) (from Boardman et al., 1987).

An important systematic diversification of the Echinoids comes from their radial symmetry. According to Riedl (1991), they can have regular pentaradial symmetry, central mouth opening on the ventral side, and central anal field on the dorsal side (Regular Echinoids); they can also have a secondary bilateral symmetry with displacement of the mouth opening forward and the anus in the opposite direction and on extreme cases both of the openings on the ventral area (Irregular Echinoids). With other defined structural and organic features used for the classification, the Class is divided into 2 Subclasses, according to recent accepted works (Kroh and Smith, 2010): Euechinoidea Bronn, 1860 and Cidaroida Smith, 1984. The former includes the sea urchins (Regular echinoids) and sand dollars (Irregular echinoids), while the latter has again sea urchins, but of a more primitive form.

Distribution and Ecology

The Echinoids are solely of marine benthonic living. Riedl (1991) describes their distribution and ecology. Their habitat depth ranges from the intertidal zone to depths over 1000 m. Regular echinoids are more frequent on hard substrates, while Irregular echinoids live mostly endobenthonically in the substrate. They feed on algae and some animals (dead or alive). Irregulars look for nutrients and organic particles. Some Echinoids usually cover themselves with bivalve shells, debris, algae etc. to protect themselves from sunlight and defend from predators which are crabs, asteroids, fishes and sea birds.



1.7 Annelida

The Phylum of the Annelids (Annelida Lamarck, 1809) has species with a wide range of ecologic adaptation, from marine to brackish and fresh water environments, as well as terrestrial (moist) environments. These segmented worms are included in 2 Classes (Clitellata, Polychaeta Grube, 1850) and 1 Superclass (Annelida incertae sedis) with taxa that are difficult to classify (Margulis and Schwartz, 1998). The majority of worms leave no hard parts after death, but some marine annelids create a protecting tube (tube worms) which they use to withdraw their body into it. Such species belong to the Class Polychaeta, which will be described below.

1.7.1 Polychaeta

The Class Polychaeta Grube (1850) includes segmented worms, generally of marine living (but also with some taxa living on other aquatic or terrestrial environments). They are widespread and diverse in most marine environments, on benthic communities (endo- or epi-) and soft sediments, on algal turfs and fouling communities (Wilson et al., 2003). A characteristic feature of this Class is the presence of parapodia on the animals, which are paddle-like appendages with numerous bristles or chaetae. Their feeding habits attribute them on different categories: carnivores, deposit feeders, suspension feeders, herbivores, and opportunistic species. The latest accepted classification of the Class is from Rouse and Pleijel (2001) and also from Struck (2011).

Genera found in the thesis material belong to a specific family of the Polychaeta, named Serpulidae Rafinesque, 1815. These polychaetes construct a hard calcareous tube in which they reside and withdraw completely in case of necessity, and it is attached to various hard surfaces. This family may or may not have an operculum. The latter, with its ornamentation, is important for distinguishing the species, as is the structure of the tube (Wilson et al., 2003). The Serpulids are filter feeders and in turn are prey to invertebrates (ex., naticoid gastropods) and some vertebrates (ex. fishes). It is common to find their calcareous tubes attached on other species, especially on mollusks. In some cases tubes are attached on large surfaces creating a thick cover.

2. Description of the study area

2.1 Geographical and geological setting

The area of the Gulf of Elefsina and the geological formation process that has led to it, has the origin in a much wider scale of events which involve and include the Mediterranean Sea and the Balkan Peninsula as major units (Fig. 2.1.A).



Figure 2.1.A Relief map of the Mediterranean region with main geotectonic elements. Red solid and dashed lines with triangles indicate active orogenic fronts; black dashed lines with triangles indicate inactive orogenic fronts; solid red arrows mark the sense of movement of strike-slip faults. Thick open arrows mark active (red) or older (black) opening of back-arc basins (from Papathanassiou and Zenetos, 2005).

The present form of the Mediterranean Sea is attributed to the continuous interaction of complex geodynamic processes during the last 50-70 ma (mega annum) i.e. from the Late Cretaceous till present (Papathanassiou and Zenetos, 2005). As explained by Papathanassiou and Zenetos (2005), the present shape, bathymetry and topography of the Hellenic region are the result of three main geotectonic processes, “which were or still are active within the last 10-15 ma: The Middle - to Late Miocene post-orogenic extension and exhumation of the alpine mountain belts; the migration of the North Anatolian

Fault (NAF) westwards into the north Aegean Sea in Late Miocene - Early Pliocene and the westward motion of the Anatolian continental block; the northward subduction of the eastern Mediterranean crust below the Aegean microplate and the resulted stretching of the latter in a north-northeast - south-southwest direction". The Aegean Sea itself can be segmented into zones with different geological and geotectonic features and processes as well. This is, especially, observed near coasts, basins, and gulfs, due to locally related evolution (Fig. 2.1.B).



Figure 2.1.B Map of the Hellenic region, with its main geotectonic features and names of morphologic domains (from Papathanassiou and Zenetos, 2005).

The present thesis material was retrieved from the Gulf of Elefsina in the northern part of Saronic Gulf,, which is a relatively closed gulf, and it is surrounded by the coasts of Attica and the Peloponnese, extending on an area of about 2600 km². The gulf was formed during the Lower Quaternary (circa 2 ma) with a tectonic “sinking” of the area. According to a geotectonic point of view, the Saronic Gulf belongs to the Eastern zones of Greece, Lavrio and Attica, which are characterized by carbonate sedimentary and metamorphic rocks (limestones, dolomites, marbles and shales) which probably constitute the bedrock of the gulf. Several coastal areas of the Saronic Gulf are covered with younger sediments of Neogene and Quaternary age, of relatively small thickness, created by river deposits (Sklivagkou, 2003).

The morphology of the Saronic Gulf and Attica is shaped by tectonic and neotectonic processes, especially considering the presence of two faulting systems (Figure 2.1.C) with a general axis of WNW-ESE and SW-NE (Lekkas, 2001).

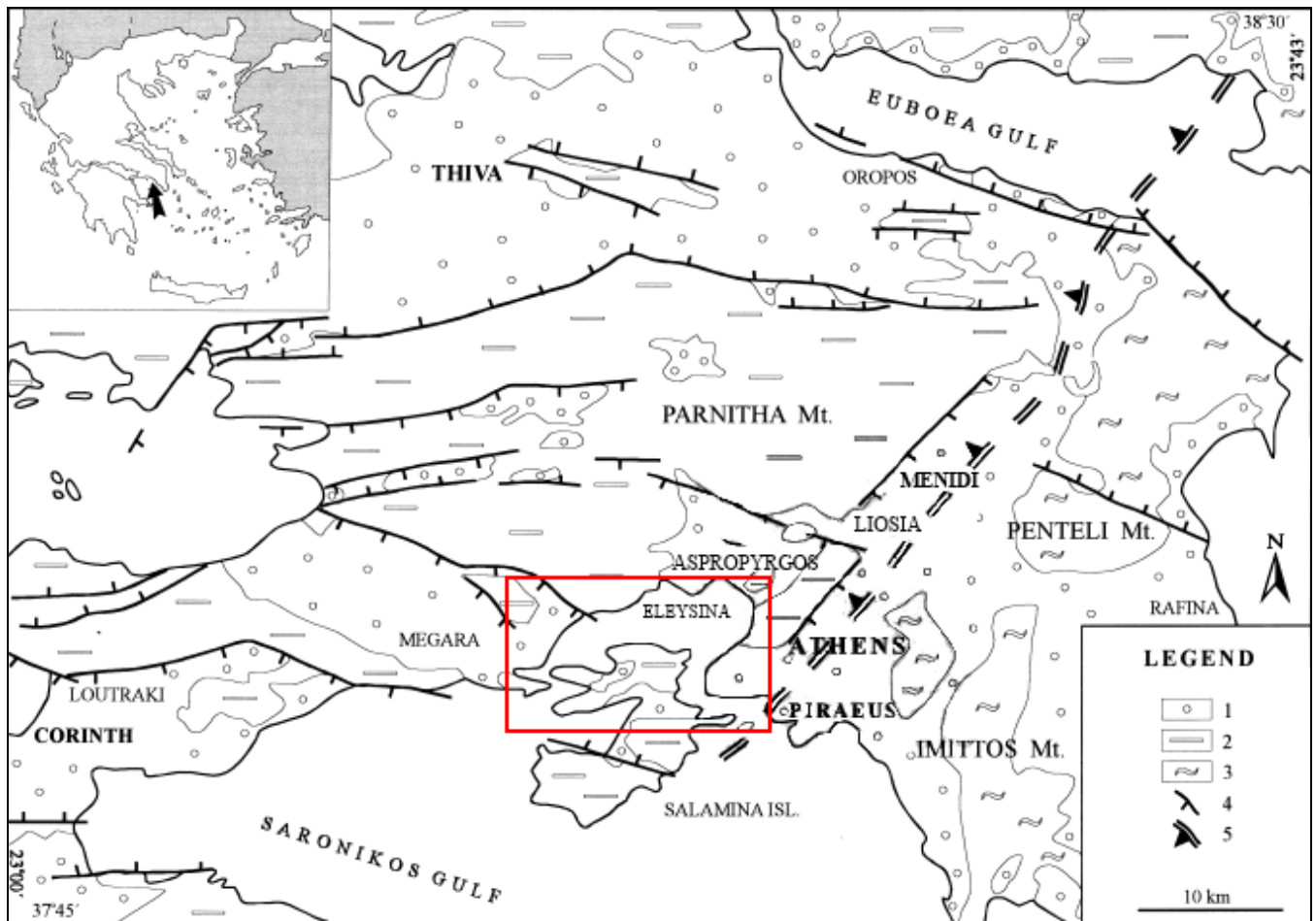


Figure 2.1.C Simplified sketch showing the study area (red rectangle), and the major tectonic and neotectonic structures of the wider area of Attica. (LEGEND: 1. Post alpine deposits of Upper Miocene/Holocene, 2. Alpine basement rocks mainly of Mesozoic carbonates, 3. Alpine basement rocks mainly of Mesozoic metamorphic rocks, 4. Major active neotectonic faults, 5. Major tectonic contact which separates the two groups of alpine basement rocks) (modified after Lekkas, 2001).

2.2 Gulf of Elefsina

The Gulf of Elefsina is part of the wider Saronic Gulf laying at its northern part (Fig. 2.2.A). It is a geomorphological embayment communicating through two narrow straits (West and East strait), with its longest axis being W-E and extending on a surface of about 67 km². The depth of the Gulf of Elefsina varies from 10-25 m on the Eastern part and 35 m on the Western part, while on the straits the depths are as shallow as 8 m and 12 m on the West and East respectively (Petropoulos et al., 2013). A bathymetric map of the Gulf of Elefsina is shown in Figure 2.2.B.

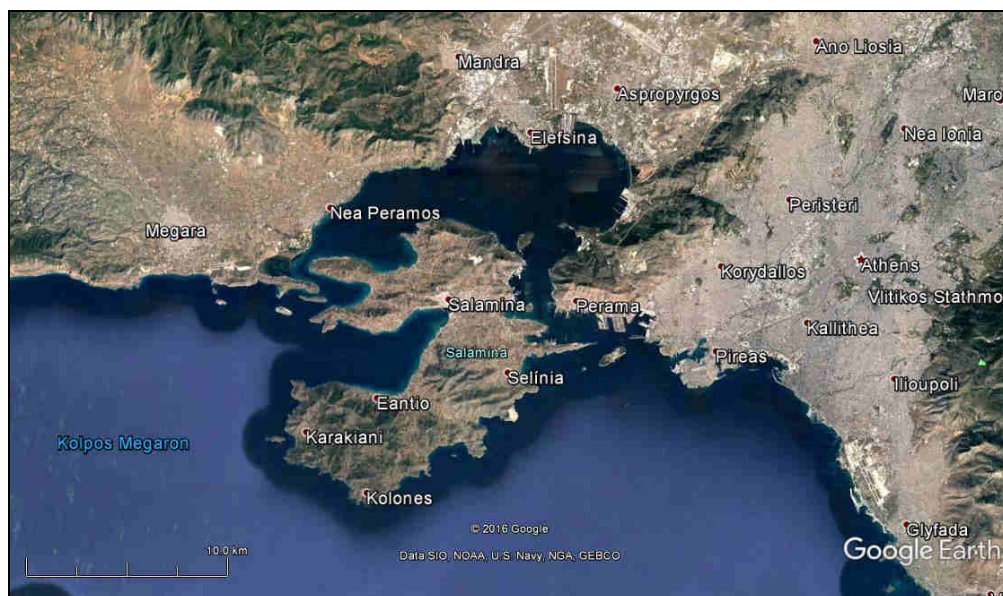


Figure 2.2.A Satellite image which shows part of the Saronic Gulf, and the characteristically enclosed Gulf of Elefsina on the North of Salamina Island. The North is on the top of this image (from Google Earth).

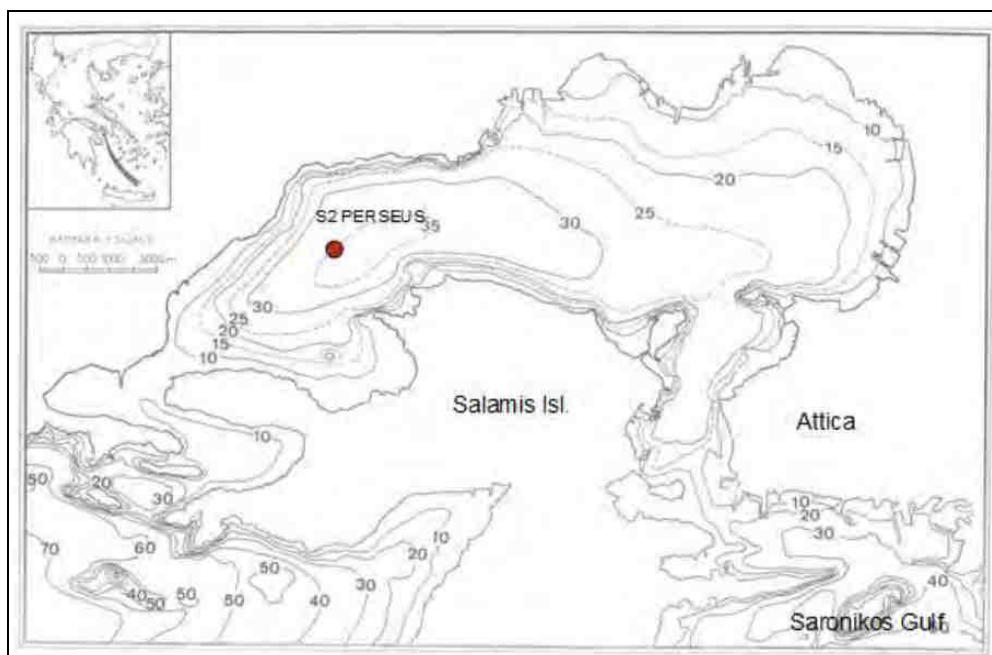


Figure 2.2.B Bathymetric map of Elefsis Bay. Red dot depicts S2-Perseus core site (from Petropoulos et al., 2013, using unpublished map of Anagnostou).

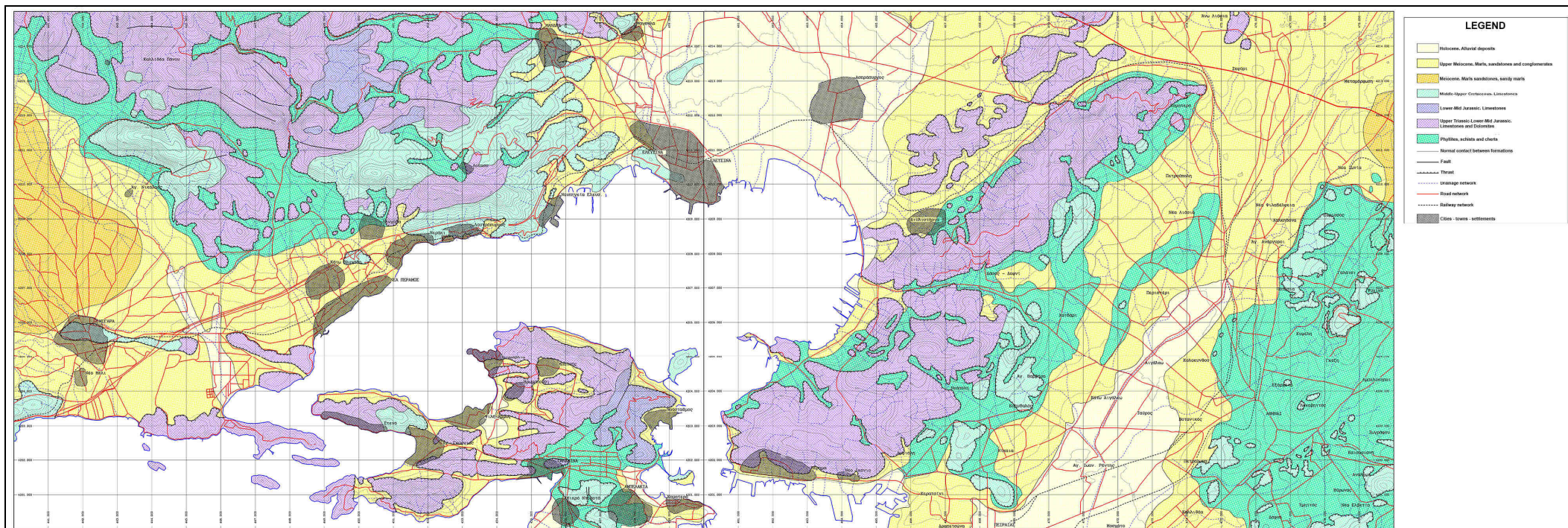


Figure 2.2.C Geologic map of the wider area of the gulf of Elefsina. Composite image of two geologic maps (code: 440_4200, 460_4200), scale 1:25.000. Legend from top to bottom: **1.** Holocene. Alluvial deposits, **2.** Upper Miocene. Marls, sandstones and conglomerates, **3.** Miocene. Marls sandstones, sandy marls, **4.** Middle-Upper Cretaceous. Limestones, **5.** Lower-Mid Jurassic. Limestones, **6.** Upper Triassic-Lower-Mid Jurassic. Limestones and Dolomites, **7.** Phyllites, schists and cherts, **8.** Normal contact between formations, **9.** Fault, **10.** Thrust, **11.** Drainage network, **12.** Road network, **13.** Railway network, **14.** Cities - towns - settlements (modified after unpublished data of K. Bezes – www.geologiaelladas.blogspot.gr).

Ψηφιακή συλλογή
"ΘΕΟΦΡΑΣΤΟΣ"
ΑΠΟ
ΤΟ
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The geology of the Gulf of Elefsina and the area that surrounds, is summarized in *Chapter 2.1* as part of the wider Saronic Gulf. The geologic map that includes the Gulf of Elefsina is shown in Figure 2.2.C. Igneous, metamorphic and sedimentary rocks of the Paleozoic and Mesozoic eras are present in the area. Noteworthy are the rock units that belong to the geotectonic zones of the Subpelagonic (i.e., limestones, schists) and Pelagonic (i.e., limestones, ophiolites). Rock units datable to the Neogene and alluvial (loose) sediments of the Quaternary are also present.

Torrents and generally the drainage network played an important role at the sedimentation of the area (Fig. 2.2.D). The sedimentation rate in the Western part of the Gulf of Elefsina is estimated about 3 mm/year (Hatzianestis et al., 2004). Recent research carried out by Petropoulos et al. (2013) revealed the sub-bottom profiles of the gulf, where Holocene marine sediments are deposited above older strata separated by an unconformity (Fig. 2.2.E). Taking the above mentioned facts for granted we can assume that the sediment deposits of the present bottom of the Gulf of Elefsina as well as the first few meters of subsurface, are relatively recent and derived mainly from fluvial-torrent debris (Sklivagkou, 2003).

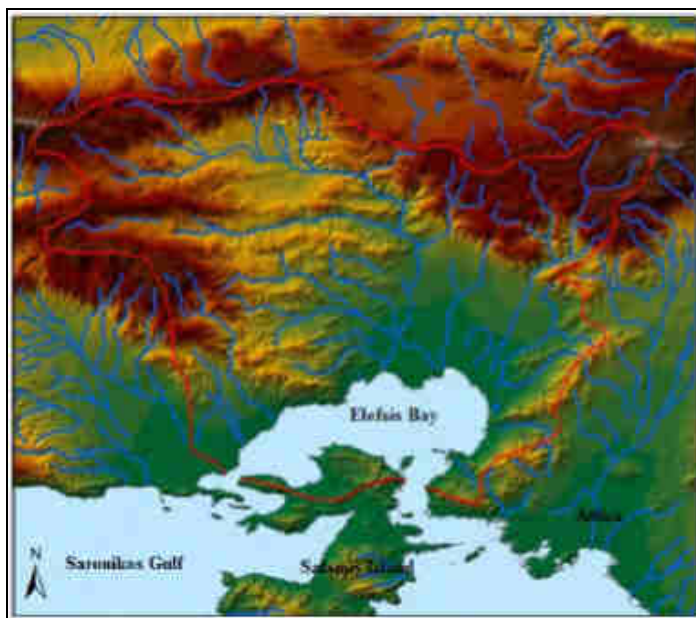


Figure 2.2.D The drainage network of the Gulf of Elefsina. Red line follows watershed (from Petropoulos et al., 2013).

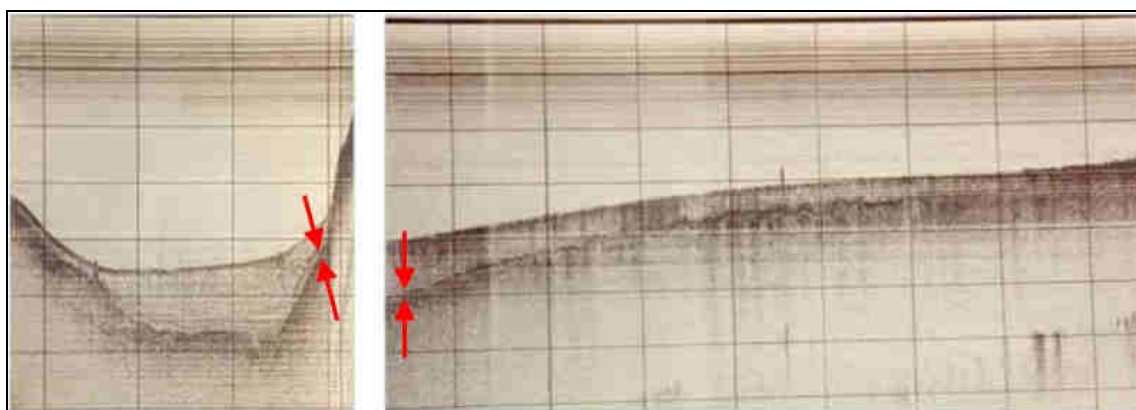


Figure 2.2.E Gulf of Elefsina sub-bottom profiles. On the Western part (Left image) the Holocene sediments have a thickness of 8-13 m, while on the Eastern part (Right image) a thickness of 3-5 m. Red arrows indicate the unconformity (modified after Petropoulos et al., 2013).

It is worth mentioning that periodic anoxic episodes noted by Pavlidou et al. (2010), are caused by the freshwater input as dealt with previously, in addition to the restricted exchange of water mass between the Gulf of Elefsina and the open sea. Besides, nowadays, the heavily industrialized and populated areas of Athens resulted in industrial and urban waste being directed to the sea, causing the accumulation of toxic elements and compounds, especially on the Northern part of the Saronic and even more on the Gulf of Elefsina, as noted by many researchers (Sklivagkou, 2003; Paraskevopoulou, 2009; Prifti et al., 2012; Prifti and Kaberi, 2014; Karageorgis et al., 2016). In some cases, the increased nutrients input, due to human activity, leads to eutrophication (Papathanassiou and Zenetos, 2005). All these factors combined definitely affect marine life.

3. Materials and methods

3.1 Study Area

The invertebrate specimens of this study originate from a core sample named S2-Perseus (S2P) which was retrieved from the northernmost part of the Saronic Gulf on the 9th February 2012, on the NW part of the smaller Gulf of Elefsina. The core sample was taken by using a 5 m long gravity core, using R/V Aegaeo of the Hellenic Center of Marine Research (HCMR); exact coordinates are 38°00'50" N, 23°27'48" E (exact spot visible in Fig. 3.1).



Figure 3.1 Satellite image of the Gulf of Elefsina and S2P Core drilling location (yellow).

3.2 S2P Core Sample

The recovered length of the core sample is 342 cm; longitudinally splitting of the core, macroscopic description (sediment color determined using the Standard Soil Color Charts, SSCC) and sub-sampling were carried out in the laboratories of the Hellenic Center of Marine Research (HCMR) by the team of micropaleontology of NKUA. The samples have been used for geochemical (Petropoulos et al., 2013), palynological (Kyrikou, 2016; Kyrikou et al., 2016), foraminiferal and mollusk (present study) analyses.

3.3 Laboratory analysis

3.3.1 Initial weighing

Sampling was succeeded in S2P core with a step of 1 to 3 cm. This procedure was carried out at the HCMR by the NKUA team. A total of 231 samples were collected. The samples (Fig. 3.2) were transported from Athens to AUTH for further paleontological analysis and for this study. Each sample (Fig 3.3a) was weighed using an A&D Model FX-320 balance (3 decimals precision) (Fig. 3.3b). All the samples were split into two distinct sub-samples; the first stored as supplementary material for future reference; the second ones (Fig 3.3c), were used for the needs of this analysis. Approximately 10 gr of each sample was collected for further molluskan analysis.



Figure 3.2 The samples of the S2P borehole at the School of Geology of AUTH.

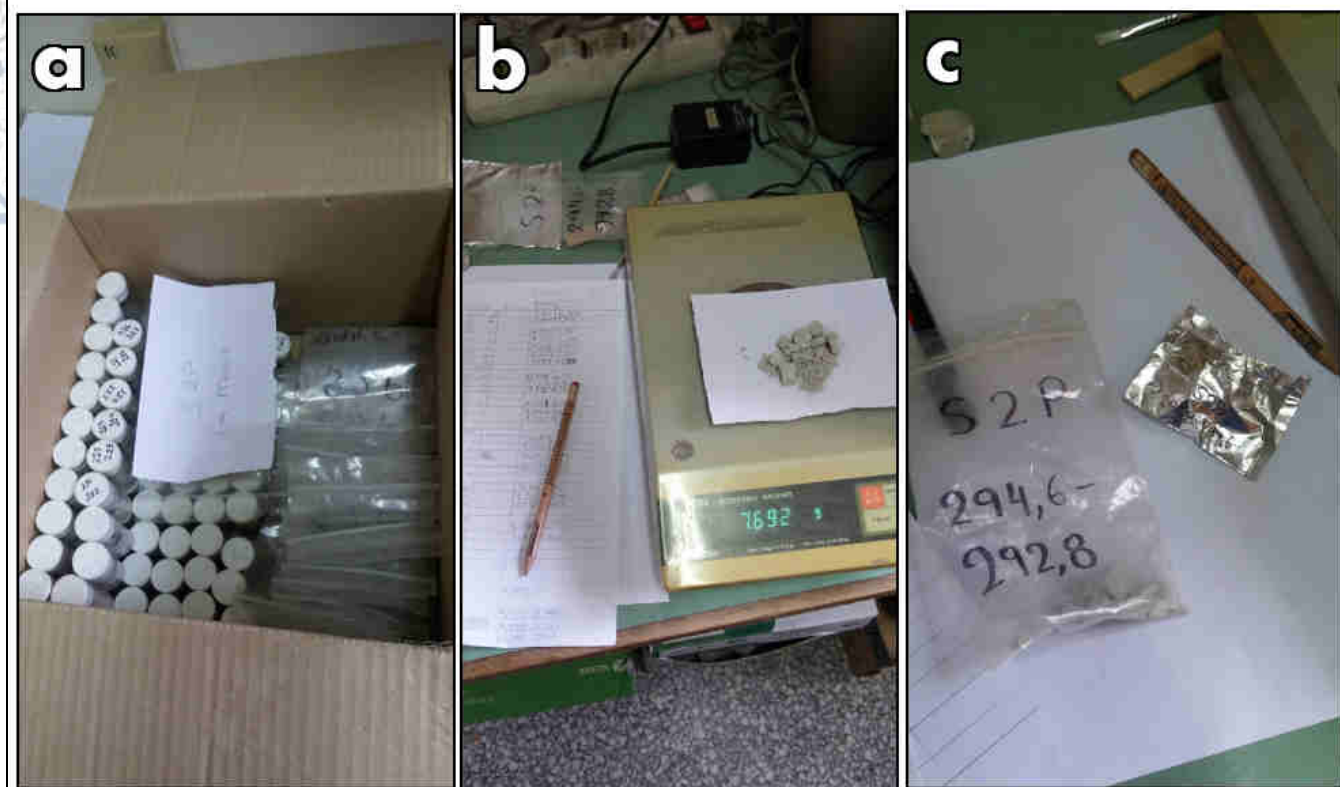


Figure 3.2 a. Initial samples, **b.** Weighing of a sample, **c.** Sub-samples for storing (plastic bag) and wet-sieving (aluminum bag).

3.3.2 Wet sieving – Grain size estimation

All samples were treated with the standard wet-sieving procedure (ex., Carboni et al, 2009; Koukousioura et al., 2012; Triantaphyllou and Dimiza, 2012; Dimiza et al., 2016). After initial weighing, the samples were placed into plastic vials (Fig. 3.4a) and soaked into natural water with diluted Hydrogen Peroxide (Perhydrol, H_2O_2 30%) (Fig. 3.4b). The prepared samples were then left to “boil” (Fig 3.4c), in order to let the Perhydrol react and remove the excessive organic mater as well as to disaggregate the silt and clay of the sediment. Then the samples were wet - sieved with natural water into a 63 μm stainless steel wire mesh sieve (Fig. 3.4d, 3.4e). This procedure removes silt and clay leaving into the sieve the sand fraction ($>62,5 \mu m$) with the included invertebrate shells. The remaining material of each sample was then transferred from the sieve, with a gentle jet of water, into a filter paper to remove the excess water and was left to dry. The washed dried samples were weighed again with a precision balance (Fig. 3.4f), and stored into small glass vials. The difference between initial sample weight and washed residue weight represents the silt and clay fraction removed from each sample and this was used to estimate the Sand / Silt + Clay proportions of the samples.

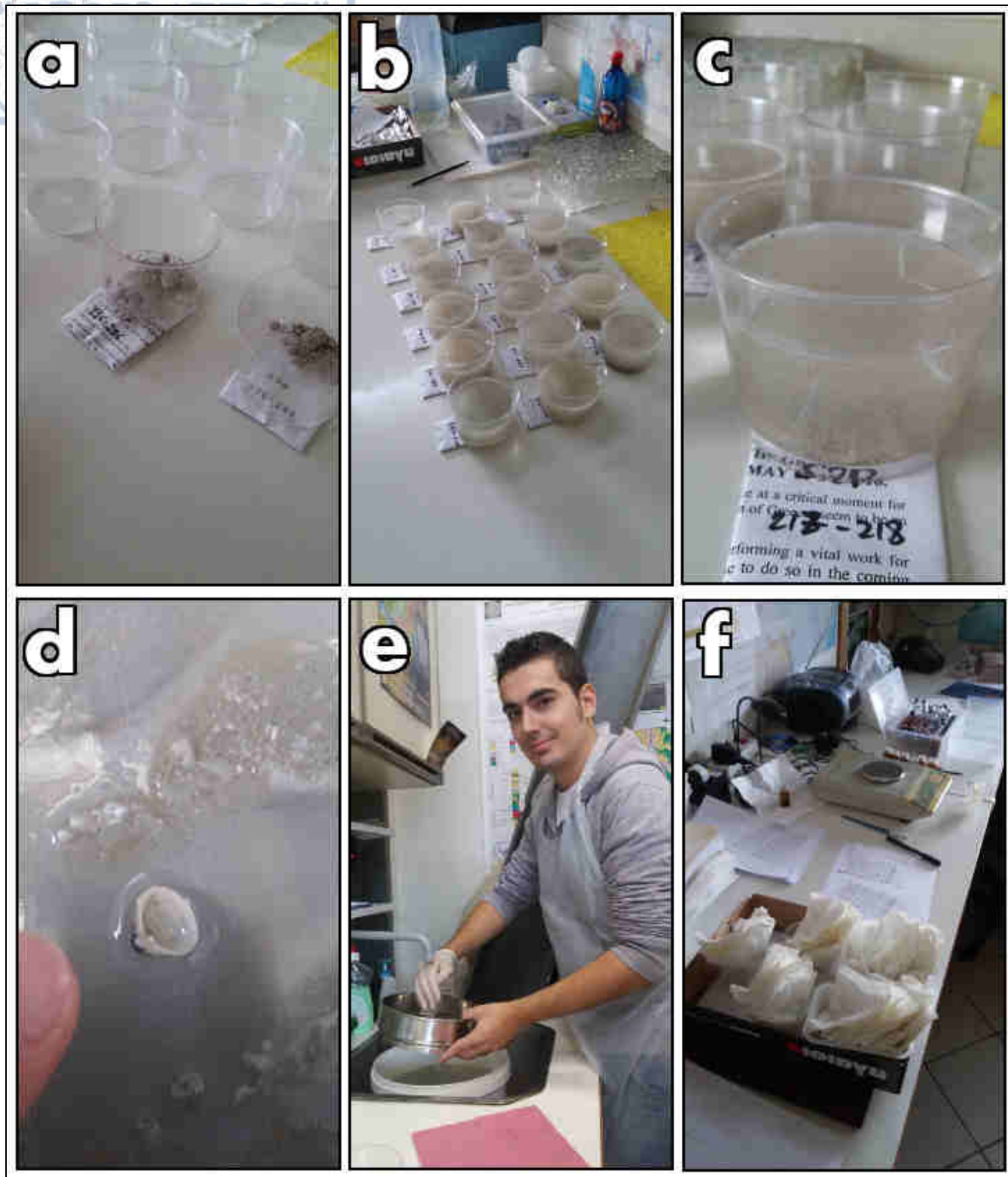


Figure 3.4 **a.** Putting the samples into plastic cups, **b.** Cups with the samples filled with water and Perhydrol, **c.** Close-up view of the “boiling” of a sample, **d.** A shell in the sieve, **e.** Sieving, **f.** The dried up samples in filter papers.

3.3.3 Collecting material from samples

The dried residue of each sample was inspected under a Leitz Wetzlar stereo microscope (under 10x, 16x, 40x magnifications). All the contained invertebrate shells were inspected and the intact and identifiable parts and fragments were selected and handpicked using thin forceps and wet thin (no0) painter's brush (Fig. 3.5a). Since the samples contained numerous fragments (Figures 3.5b and 3.5c) only those preserving recognizable characteristic features were picked and elaborated. Such features have to do with the shell morphology (i.e., hinge, hinge teeth, shape, decoration) that can help us determine the genera and species. The main criterion of the selected shells parts and characteristic fragments was to be involved in the estimation of MNI (Minimum Number of Individuals) and be elaborated with quantitative and statistical analysis.



Figure 3.5 a. The Stereo-microscope Leitz Wetzlar used for the research, **b.** Example mollusk specimens found in one of the samples, **c.** Foraminifera (center bottom) and fragments of various species can be observed in this sample.

The specimens were recorded and identified. Concerning bivalves, the specimens were sorted according to the valve (left or right valve) and the size of the shell (normal, small and juvenile); for gastropods, according to the shell's preserved parts and characteristics (intact, spire, aperture and fragment). Specimens from other classes (Arthropoda, Scaphopoda, Echinoidea) were retrieved only as a reference point. In total, 10500 specimens were collected. The tables listing the taxa and quantities are given in the section *Appendix* of this thesis.

3.3.4 AMS 14C dating

Mollusk specimens and organic material were retrieved from samples and used for radiocarbon dating using the Accelerator Mass Spectrometry (AMS) method (Kyrikou et al., 2016). It is well known that the ^{14}C is a valuable resource in order to determine the age of the material used, which in turn also gives us an idea of the relative ages of the layers of the core sample. All samples were analyzed at the laboratory of Beta Analytics Inc. (Miami, Florida, USA). The radiocarbon dates that resulted from the analysis of calcareous shells have been calibrated using CALIB 7.1 (Stuiver and Reimer, 1993) with a regional reservoir age correction $\Delta R 35 \pm 70$ proposed for Piraeus (Facorellis and Vardala-Theodorou, 2015). Results are shown in Table 5.A and Figure 5.4.

3.4 Data analysis methods

3.4.1 Faunal analysis

The resulted data from the specimens' collection, observation and determination of species showed already clear distinctions within the faunal elements. The relative frequencies of species per sample were calculated, in order to better evaluate the abundance of species and whether there is any connection or interaction between them. The presence or absence of highly abundant species throughout the core sample would give a good “signal” of diversification within the fauna. Considering the adaptiveness of certain species to certain environmental conditions (i.e., salinity, oxygenation, material of the bottom's surface), such diversification could give insights on possible paleoenvironmental changes of the gulf of Elefsina.

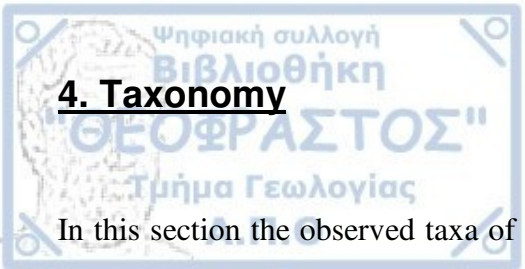
3.4.2 Faunal indices

The studied fauna gave out valuable results by applying quantitative analysis methods. The ones used in this research included Taxa (S), Shannon-Wiener diversity Index (H'), Density (per 10g of dry sediment) and the amount of rounded specimens collected from the S2P core sample. The first two were calculated using the software PAST.exe (Hammer et al., 2001). Diversity indices help us assess the correlation between presence and abundance of species. Taxa as an index provides the number of species recorded and is helpful compared to other indices. The Shannon-Wiener index “*measures heterogeneity evaluation, which means the distribution of individuals in the different species*” (Magurran 1988 cited in Koukousioura et al., 2012). Density gives us a better view of abundance and diversity of the fauna. Rounded specimens were found in specific layers and therefore their presence or absence was considered.

3.4.3 Statistical analysis

In order to confirm the validity of the faunal analysis, a statistical analysis was performed. This method applied to dead faunal assemblages for paleoenvironmental studies is well noted by many researchers (e.g., Goiran et al., 2011; Koukousioura et al., 2012; Dimiza et al., 2016). The statistical methods used to further analyze the specimen's data include Principal Component Analysis (PCA), using the software PAST.exe (Hammer et al., 2001), as well as multivariate analyses (Q and R mode Cluster Analysis), using the software package SPSS Statistics (IBM) version 24. Principal components “*are eigenvectors of a variance-covariance matrix or a correlation matrix, and they provide significant insight into the structure of the matrix*” (Davis, 2002). The R-mode hierarchical cluster analysis helps to determine species associations and assess the ecological affinity among groups, while the Q-mode hierarchical cluster is used to focus the ecological information contained in assemblages from single samples, by calculating the associations (Koukousioura et al., 2012 and references). For the Cluster Analysis in general, the data were logarithmically transformed “*to reduce the score and bias of other abundant species that may have otherwise masked the effect of less abundant species*” (Koukousioura et al., 2012); also, in order to reduce possible “noise”, species with percentage participation on the samples of values less than 5 % were removed.

Additionally, a series of graphs and columns were made using the softwares Strater 3 and Grapher v9.2.612 (Goldensoftware) with data from the S2P core sample, specimens (i.e., presence and abundance of certain species or groups) and sand/mud percentages. The data provided from the statistical analysis helped to further validate the proposed model for the paleoenvironmental reconstruction of the Gulf of Elefsina.



4. Taxonomy

In this section the observed taxa of the S2P core samples are presented. This chapter classifies the taxa into Phyla, Classes, Subclasses, Families and Genera. Only few mollusk taxa could be determined at the taxonomic rank of species, as the differentiation of such rank depends not only on the shell morphology, but occasionally also on the observation of soft body parts of the animals (Riedl, 1991). From 10500 specimens collected, a total of 7710 (7251 fresh and 459 etched) belonged to 45 Genera and 47 different species of bivalve and gastropod mollusks (the amount of specimens of the scaphopod genus *Dentalium* sp. described in this chapter was not considered for statistical analysis). The taxonomy of this thesis follows the suggestions of the World Register of Marine Species (WoRMS), the Marine Species Identification Portal and the species classification and nomenclature done by Sakellariou (1957) and Riedl (1991). Other authors' comments were taken into consideration, in case the information provided was missing or insufficient. The photos of specimens displayed in this chapter were taken by the author and Prof. George Syrides. The species are shown in plates A, B, C, D. Plates A, B include gastropod species, while Plates C, D include bivalve and scaphopod species.

Phylum: Mollusca

Class: Gastropoda Cuvier, 1795

Subclass: Vetigastropoda Salvini-Plawen, 1980

Family: Trochidae Rafinesque, 1815

Genus: *Steromphala* Gray, 1847

1. *Steromphala adansonii* (Payraudeau, 1826)

(Table A, Fig. 1)

1826 *Trochus adansonii* Payraudeau; Payraudeau, p. 127, pl. 6, fig. 7-8

1843 *Trochus agathensis* Récluz; Récluz, p. 11-12

1888 *Gibbula conemenosi* Monterosato; Monterosato, p. 172

2004 *Gibbula adansonii* (Payraudeau); Antoniadou et al., p. 1122 - 1128

2017 *Steromphala adansonii* (Payraudeau, 1826); Affenzeller et al., p. 806-808, fig. 7

Material: 3 individuals present in the S2P at core depths of 100-101 cm (small fragment), 102-103 cm (small sized intact shell ~ 5 mm) and 159-160 cm (fragment).

Description: The shell has a characteristic conical (trochiform) shape with 6-7 whorls, separated by a deep suture in between. The whorls are usually decorated by multiple spiral bands. Shell of various coloration.

Comparison: The intact specimen has the same morphology as seen in the species *Steromphala adansonii*. Notable is the obscured umbilicus due to the folding of the columella, while the aperture is evidently displaced on the right compared to the spire and the columellar axis. Affenzeller et al. (2017 and references) observed that the shell shape of *St. adansonii* is similar to that of *St. umbilicaris*, but of much smaller size, and morphologically resembles the species *St. adriatica*.

Ecology: Marine species (Affenzeller et al., 2017). Usually attached on algae or rocks, they can live on various hard substrates. This species is found in the littoral zone, up to a depth of 40 m (data from www.iobis.org)

Subclass: Neritimorpha Golikov and Starobogatov, 1975

Family: Neritidae Rafinesque, 1815

Genus: *Theodoxus* Montfort, 1810

2. *Theodoxus* sp.

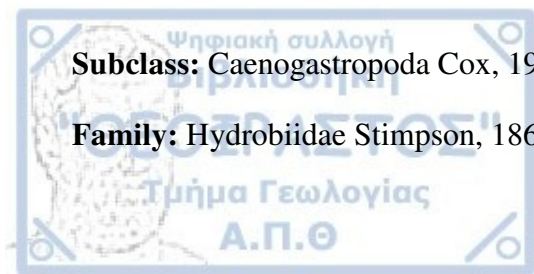
(Table A, Fig. 2-3)

Material: 146 individuals found. Normal-small sized (1,5-0,5 cm) individuals are the most abundant, while juveniles are also frequent. Present in S2P from a core depth of 296,8 cm up to 229 cm.

Description: Gastropod with a shiny small, diagonally oval shell. It is usually adorned with thin radial stripes. Those stripes are coloured with a brown-purple to reddish hue, while the shell itself is white-yellowish. Important feature for the classification of the species is the differentiated shape of the operculum.

Comparison: The studied material presents the same shape and decoration with stripes as observed in the genus *Theodoxus*.

Ecology: It is well noted in literature (e.g., Riedl, 1991) that *Theodoxus* species live exclusively in freshwater conditions (rivers, lakes), but there are also cases where they have been found in coastal brackish water or springs. It is common near river estuaries, according to Riedl (1991). Generally prefers rocky and hard substrates.



Subclass: Caenogastropoda Cox, 1960

Family: Hydrobiidae Stimpson, 1865

3. Hydrobiidae indet.

(Table A, Fig. 4)

Material: 268 individuals found. The specimens are very small (max 1 mm) to mostly juvenile. Present in the S2P between 200 cm and 7 cm.

Description: Small but robust shell, of conical-turritiform shape, with convex whorls. The aperture has no siphonal notch and is oval in shape, while there is a small umbilicus present.

Comparison: The studied material is morphologically similar to *Hydrobia*, yet difficult to classify, given the dimension (juveniles). The specimens have convex whorls and absence of a siphonal notch, with a visible umbilicus, typical of Hydrobiid species.

Ecology: Hydrobiid species are mostly found in freshwater conditions, but there are species that can also live under marine-brackish conditions (Riedl, 1991).

Genus: *Hydrobia* Stimpson, 1865

4. *Hydrobia* sp.

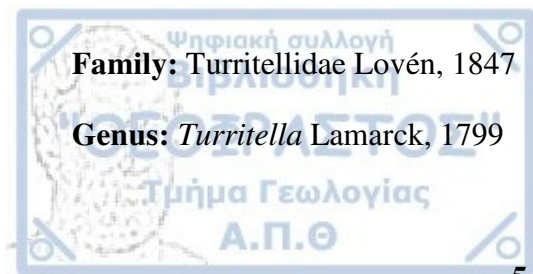
(Table A, Fig. 5-10)

Material: 731 individuals found. Different sized shells, with 40% being normal sized (3-1,5 mm), 20% small (1,5 - 1 mm) and 50% juvenile (<1 mm). Present in the S2P core depths from 296,8 cm up to 200 cm.

Description: Small but robust shell, of conical-turritiform shape. Convex whorls of 6-7 rounds with distinct suture. A small umbilicus can be noticed near the aperture, while the latter has no siphonal notch, is oval in shape and angulated on its top part. The shell has a white to yellowish colour.

Comparison: The studied material has the same morphological features (convex whorls, umbilicus, absence of siphonal notch and oval aperture) as in the genus *Hydrobia*.

Ecology: While most species of the Hydrobiidae family live in freshwater conditions (Riedl, 1991), there are some that can live in the marine littoral zone and in brackish water. Di Rita et al. (2011) mention the salinity fluctuation preference of Hydrobiidae, being 2-34 ‰ usually, although they prefer a narrower 6-25 ‰.



Family: Turritellidae Lovén, 1847

Genus: *Turritella* Lamarck, 1799

5. *Turritella communis* Risso, 1826

(Table A, Fig. 11)

1826 *Turritella communis* Risso; Risso, p. 106, pl. 4, fig. 37

1833 *Turritella linnaei* Deshayes in Bory de Saint Vincent; Bory de Saint Vincent, p. 146-147

1890 *Turritella mediterranea* Monterosato; Monterosato, p. 148-149

1991 *Turritella communis* Risso; Riedl, p. 246

Material: 873 individuals found. About 60% are juveniles (<5 mm) and 40 % are normal/small sized (max 4,5 cm). Constantly present in the S2P from a core depth of 191 cm and above.

Description: Characteristic turritiform shaped shell, with up to 19 whorls, slightly convex. A series of striae are present on the whorls, parallel to the coiling. Colour usually white-yellowish, but it may variate. The aperture is small and angulated, while the outer lip is crenulated. No umbilicus is present.

Comparison: The studied material presents a series of 8-10 striae parallel to the coiling and has the same morphological features of the species *Turritella communis*.

Ecology: A marine species, very common on soft bottoms (Riedl, 1991).

Family: Rissoidae Gray, 1847

Genus: *Rissoa* Desmarest, 1814

6. *Rissoa* sp.

(Table A, Fig. 12-13)

Material: 35 individuals found. From them, 11 are normal sized (max 5 mm), 9 small (2,5-1,5 mm) and 15 juvenile (<1 mm). Present in S2P from the core depth of 240 cm up to 202 cm.

Description: Shell oval-conical with 7-8 semi-transparent, glossy, slightly tumid whorls. Characteristic are the slightly protruding radial bulges. The aperture is oval, without a siphonal notch. The apex is slightly elongated.

Comparison: The studied material has the same shell shape (oval-conical) and morphology (radial bulges) as referred for the genus *Rissoa*. In comparison to similar *Rissoa* species (e.g., *R. splendida*, *R. ventricosa*, *R. violacea*), it lacks pronounced inner and outer lips.

Ecology: The different *Rissoa* species are usually of marine living, according to Riedl (1991), attached on algae or other floral elements of the littoral zone. Some researchers (e.g., Barnes, 2008) annotated the presence of species capable of living in brackish water conditions.

Family: Cerithiidae Fleming, 1822

Genus: *Bittium* Gray, 1847

7. *Bittium reticulatum* (da Costa, 1778)

(Table A, Fig. 14)

1778 *Strombiformis reticulatus* da Costa; da Costa, p. 117-118, pl. 8, fig. 13

1855 *Rissoa vulgatissima* Clark; Clark, p. 375-377

1865 *Cerithium jadertinum* Brusina; Brusina, p. 16

1977 *Bittium atticum* Nordsieck, Nordsieck, p. 14-15

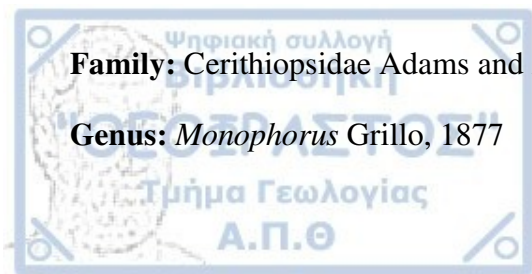
1991 *Bittium reticulatum* (da Costa), Riedl, p. 248

Material: 779 individuals found. Mostly juvenile specimens with few small sized (max 3 mm) individuals. Present in the S2P from a core depth of 199 cm and above.

Description: Small shell, elongated and turritiform. The whorls are decorated with nodule-bearing spiral bands. The aperture is oval and angulated on the top part, while on the bottom part a short siphonal notch is present which protrudes laterally. Colour varies from brown-orange to white.

Comparison: The studied material includes mostly juvenile individuals, with only few whorls being well developed. However, distinct morphological features are already visible in the shells (whorl decoration, siphonal notch), which are identical with the *Bittium reticulatum* described above.

Ecology: A marine species that as Riedl (1991) states is very common on algae but also on soft bottoms.



Family: Cerithiopsidae Adams and Adams, 1853

Genus: *Monophorus* Grillo, 1877

8. *Monophorus* sp.

(Table A, Fig. 15)

Material: 2 fragments (max 2 mm) found in the S2P at core depths of 40-42 cm and 153-154 cm.

Description: Elongated turritiform shell with a plump appearance, bearing a decoration similar to *Bittium*. The coiling is characteristically sinistral, with an oval aperture and short siphonal notch that protrudes laterally.

Comparison: Only fragments with just the intact aperture were found in the S2P. The morphology, decoration and coiling of the shells are the same as in species of the genus *Monophorus*.

Ecology: Marine species which can be locally abundant till 100 m of depth (Riedl, 1991). This species prefers to live on soft bottoms.

Family: Aporrhaidae Gray, 1850

Genus: *Aporrhais* da Costa, 1778

9. *Aporrhais pespelecani* (Linnaeus, 1758)

(Table A, Fig. 16)

1758 *Strombus pespelecani* Linnaeus; Linnaeus, p. 742

1957 *Chenopus pes pelecani* Linnaeus; Sakellariou, p. 200, pl. XLVII (IX), figs. 6-7

1991 *Aporrhais pes-pelecani* (Linnaeus); Riedl, p. 248-249, pl. 95, fig. 1

2013 *Aporrhais pespelecani pespelecani* (Linnaeus); Brunetti and Forli, p. 183-208, figs. 1-10, 70, 71

Material: Only few shell fragments (12 in total - max 1,5 cm) of this species present in the S2P from the core depth of 187 cm and above.

Description: Very thick shell, turiform, with 10 whorls. The upper spire has a series of nodules, while the lower has 3. The margin of the aperture is engrossed and extends laterally into 3 distinct appendices. The aperture is provided with a siphonal notch. The shell has a variety of coloration, which can be white-gray to yellow-pink.

Comparison: The studied material includes fragments that preserve parts of the protoconch and of the upper spire, as well as smaller spire fragments preserving decoration. The series of nodules present on the spires and overall the fragments' morphology are the same as in the species *Aporrhais pespelecani*.

Ecology: Riedl (1991) and Sakellariou (1957) note the common presence of this marine species near the coast, starting from a depth of 10 m. Riedl (1991) mentions the preference of *Aporrhais pespelecani* to live on soft, muddy bottoms.

Family: Naticidae Guilding, 1834

Genus: *Natica* Scopoli, 1777

10. *Natica* sp.

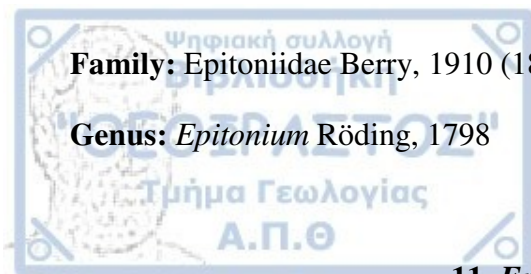
(Table A, Fig. 17)

Material: 13 individuals found. The specimens include 6 fragments (max 1 cm) and 7 small-juvenile intact shells. Despite the small amount, the presence is frequent and evident from the several round bores on various specimens from 189 cm and upcore.

Description: Small to medium sized, with thick walls, oval-ear shaped. Smooth surface of the shell without any relief decoration, but with a well defined umbilicus that is partially covered by a callus, a protuberance of the inner lip. The aperture has a half-moon like shape.

Comparison: The juvenile specimens, as well as the fragments of normal-sized shells of the studied material, have the same morphological features as in the genus *Natica*.

Ecology: A marine species, known (Riedl, 1991) to be predator of bivalves and gastropods. Their hunting method consists of perforating the shell of the prey to feed on them, leaving a small rounded hole, which in turn is an important indicator of their presence in the ecosystem. Riedl (1991) mentions their preference to live on soft bottoms.



Family: Epitoniidae Berry, 1910 (1812)

Genus: *Epitonium* Röding, 1798

11. *Epitonium cf. clathrus* (Linnaeus, 1758)

(Table A, Fig. 18)

1758 *Turbo clathrus* Linnaeus; Linnaeus, p. 765

1822 *Scalaria communis* Lamarck; Lamarck, p. 232

1986 *Epitonium communis* Lamarck; Backeljaou, p.13

1991 *Epithonium clathrus* Linnaeus; Riedl, p. 257, pl. 99, fig. 1

Material: 5 specimens found in the S2P (3 intact, normal/small sized shells - max 3,5 mm - and 2 fragments), from a core depth of 183 cm up to 118 cm.

Description: Medium sized shell with thick walls, turritiform, with characteristic protruding radial lamellae on the whorls, with the latter being quite convex. The aperture is rounded, with reinforced walls and no siphonal notch. The shell has a white to pink colour.

Comparison: The morphological features of the studied material are similar to those of the species *Epitonium clathrus*, with a small difference on the protruding radial lamellae: while typically *E. clathrus* has continuous lamellae over the whorls, the S2P specimens bear continuous lamellae that slightly angulate at the upper part of each whorl.

Ecology: Marine species that lives on soft bottoms (Riedl, 1991) in average to high depths.

Family: Eulimidae Philippi, 1853

Genus: *Eulima* Risso, 1826

12. *Eulima* sp.

(Table A, Fig. 19)

Material: 7 individuals found. Very small sized shells (max 1 mm). Present in the S2P from a core depth of 184 cm up to 104 cm.

Description: Small, turritiform, conical and elongated. Several rounds of the spire present. The whorls are smooth and flat, glass-like, giving the shell the shape of a small canine tooth. The aperture is triangular-oval. The colour ranges from ivory white to brown.

Comparison: The studied material has the same morphological features as in the genus *Eulima*.

Ecology: Not much is known about the family Eulimidae, according to Riedl (1991). The same author describes the species as a marine, living on muddy and rocky bottoms or as parasites to echinoderms and other animals.

Family: Muricidae Rafinesque, 1815

Genus: *Bolinus* Pusch, 1837

13. *Bolinus brandaris* (Linnaeus, 1758)

(Table A, Fig. 20)

1758 *Murex brandaris* Linnaeus; Linnaeus, p. 747

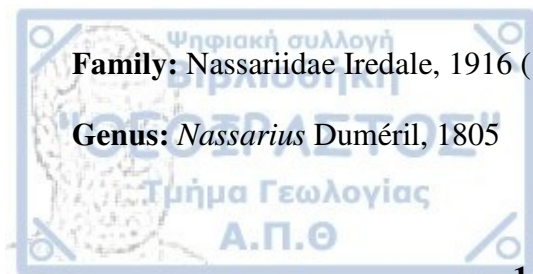
1991 *Murex brandaris* Linnaeus; Riedl, p. 259, pl. 100, fig. 2

Material: 1 fragment of spire (max 2,5 cm) found in the S2P at the core depth of 123-124 cm.

Description: Large shell with thick walls and 6-7 rounds of coiling. The whorls are featured with spines/thorns. On the lower part of the spire and the body whorl the radial protuberances are present as 2 straight thorns, plunged by a channel and crossed by spiral bundles. The region of the aperture is oval shaped and has a straight and elongated siphonal canal. The outer lip is serrated. Of white-yellowish colour, while the aperture is yellow-orange.

Comparison: The only specimen found is a fragment (2,5 cm) of the spire which carries the characteristic spines and the spire striae decoration, matching the one observed in the species *Bolinus brandaris*.

Ecology: This marine species is described to live on soft bottoms according to Riedl (1991). Sakellariou (1957) noted their preference to live in modern anthropogenic structures (i.e., ports) and near the estuaries of rivers, which also indicates an euryhaline adaptation. Like other Muricids, this species is a predator, and creates small holes on the shells of other bivalves and gastropods to prey on them, leaving us an indication of their presence in the ecosystem (Riedl, 1991).



Family: Nassariidae Iredale, 1916 (1835)

Genus: *Nassarius* Duméril, 1805

14. *Nassarius lima* (Dillwyn, 1817)

(Table A, Fig. 21)

1817 *Buccinum lima* Dillwyn; Dillwyn, pp. 581-1092

1836 *Buccinum limatum* Philippi; Philippi, p. 220

1838 *Buccinum limatum* Philippi; Deshayes and Milne-Edwards, p. 200

1891 *Nassa praelonga* Monterosato; Monterosato, p. 15

Material: 3 small sized intact specimens (max 8 mm) found in the S2P at the core depths of 220-221 cm, 108-109 cm, 33-35 cm.

Description: Species with a conical-oval and shortly shaped shell, and convex whorls decorated with cross-linked sculptures. The aperture is oval or oval-oblique and has a short siphonal notch. The colour of the shell is gray.

Comparison: The studied material has the same morphological features of this species. The specimens reveal similarities with other Nassariid species (e.g., *Nassarius reticulatus*) because of the characteristic cross-linked (reticulated) decoration on the whorls. Notable difference from *Nassarius* species is the absence of well pronounced inner and outer lips and the broader interspaces between the axial ridges.

Ecology: The Nassariid species are marine living animals that mostly live on soft bottoms, according to Riedl (1991).

15. *Nassarius reticulatus* (Linnaeus, 1758)

(Table A, Fig. 22)

1832 *Buccinum reticulatum* Linnaeus; Deshayes, p. 196

1868 *Nassa reticulata* (Linnaeus); Weinkauff, p. 58

1957 *Nassa (Hinia) reticulata* (Linnaeus); Sakellariou, p. 205, pl. XLVII (IX), fig. 2

1994 *Nassarius reticulatus* (Linnaeus); Rolán and Ángel, p. 59-76

Material: 5 fragments (max 1,5 mm) found in the S2P from a core depth of 170 cm and above.

Description: Medium, conical-oval shell, with an evident cross-linked sculpture on the whorls. The colour is gray to brownish gray.

Comparison: Only fragments of shell occur in the S2P, which have the characteristic reticulated sculpture as seen in the species *Nassarius reticulatus*.

Ecology: While the Nassariids live on soft, muddy bottoms, Riedl (1991) mentions that this particular marine species lives on sandy bottoms as well.

Family: Fascioliidae Gray, 1853

Genus: *Fusinus* Rafinesque, 1815

16. *Fusinus* sp.

(Table B, Fig. 1)

Material: 1 juvenile individual (max 3 mm) present in the S2P at a core depth of 68-70 cm.

Description: Medium to large size shell, characteristic fusiform, with an elongated spire and a long siphonal canal. The upper whorls are convex, whereas the bottom whorls are more or less beveled. Radial bumps and thick spiral bands. The aperture is oval and distinct from the siphonal canal and smaller in length than the latter. The colour of the shell is brown-orange.

Comparison: The single specimen found in the S2P presents 5 semi-transparent whorls. The last whorls and body whorl have already developed the decoration. The observed characteristics and the morphology are the same as in the genus *Fusinus*.

Ecology: Riedl (1991) mentions a differentiation of these marine species habitat. While they prefer bottoms rich on detritus from the littoral zone, the forms with well defined sculptures usually live on muddy, high depths.

Family: Mangeliidae Fischer, 1883

Genus: *Sorgenfreispira* Moroni, 1979

17. *Sorgenfreispira brachystoma* (Philippi, 1844)

(Table B, Fig. 2)

1844 *Pleurotoma brachystomum* Philippi; Philippi, p. 169, pl. XXVI, fig. 10

1897 *Bela confusa* (Locard); Locard, p. 227-228, pl. 11, fig. 27-32

2015 *Sorgenfreispira brachystoma* (Philippi, 1844); Mariottini et al., p. 434, fig. 14-17

Material: 16 individuals found. The specimens include 6 fragments, 2 normal sized shells (max 2,5 mm), 4 small and 4 juvenile (<1 mm). Present in the S2P from a core depth of 191 cm and above.

Description: Small shell, oval-fusiform. The first apical whorls are smooth, while the rest are decorated with a reticulated sculpture of 4-5 granulose spirals, crossed by an axial sculpture of 8–9 protruding, slightly opisthocline, flexuous and narrowly rounded ribs, regularly spaced, with broader interspaces. The aperture is narrow and ends to a short siphonal canal tending to the left. The shell has an orange to brown-orange colour.

Comparison: The studied material has the same morphological features as those described above for the species *Sorgenfreispira brachystoma*, as also noted by Mariottini et al. (2015).

Ecology: Marine species that prefers soft bottoms, common for the family Mangelidae (Riedl, 1991).

Subclass: Heterobranchia Burmeister, 1837

Family: Pyramidellidae Gray, 1840

Genus: *Chrysallida* Carpenter, 1856

18. *Chrysallida* sp.

(Table B, Fig. 3)

Material: 27 individuals found, mostly small sized intact shells (max 1 mm) and apertures. Present in the S2P from a core depth of 188 cm and above.

Description: Very small, conical-oval shell with 4-5 rounds. Characteristic are the large radial protuberances and the presence of a bend (tooth) of the columella, which is visible at the aperture. The latter is oval and doesn't have a siphonal notch. The apex faces to the right.

Comparison: The studied material presents the same decoration of the shell and columellar tooth, observable in the genus *Chrysallida*.

Ecology: As the other Pyramidellids, they are parasites, of marine living. Riedl (1991) mentions their preference to live on muddy bottoms, at various depths.



Genus: *Odostomia* Fleming, 1813

19. *Odostomia* sp.

(Table B, Fig. 4)

Material: 63 individuals found, including normal-small sized intact shells (max 1,8 mm) and apertures. Present in the S2P from a core depth of 190 cm up to 18 cm.

Description: Small shell, turritiform, with flat and smooth whorls. Characteristic the presence of a well defined bend of the columella (tooth). The shell colour is ivory white.

Comparison: The study material has the same morphology as in the genus *Odostomia*.

Ecology: Species of *Odostomia* are known to prefer sandy-muddy bottoms and/or beneath small rocks illuminated near the shore (Riedl, 1991)

20. Pyramidellidae sp.

(Table B, Fig. 5)

Material: 32 individuals found. The specimens include small-juvenile sized intact shells (max 1 mm) and apertures. Present in the S2P from a core depth of 188 cm and above.

Description: The morphological features of the shell are similar to other Pyramidellids (small oval/turritiform shells, slightly flat/convex whorls).

Comparison: The studied material has morphological features attributable to the family Pyramidellidae. The shell shape is similar to *Odostomia* sp., but without a columellar bent.

Ecology: Difficult to determine, but as a member of the Pyramidellid family, it is a marine species that probably lives on soft, muddy bottoms, as well (Riedl, 1991).

Genus: *Turbonilla* Risso, 1826

21. *Turbonilla acuta* (Donovan, 1804)

(Table B, Fig. 6)

1804 *Turbo acutus* Donovan; Donovan, pl. 179, fig. 1

1844 *Chemnitzia gracilis* Philippi; Philippi, p. 238

1874 *Odostomia delicata* Monterosato; Monterosato, p. 267

2013 *Turbonilla acuta* (Donovan); Öztürk and Bakır, p. 429, fig. 14

Material: 23 individuals found. The specimens are normal-small sized intact shells (max 2,5 mm) and few apertures. Present in the S2P from a core depth of 199 cm and above.

Description: Small turritiform shell with slightly convex whorls (9-10 rounds). The protoconch has a helicoid form. The first 2-3 whorls are smooth (hard visible fine spirals present) and the following ones have straight, slightly opisthocline axial ribs, with narrower interspaces in between. The columellar tooth is absent. The colour of the shell is white to slightly transparent.

Comparison: The studied material has the same morphology to that attributable to the species *Turbonilla acuta*, as also referred by Öztürk and Bakır (2013).

Ecology: Common marine species that lives on soft or hard muddy bottoms. They can be found as parasites on Polychaeta (Riedl, 1991).

Family: Cimidae Warén, 1993

Genus: *Cima* Chaster, 1896

22. *Cima* sp.

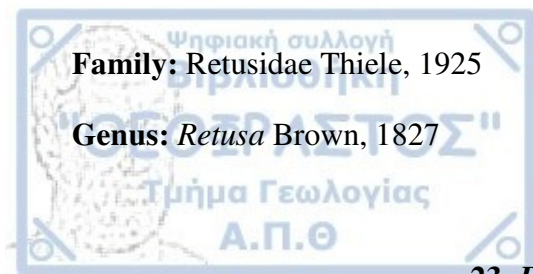
(Table B, Fig. 7)

Material: 9 individuals found. Very small sized intact shells (max 1 mm). Present in the S2P from a core depth of 188 cm and above.

Description: Very small and slender shell, turritiform. The whorls are very convex with a deep suture in between. The aperture is oval in shape and has no siphonal notch. The shell's surface is semi-transparent and polished.

Comparison: The morphology of the studied material is the same as in the genus *Cima*.

Ecology: Marine species.



Family: Retusidae Thiele, 1925

Genus: *Retusa* Brown, 1827

23. *Retusa leptoneilema* (Brusina, 1866)

(Table B, Fig. 8)

1866 *Cylichna leptoneilema* Brusina; Brusina, p. 39

Material: 112 individuals found. The specimens include normal-small sized intact shells (max 1,5 mm) and few spiral fragments. Present in the S2P from a core depth of 197 cm and above.

Description: Obovate shell shape, small in size. The spire sinks inwards and has a sculpted spiral on it. The whole shell is practically the body whorl, with the aperture being placed laterally. The latter has a very narrow opening line on the upper part and becomes larger, with an oval shape, on the lower part. Faint striatures present on the body whorl.

Comparison: The studied material has the same morphology as in the species *Retusa leptoneilema*. The specimens differ from other similar *Retusa* species (e.g., *R. crebisculpta*, *R. laevisculpta*), as the spire is more pronounced, the shell has a more defined cylindrical shape and the aperture's upper part is placed lower in correspondence to the spire.

Ecology: Marine species present on the littoral zone but also on bigger depths, with a preference to live on sandy or mixed bottoms (Riedl, 1991).

Class: Bivalvia Linnaeus, 1758

Subclass: Protobranchia Pelseneer, 1889

Family: Nuculidae Gray, 1824

Genus: *Nucula* Lamarck, 1799

24. *Nucula nitidosa* Winckworth, 1930

(Table C, Fig. 1-2)

1930 *Nucula nitidosa* Winckworth; Winckworth, p. 14-15

1996 *Nucula nitidosa* Winckworth; Gofas and Salas, p. 427-435, fig. 8-9

Material: 614 individuals found. From these, a 1/5 are normal sized intact shells or fragments (6 - 3 mm), while a 4/5 has sizes less than 3 mm and are small/juvenile intact shells or fragments. Present in the S2P core from 191 cm and above.

Description: Small in size with a round to triangular shape, with a serrated feature on the bottom edge of the valves. Equivalve. Evident taxodontic hinge teeth, which form a zipper-like structure when both valves meet. The ligament points slightly obliquely forwards and is deeply wedged between the two segments of teeth. The exterior of the shell has a white to soft yellow colour, whereas the interior is pearly.

Comparison: Juvenile specimens from the S2P core have a characteristic swelling of the early part of the teleoconch, as seen respectively in *Nucula nitidosa*, which is not found in other *Nucula* species, such as *N. nucleus* or *N. hanleyi* (Gofas and Salas, 1996). In normal sized specimens the shell has a triangular outline, more distinct than in *N. nucleus*.

Ecology: According to Riedl (1991) this marine mollusk is commonly spread on all sedimentary basins deeper than 5 m, and prefers to live in muddy sediments. Although *Nucula* species are broadly sympatric, *N. nitidosa* does not occur together with *N. nucleus* and *N. hanleyi* (Gofas and Salas, 1996).

Family: Nuculanidae H. Adams and A. Adams, 1858 (1854)

Genus: *Nuculana* Link, 1807

25. *Nuculana* sp.

(Table C, Fig. 3)

Material: 2 individuals (fragments) found in the S2P (max 1,2 mm) at the core depths of 29-31 cm and 10-11 cm.

Description: Small sized equivalve with the rear part of the shell elongated. Characteristic taxodont hinge teeth. The front part is elongated with striatules. The shell has a white-yellowish colour.

Comparison: Both of the shell fragments preserve parts of the hinge edges with few small teeth. Although these edge teeth are similar to *Nucula*, the outer part of the fragmented shells presents striatures, observable characteristic on the elongated portion of the shells of the genus *Nuculana*.

Ecology: Riedl (1991) mentions that this marine genus is not common to rare depending on the species, living in all kind of sediments, starting from 10 m of depth.

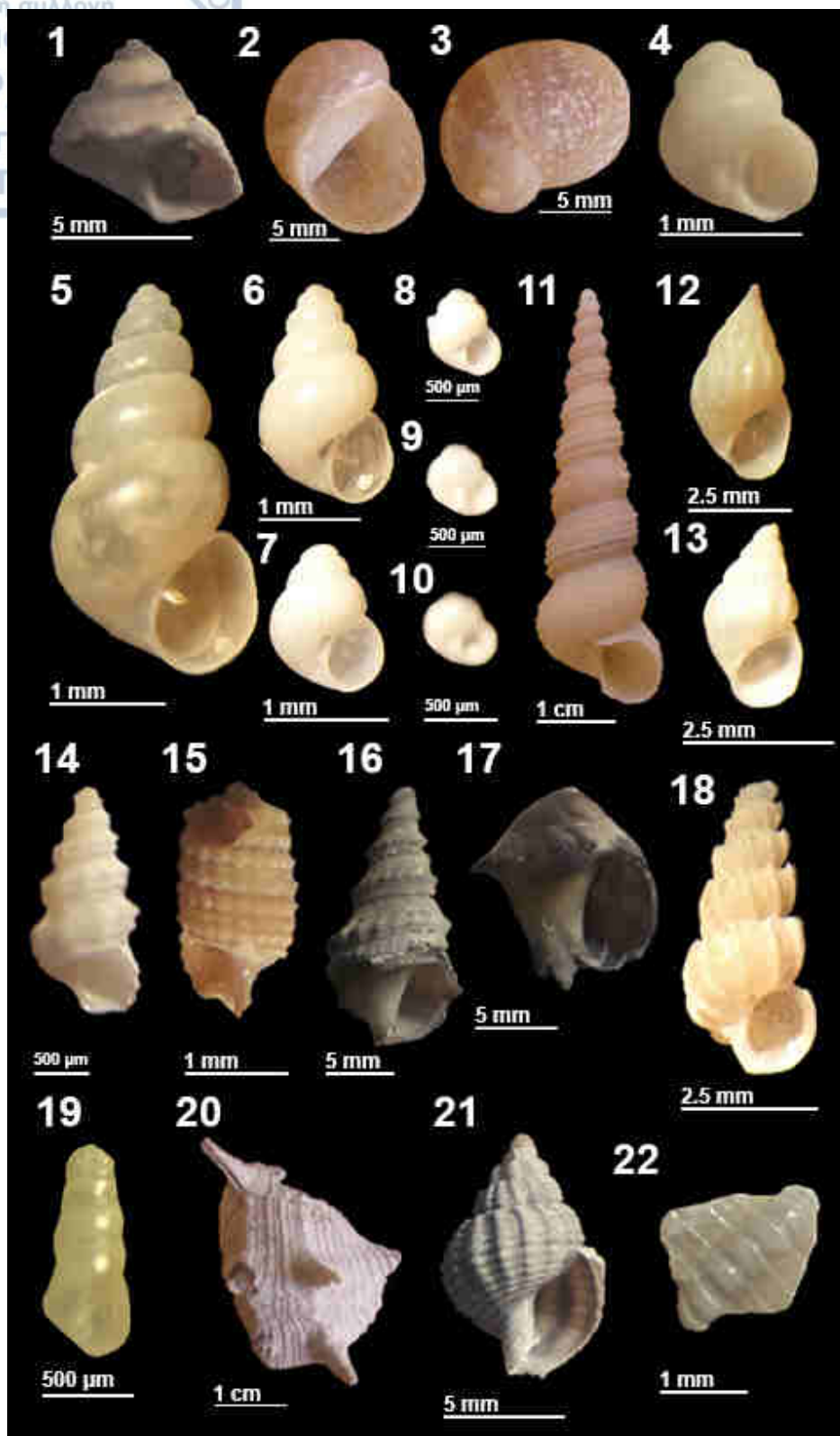


Plate A Gastropod species recorded from the S2P core sample. **1.** *Steromphala adansonii* (Payraudeau, 1826) (S2P 102-103), **2-3.** *Theodoxus* sp., aperture and spire view (S2P 294,6-296,8), **4.** Hydrobiidae sp. (S2P 180-181), **5-10.** *Hydrobia* sp., adult and juvenile forms (S2P 234-236), **11.** *Turritella communis* Risso, 1826 (S2P 64-66), **12-13.** *Rissoa* sp., adult and juvenile forms (S2P 214-215), **14.** *Bittium reticulatum* (da Costa, 1778) (S2P 33-35), **15.** *Monophorus* sp., fragment (S2P 40-42), **16.** *Aporrhais pespelecani* (Linnaeus, 1758), spire fragment (S2P 120-122), **17.** *Natica* sp., fragment (100-101), **18.** *Epitonium* cf. *clathrus* (S2P 168-169), **19.** *Eulima* sp. (S2P 104-105), **20.** *Bolinus brandaris* (Linnaeus, 1758), spire fragment (S2P 123-124), **21.** *Nassarius lima* (Dillwyn, 1817) (S2P 33-35), **22.** *Nassarius reticulatus* (Linnaeus, 1758), fragment (S2P 7-8).

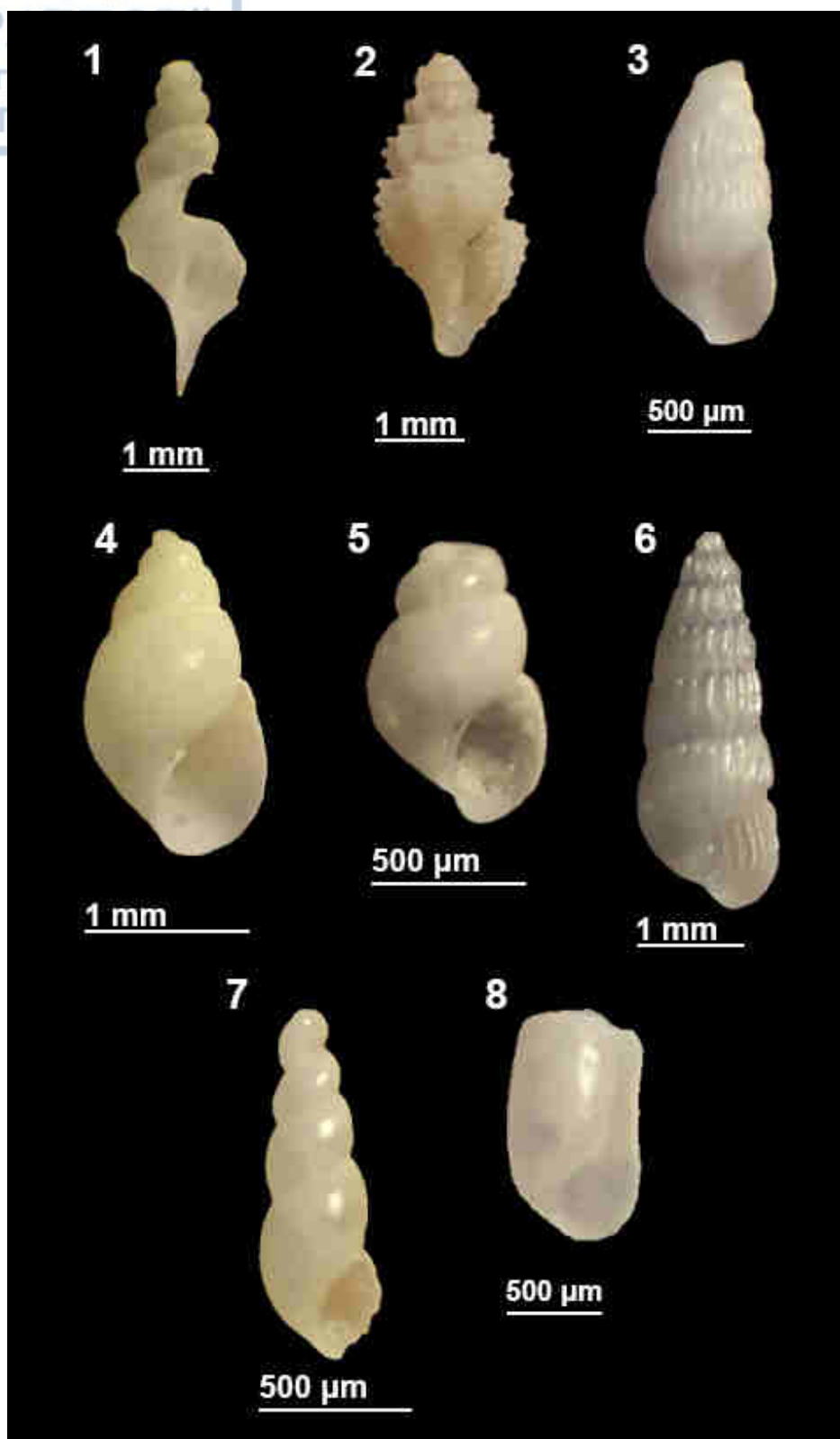
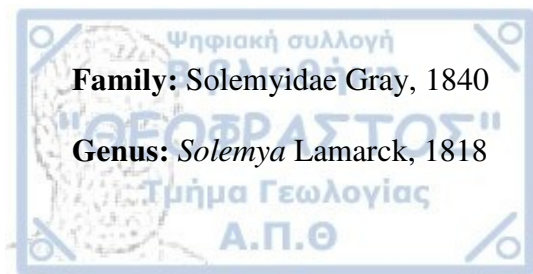


Plate B Gastropod species recorded from the S2P core sample. **1.** *Fusinus* sp. (S2P 68-70), **2.** *Sorgenfreispira brachystoma* (Philippi, 1844) (S2P 101-102), **3.** *Chrysallida* sp. (S2P 33-35), **4.** *Odostomia* sp. (S2P 180-181), **5.** *Pyramidellidae* sp. (S2P 182-183), **6.** *Turbonilla acuta* (Donovan, 1804) (S2P 100-101), **7.** *Cima* sp. (S2P 180-181), **8.** *Retusa leptoneilema* (Brusina, 1866) (S2P 33-35).



Family: Solemyidae Gray, 1840

Genus: *Solemya* Lamarck, 1818

26. *Solemya togata* (Poli, 1791)

(Table C, Fig. 4-5)

1791 *Tellina togata* Poli; Poli, p. 42

Material: 2 individuals (fragments – max 1,2 cm) found in the S2P at the core depths of 163-164 cm and 99-100 cm.

Description: This mollusk species can reach large sizes. According to Taylor et al. (2008), species of the family Solemyidae have “*elongate, near cylindrical shape and covered with glossy, thick, brown periostracum extended as a broad, pleated, flexible fringe*”. Juvenile individuals of *Solemya togata* found in the S2P have a semi-transparent shell and distinguishable hinge teeth.

Comparison: The studied material comprises shell fragments with only the hinge teeth preserved. Their morphology is the same as in the species *Solemya togata*.

Ecology: According to Riedl (1991) this species prefers shallow water and lives on soft bottoms.

Subclass: Pteriomorphia Beurlen, 1944

Family: Mytilidae Rafinesque, 1815

Genus: *Mytilaster* Monterosato, 1884

27. *Mytilaster marioni* (Locard, 1889)

(Table C, Fig. 6-7)

2002 *Mytilaster marioni* (Locard); Öztürk et al., p. 126, fig. 4

Material: 348 individuals found. The specimens are about 1/5 normal (max 1 cm), 1/5 small (5-2 mm) and 3/5 juvenile (<2 mm). Present in the S2P from a core depth of 253 cm up to 191 cm.

Description: Small in size, elongated in shape, with the umbo facing completely on one side. The shell has an obtuse angle on the rear margin of each valve and a straight line on the front, while the bottom is slightly arched. The interior rear edge of the shell has a serrated-like decoration. The hinge is reduced to a very small area, with no presence of teeth. The colour of the valves is brown-orange externally with light concentric streaks which start from the umbo, whereas internally it is iridescent and reddish.

Comparison: The straight front part and the angulated rear part of the shell is the most recognizable characteristic of *Mytilaster marioni*, as also described by Öztürk et al. (2002), which is observable in the studied material, hence why the attribution to this species. A close similar species to *M. marioni* is *M. solidus*, which however has a slightly angulated front margin (Bitlis et al., 2017).

Ecology: The genus of *Mytilaster* is known to include species of marine living attached with byssus on hard surfaces (fissures, rocks, pebbles, algae etc.) in the intertidal zone (Riedl, 1991; Öztürk et al., 2002). Some researchers (e.g., Barbieri et al., 2011) mention the presence of such species in brackish waters, which indicates it as tolerant in euryhaline conditions.

Genus: *Mytilus* Linnaeus, 1758

28. *Mytilus* sp.

(Table C, Fig. 8-9)

Material: 1 individual (fragment - max 1 cm) found in the S2P at a core depth of 3-4 cm.

Description: Medium-large size shell, with a straight line on the front and arched rear with a slight obtuse angle. The hinge is reduced to a very small area, with no presence of teeth. The anterior abductor is greatly reduced in comparison to the posterior. The colour of the valves is a characteristic black-blue on the exterior, whereas the interior is gray blue.

Comparison: Only one small fragment of shell was observed in the S2P. The rounded bottom margin, the accretion lines and the color (black-purple) are the same as in the genus *Mytilus*.

Ecology: Marine species, common on the intertidal zone, attached with byssus on hard surfaces (Riedl, 1991).

Family: Anomiidae Rafinesque, 1815

Genus: *Anomia* Linnaeus, 1758

29. *Anomia* sp.

(Table C, Fig. 10-11)

Material: 12 individuals found (small-juvenile intact shells - max 1,5 mm - or fragments). Present in the S2P from a core depth of 185 cm and above.

Description: Thin and irregular shell (depends on the surface it is attached). Colour varies as well. The interior of the left valve is pearly. No hinge teeth are present. The right valve presents a hole from which the calcareous byssus produced by the animal attaches to the substrate or any other hard surface.

Comparison: The studied material has the same morphological features of the genus *Anomia*.

Ecology: A marine species that attaches itself on hard surfaces. According to Riedl (1991), it is a common species at low depths with preference to live on hard bottoms, or even empty shells.

Family: Ostreidae Rafinesque, 1815

Genus: *Ostrea* Linnaeus, 1758

30. *Ostrea* sp.

(Table C, Fig. 12)

Material: 5 individuals (fragments) present in the S2P from a core depth of 183 cm and above.

Description: Medium to large size shell. It is characterized by the presence of intense growth lines starting from the umbo. The interior is smooth and has only one muscle scar. The right valve (only valve present in the S2P core samples) is smaller and almost flat.

Comparison: The studied material includes fragments with an observable characteristic structure of the shell made of lamellae, typical of the genus *Ostrea*.

Ecology: Common marine species of the intertidal zone in rocky coasts and generally on hard bottoms (Sakellariou, 1957; Riedl, 1991).

Subclass: Heterodonta Neumayr, 1884

Family: Cardiidae Lamarck, 1809

Genus: *Acanthocardia* Gray, 1851

31. *Acanthocardia* sp.

(Table C, Fig. 13)

Material: 50 individuals found (only juveniles). Present in the S2P from a core depth of 193 cm and above.

Description: The shell has elevated radial ridges, alternated by groove intervals. The latter ones feature dense concentric bands.

Comparison: Juvenile Cardiid species similar to the genus *Acanthocardia*, described below, impossible to determinate further, as the S2P specimens have not well developed features and shape of the shell.

Ecology: Marine mollusk. Riedl (1991) mentions that the species of *Acanthocardia* can live on all sedimentary bottoms, especially on sand, and occasionally (*Acanthocardia pausicostata*) on muddy bottoms.

32. *Acanthocardia pausicostata* (Sowerby, 1834)

(Table C, Fig. 14-15)

1834 *Cardium pausicostatum* Sowerby; Sowerby, part 49, catalogue p.2, fig. 20

1957 *Cardium pausicostatum* Sowerby; Sakellariou, p. 161, pl. XLIII (V), fig. 4

1991 *Acanthocardia pausicostata* (Sowerby); Riedl, p. 333, pl. 127, fig. 10

2013 *Acanthocardia pausicostata* (Sowerby); La Perna and D'Abramo, p. 481-492

Material: 36 individuals found with only 1 intact small sized shell (max 2,5 cm) and the rest fragmented. Present in the S2P from a core depth of 185 cm and above.

Description: Medium to large size shell, thin, equivalved, closed shut and a little uneven. With 16-17 radial ridges (which may have small tubercles on them) alternated by groove intervals. Those intervals feature dense concentric bands. The colour of the shell is blonde to pink. The hinge teeth type is a characteristic heterodont, like other species of *Acanthocardia*, but smaller.

Comparison: The intact S2P specimen has the same morphological features as observed in the species *Acanthocardia pausicostata*. The fragments also present the same sculpture.

Ecology: Sakellariou (1957) notes that the depth range of this marine species is between 2 m to 70 m. Riedl (1991), mentions that *A. pausicostata* is spread across all sedimentary bottoms, like other species of the genus, but in particular it prefers to live on muddy bottoms.

33. *Acanthocardia tuberculata* (Linnaeus, 1758)

(Table C, Fig. 16)

1957 *Cardium tuberculatum* Linnaeus; Sakellariou, p. 158, pl. XLII (IV), fig. 3

1991 *Acanthocardia tuberculata* (Linnaeus); Riedl, p.333, pl. 127, fig. 7

Material: 1 individual (fragment) found in the S2P at a core depth of 33-35 cm.

Description: Heart-shaped shell, solid with thick walls, equivalved and uneven. The front part is rounded, whereas the rear is slightly reduced. Characteristic tubercles present on the radial ridges. The ridges are 22-24 in total and are alternated by groove intervals.

Comparison: Only a small fragment of shell was retrieved from the S2P, which has the tubercles preserved. These features are the same as in the species *Acanthocardia tuberculata*.

Ecology: Marine species present on sandy/gravelly bottoms (Riedl, 1991).

Genus: *Cerastoderma* Poli, 1795

34. *Cerastoderma glaucum* (Bruguière, 1789)

(Table C, Fig. 17-18)

1789 *Cardium glaucum* Bruguière; Bruguière, p. 221

1845 *Cardium lamarckii* Reeve; Reeve, p. 476, pl. XVIII

Material: 145 individuals found. The specimens are few small sized intact shells (max 2,2 cm), 3/5 small and 2/5 juvenile shell fragments. Present in the S2P mostly from a core depth of 253 cm up to 191 cm and restricted in numbers (7) from 191 cm up to 159 cm.

Description: Medium sized shell with a thick series of ridges and knot-like features at the accretion streaks. It has a high variability, with a total of 19-28 ridges (20-23 regular or 24-27 unequal), of which at least the ones of the front part of each valve have lamellae. The right valve's hinge has 2 main teeth, 2 front and 2 rear teeth. The umbo bends strongly in the direction of the sagittal plane. The colour of the shell is also variable, between whitish and yellow-brown.

Comparison: The S2P specimens have the same morphology as in the species *Cerastoderma glaucum*. A closely similar species is *C. edule*. Boyden (1973) observed differences in rib morphology between *C. edule* and *C. glaucum*, where the first one has more pronounced and deep ridges. Moreover, *C. glaucum* has a thinner shell, which is observed in our material.

Ecology: Spread and very common on shallow protected sandy bottoms (Riedl, 1991). It is known to be a species of brackish water living (Sakellariou, 1957). Researchers attribute to *Cerastoderma* (*C. glaucum*) a tolerance to low salinities as low as 5‰ and median ones of 18‰ and 37‰, typical of lagoons (Di Rita et al., 2011).



Genus: *Laevicardium* Swainson, 1840

35. *Laevicardium* sp.

(Table C, Fig. 19-20)

Material: 3 individuals (intact juvenile shells - max 1,5 mm) found in the S2P at core depths of 189-190 cm, 100-101 cm and 70-72 cm.

Description: Medium sized and slim shell, with well-formed and delicate sculptures. The internal margin of the valves is serrated. The edge of the hinge is arched. The radial ridges are barely visible. The periostracum (outermost part of the shell) is smooth and of a yellowish gray colour, whereas the shell is whitish and dark spotted.

Comparison: The studied material includes intact juveniles that have already some morphological characteristics (shape, hinge teeth, radial ridges) observable in the genus *Laevicardium*.

Ecology: Marine species, only locally common, present on sandy or rocky bottoms (Riedl, 1991).

Family: Tellinidae Blainville, 1814

Genus: *Abra* Lamarck, 1818

36. *Abra segmentum* (Récluz, 1843)

(Table C, Fig. 21-22)

1836 *Erycina ovata* Philippi; Philippi, p. 13, pl. 1, fig. 13

1843 *Syndosmya segmentum* Récluz; Récluz, p. 359-369

2000 *Abra ovata* (Philippi); Kevrekidis et al., p. 107

2009 *Abra segmentum* (Récluz); Kevrekidis et al., p. 277-285

Material: 195 individuals found. The specimens are about 1/5 normal sized intact shells (max 2,5 cm), 2/5 small fragments and 2/5 juvenile + fragments. Present in the S2P from a core depth of 253 cm and above.

Description: Small to medium sized, slim and shiny shell. The valves are convex, quite variable morphologically on each individual, slightly elongated in the front. Very thin concentric and radial streaking. The hinge features on the right valve 2 main teeth and 2 secondary, while on the left valve there is 1 main tooth and 1 secondary. The colour of the shell is white, slightly iridescent.

Comparison: The studied material has the same shell morphology as observed in the species *Abra segmentum*. It mostly differs from other similar *Abra* species (e.g., *A. alba*, *A. tenuis*, *A. renieri*) in the shell shape, which is more oval and has only the rear margin angulated.

Ecology: Lives on various sedimentary basins, particularly common in mud (Riedl, 1991), adapted to marine but also brackish water living. Barnes (2008) and De Rita et al. (2011) mention that species of *Abra* can inhabit lagoons or intertidal estuarine muds, and Kevrekidis and Kasapis (2009) mention that *Abra segmentum* is an “infaunal, deposit-feeding bivalve” and a “very euryhaline species living in waters, which vary from oligohaline to hyperhaline”.

Genus: *Tellina* Linnaeus, 1758

37. *Tellina* sp.

(Table C, Fig. 23-24)

Material: 33 individuals found. The specimens comprise 2 small sized intact shells (max 2,5 cm), while the rest include fragments of different sizes. Present in the S2P from a core depth of 183 cm and above.

Description: Small to medium sized, subtriangular-elongated and thin shell. The hinge features on both valves are 2 main teeth, and on the right secondary ones are present as well (missing on the left). The umbo characteristically faces backward. The inside features 2 distinct muscle scars and the pallial line with a deep sinus. The shell's accretion lines are evident, especially on the juvenile individuals.

Comparison: The intact and fragmented specimens of the studied material have the same morphological characteristics as in the genus *Tellina*.

Ecology: Marine living, the sediment of preference depends on the species as Riedl (1991) annotated.

Family: Veneridae Rafinesque, 1815

Genus: *Timoclea* Brown, 1827

38. *Timoclea ovata* (Pennant, 1777)

(Table C, Fig. 25-26)

1991 *Venus ovata* Pennant; Riedl, p. 334, pl. 128, fig. 6

Material: 130 individuals found. The specimens are 2 normal sized intact shells (max 1,5 cm), while about a 1/5 is small and 4/5 juvenile. Present in the S2P from a core depth of 188 cm and above.

Description: Medium sized shell, thin, subtriangular and tumid. Numerous radial ridges alternated by grooves. The bottom margins of the valves have a crenate sculpture, which in the interior is accompanied with a serrated decoration. Each valve has 3 main hinge teeth. The muscle scars and pallial line are distinct, and the pallial sinus is small. The colour of the shell is yellowish on the exterior, whereas on the interior is white, occasionally with pink spots.

Comparison: The adult specimens of the studied material have the same morphological features as in the species *Timoclea ovata*. The juvenile have a more rounded shape and a semi-transparent shell, with already visible some features (crenate sculpture, hinge teeth).

Ecology: This marine species lives on sandy muddy bottoms (Riedl, 1991).

Genus: *Petricola* Lamarck, 1801

39. *Petricola* sp.

(Table C, Fig. 27-28)

Material: 10 individuals found. The specimens are small sized intact shells (max 2 cm). Present in the S2P from a core depth of 186 cm and above.

Description: Medium sized shell, rounded and tumid on the front part. The right valve's hinge teeth are situated parallel to the hinge. The shell has a grey-white colour.

Comparison: Only juvenile specimens were retrieved from the S2P, which have an angulated shell with intense accretion ridges, as seen in the non-adult individuals of the genus *Petricola*.

Ecology: This marine species pierces hard surfaces (sediments, rocks, bivalve shells) and lives inside (Riedl, 1991).

Genus: *Venus* Linnaeus, 1758

40. *Venus* sp.

(Table C, Fig. 29-30)

Material: 17 individuals found. The specimens include juvenile protoconch fragments (max 500 µm). Present in the S2P from a core depth of 193 cm and above.

Description: Large, oval, tumid, rugose shell. Characteristic of this species are the numerous prominent, concentric ridges on the exterior of the valves. The hinge features 3 main teeth in each valve, with a

small lateral tooth in front of the anterior main tooth of the left valve, and a corresponding pit in the right. Muscle scars (2) evident, with the posterior one often coloured pinkish brown, brown, or light purple. The pallial line is faint, featuring a small pallial sinus of triangular shape, which extends closely to the inner edge of the posterior muscle scar. The interior of the shell is finely serrated. It also has a variable colour of white to yellowish-brown.

Comparison: The study material comprises fragments with the lamellar decoration, and preserves few small fragments of the umbo, with recognizable features (accretion lines, hinge teeth) attributable to the genus *Venus*.

Ecology: This marine species is common and can live on all types of sedimentary bottoms (Riedl, 1991) in the littoral zone (Sakellariou, 1957).

Family: Lucinidae Fleming, 1828

41. Lucinidae sp.

(Table C, Fig. 31-32)

Material: 8 individuals found in the S2P from a core depth of 234 cm up to 161 cm, and 1 individual at a core depth of 6-7 cm (juvenile intact shells - max 1,5 mm).

Description: The shell is lens shaped. The hinge, depending on the genera, may or may not have teeth.

Comparison: These specimens can be attributed to the family Lucinidae, due to the observation of typical morphological features.

Ecology: According to Riedl (1991), species of Lucinidae live on soft bottoms. They can live in marine conditions but also in brackish water (Balian et al., 2008).

Genus: *Myrtea* Turton, 1822

42. *Myrtea spinifera* (Montagu, 1803)

(Table D, Fig. 1-2)

1803 *Venus spinifera* Montagu; Montagu, p. 577, pl. 17, fig. 1

1845 *Lucina spinifera* Hanley; Agnes and Lovell, p. 27

1827 *Ortygia spinifera* Brown; Brown, 1st ed., p. 98, pl. 20, fig 15-16

1844 *Myrtea spinifera* (Montagu); Brown, p. 98, pl. XXXVI, fig 15-16, pl. XXXIX, fig. 14-15

Material: 112 individuals found. The specimens are about 1/5 normal/small sized intact shells (max 6 mm) and 4/5 fragments of different sizes. Present in the S2P from a core depth of 200 cm and above.

Description: Small to medium sized, thick oval shell. The shell features a sculpture of various thin, closely spaced, concentric ridges, which protrude on the borders, especially visible on the rear part of each valve. The hinge of the right valve has 1 main tooth, whereas the left one has 2 main teeth. Both valves have single anterior and posterior secondary teeth. Additionally, ridges in the interior of the left valve may be present along the hinge line, appearing as extra teeth. The pallial line is evident, with no sinus present. The front muscle scar is elongated, oval in shape. The colour of the shell is white to semi-transparent.

Comparison: The studied material presents the same morphological features as in the species *Myrtea spinifera*.

Ecology: The Marine Species Identification Portal annotates that *Myrtea spinifera* is a marine species, living on mud and muddy sands, offshore up to ~100 m.

Family: Kelliidae Forbes and Hanley, 1848

Genus: *Bornia* Philippi, 1836

43. *Bornia sebetia* (Costa, 1830)

(Table D, Fig. 3-4)

1830 *Cyclas sebetia* Costa; Costa, p. 131, pl. 2, fig. 6

1836 *Bornia corbuloides* Philippi; Philippi, p. 30

1836 *Erycina crenulata* Scacchi; Scacchi, p. 6

1976 *Bornia (Bornia) sebetia* (Costa) - Brambilla, p. 107, pl. 27, fig. 25-26

Material: 818 individuals found. The shells are about 1/5 normal/small sized intact shells (3-1,5 mm) and 4/5 juvenile (<1,5 mm). Present in the S2P from a core depth of 202 cm and above.

Description: Very small sized, thin but robust subtriangular equivalve shell. The valves are smooth. The hinge features prominent teeth. The right valve has a large triangular tooth in front of the ligament pit and a large laminar tooth posterior of the ligament pit with a small laminar tooth above. The left valve has a short vertical laminar tooth in the front part of the shell, a larger oblique laminar tooth in front of the ligament pit and a single large laminar tooth posterior of the pit. The pallial line is near the edge and has no sinus, and the muscle scars are small. The shell has a white colour.

Comparison: The S2P specimens have the same morphological features as in the species *Bornia sebetia*.

Ecology: Mainly sublittoral marine species (Van Aartsen, 1996).

Family: Basterotiidae Cossmann, 1909

Genus: *Saxicavella* P. Fischer, 1878

44. *Saxicavella* sp.

(No figure – specimen lost)

Material: 1 juvenile individual found in the S2P at a core depth of 70-72 cm.

Description: Small sized, thin and fragile equivalve shell. The shape is obliquely rhomboidal, with the front part being much narrower than the rear part. The rear margin part of the shell is straight, while the front is obliquely subtruncate. The shell features fine concentric lines. The hinge features on the right valve a flange-like main tooth fitting into a corresponding depression in the left valve. The pallial line is wide, without a sinus. The shell colour is white to semi-transparent.

Comparison: The studied material includes a transparent juvenile shell that presents same morphological features as the genus *Saxicavella*.

Ecology: Marine species known to live on mud and muddy sand.

Family: Solenidae Lamarck, 1809

Genus: *Solen* Linnaeus, 1758

45. *Solen* sp.

(Table D, Fig. 5-6)

Material: Only some fragments (counting as 4 individuals) present in the S2P at the core depths of 184-185 cm, 110-111 cm. 33-35 cm and 2-3 cm.

Description: Characteristic elongated and straight shell, approximately rectangular. The hinge features for each valve a short and small tooth. Accretion streaks parallel to the bottom margin of the shell. As they reach towards the rear they become parallel to the rear edge. This sudden change follows a line that slopes obliquely on the valve, dividing it into two sharp angled triangles. The colour of the shell is white to yellow.

Comparison: The studied material comprises few fragments with the same shape as observed in the genus *Solen*.

Ecology: Common marine species spread on all sandy bottoms (Riedl, 1991).

Family: Corbulidae Lamarck, 1818

Genus: *Corbula* Bruguière, 1797

46. *Corbula gibba* (Olivi, 1792)

(Table D, Fig. 7-9)

1792 *Tellina gibba* Olivi; Olivi, p. 101, pl. 20, fig. 143

1898 *Corbula curta* Locard; Bouvier et al., p. 493

1991 *Corbula gibba* (Olivi); Riedl, p. 343, pl. 131, fig. 6

Material: 942 individuals found (1/5 normal - max 1 cm, 1/5 small, 3/5 juvenile). The most abundant species in the S2P, present from a core depth of 202 cm and above.

Description: Small sized slightly elongated oval shell. Hinge with 1 tooth in each valve. The right valve is larger than the left, and it features a more robust tooth. Both valves have evident accretion streaks. The shell is of white to gray colour.

Comparison: The studied material presents the same morphological features as the species *Corbula gibba*.

Ecology: According to Riedl (1991), this marine species can be locally common and spread on all type of soft bottoms, especially on mud.

Family: Cuspidariidae Dall, 1886

Genus: *Cuspidaria* Nardo, 1840

47. *Cuspidaria cuspidata* (Olivi, 1792)

(Table D, Fig. 10-11)

1792 *Tellina cuspidata* Olivi; Olivi, p. 101

1843 *Neaera cuspidata* Hinds; Hinds, p. 76

1844 *Anatina brevirostris* Brown; Brown, p. 110

1991 *Cuspidaria cuspidata* (Olivi); Riedl, p. 348, pl. 133, fig. 2

Material: Only 5 individuals found in the S2P (normal intact shells - max 1,3 cm), at the core depths of 170-171 cm, 153-154 cm, 127-128 cm, 50-52 cm and 35-37 cm.

Description: Small to medium sized oval shell. The umbo, although small, is quite swollen. Evident accretion lines present. Characteristic of the species is the elongation of the rear part of the valves to form a beak-like feature. The colour of the shell is white.

Comparison: The studied material has the same morphological features as the species *Cuspidaria cuspidata*.

Ecology: According to Riedl (1991) this marine species can be present on muddy bottoms starting from a depth of 30 m.

Class: Scaphopoda Bronn, 1862

Family: Dentaliidae Children, 1834

Genus: *Dentalium* Linnaeus, 1758

48. *Dentalium* sp.

(Table D, Fig. 12)

Material: 294 individuals found (few intact shells and mostly fragments). Present in the S2P from a core depth of 191 cm and above.

Description: Characteristic tusk shaped shell. A section of the shell reveals a smooth, round interior, and a polygon-like exterior, which is caused by the longitudinal sculpture present on the outside of the shell.

Comparison: The studied material comprises individuals that present the same shell morphology as the genus *Dentalium*.

Ecology: Of marine living, the genus *Dentalium* can live on various sedimentary bottoms depending on the species (Riedl, 1991)



Plate C. Bivalve species recorded from the S2P core sample. **1-2.** *Nucula nitidosa* Winckworth, 1930, left valve inner view and right valve outer view (S2P 58-60), **3.** *Nuculana* sp., fragment (S2P 10-11), **4-5.** *Solemya togata* (Poli, 1791), hinge are fragment, inner and outer view (S2P 99-100), **6-7.** *Mytilaster marioni* (Locard, 1889), left valve, inner and outer view (S2P 232-234), **8-9.** *Mytilus* sp., fragment of left valve, inner and outer view (S2P 3-4), **10-11.** *Anomia* sp., fragment, inner and outer view (S2P 56-58), **12.** *Ostrea* sp., fragment (S2P 3-4), **13.** *Acanthocardia* sp., left valve, inner view (S2P 169-170), **14-15.** *Acanthocardia paucicostata* (Sowerby, 1834), left valve, inner and outer view (S2P 0-1), **16.** *Acanthocardia tuberculata* (Linnaeus, 1758), fragment (S2P 33-35), **17-18.** *Cerastoderma glaucum* (Bruguière, 1789), left valve, inner and outer view (S2P 231-232), **19-20.** *Laevicardium* sp., left valve, inner and outer view (S2P 70-72), **21-22.** *Abra segmentum* (Récluz, 1843), left valve, inner and outer view (S2P 242-244), **23-24.** *Tellina* sp., right valve, inner and outer view (S2P 29-31), **25-26.** *Timoclea ovata* (Pennant, 1777), left valve, inner and outer view (S2P 23-25), **27-28.** *Petricola* sp., right valve, inner view, left valve, outer view (S2P 29-31), **29-30.** *Venus* sp., left valve fragment, inner and outer view (S2P 115-116), **31-32.** Lucinidae sp., right valve, inner and outer view (S2P 232-234).

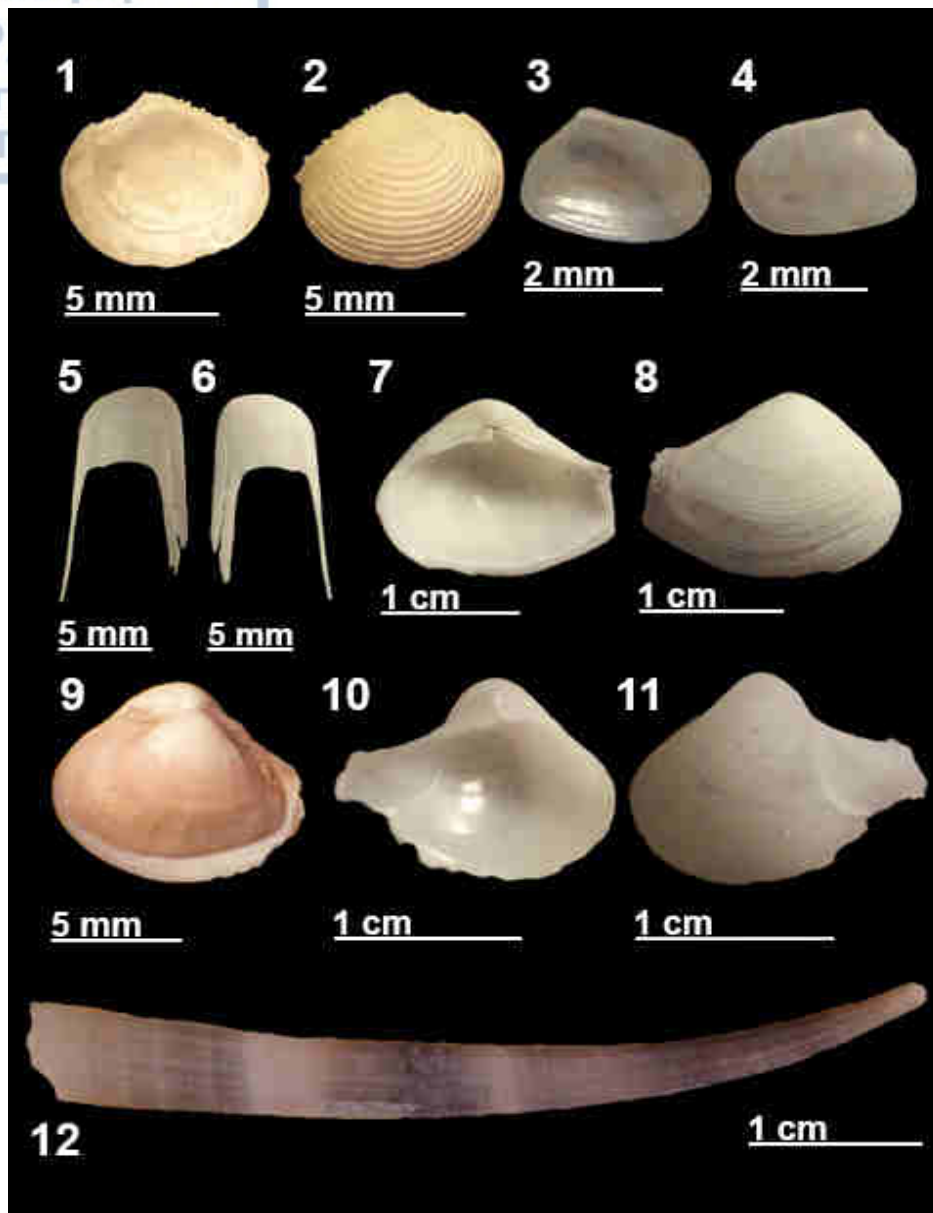


Plate D. Bivalve and scaphopod species recorded from the S2P core sample. **1-2** *Myrtea spinifera* (Montagu, 1803), right valve, inner and outer view (S2P 100-101), **3-4**. *Bornia sebetia* (Costa, 1830), left valve, inner and outer view (S2P 56-58), **5-6**. *Solen* sp., fragment, inner and outer view (S2P 2-3), **7-9**. *Corbula gibba* (Olivi, 1792), right valve, inner and outer view, and complete shell from different individual (S2P 187-188), **10-11**. *Cuspidaria cuspidata* (Olivi, 1792), left valve, inner and outer view (S2P 35-37), **12**. *Dentalium* sp., lateral view (S2P 14-16).

5.1.1 Macroscopic Description

The macroscopic description of the S2P core was realized by Petropoulos et al. (2013). In the layers within the 342 cm of the core, changes in colour (noted using SSCC charts) have been observed. S2P core consists of mud (silt+clay) and sand. A general view of the S2P core sample is presented in Figure 5.1. A detailed stratigraphic column is presented in Figure 5.2.

According to Petropoulos et al. (2013), the S2P core sample has 5 main depositional units, with a clear presence of invertebrate shells and shell fragments within the layers. The units are described by the same authors as the following.

Unit A comprises the core depths between 0 and 192 cm, consists of light olive gray to olive gray mud. More specifically, the first 3 cm from the top of the core are black mud, with light olive gray mud from 3 cm to 92 cm. From 92 cm to 192 cm the mud colour is olive gray. At 192 cm and following the deeper layers of Unit B, there's a sharp colour boundary. The presence of invertebrate shells and fragments is evident.

Unit B includes the core depths between 192 cm and 231 cm and the sediment type is gray clay on the whole extent, without any remarkable sediment or colour change. Invertebrate shells and shell fragments present.

Unit C (231-296,8 cm) presents a more complex alternation between mud and sandy mud layers, with a colour differentiation from pale yellow to light gray and gray sediments. Invertebrate shells and shell fragments present.

Unit D (296,8-300 cm) is well distinguished with a dark colour, which is attributed to the high concentration of organic material (gyttja). This fine layer has coarser sand particles that gradate from coarser grains at the base of the layer to progressively finer grains on the top.

Unit E (300-342 cm) has a gray colour with coarse sand grains and smaller amounts of mud. Only few invertebrate fragments are present.

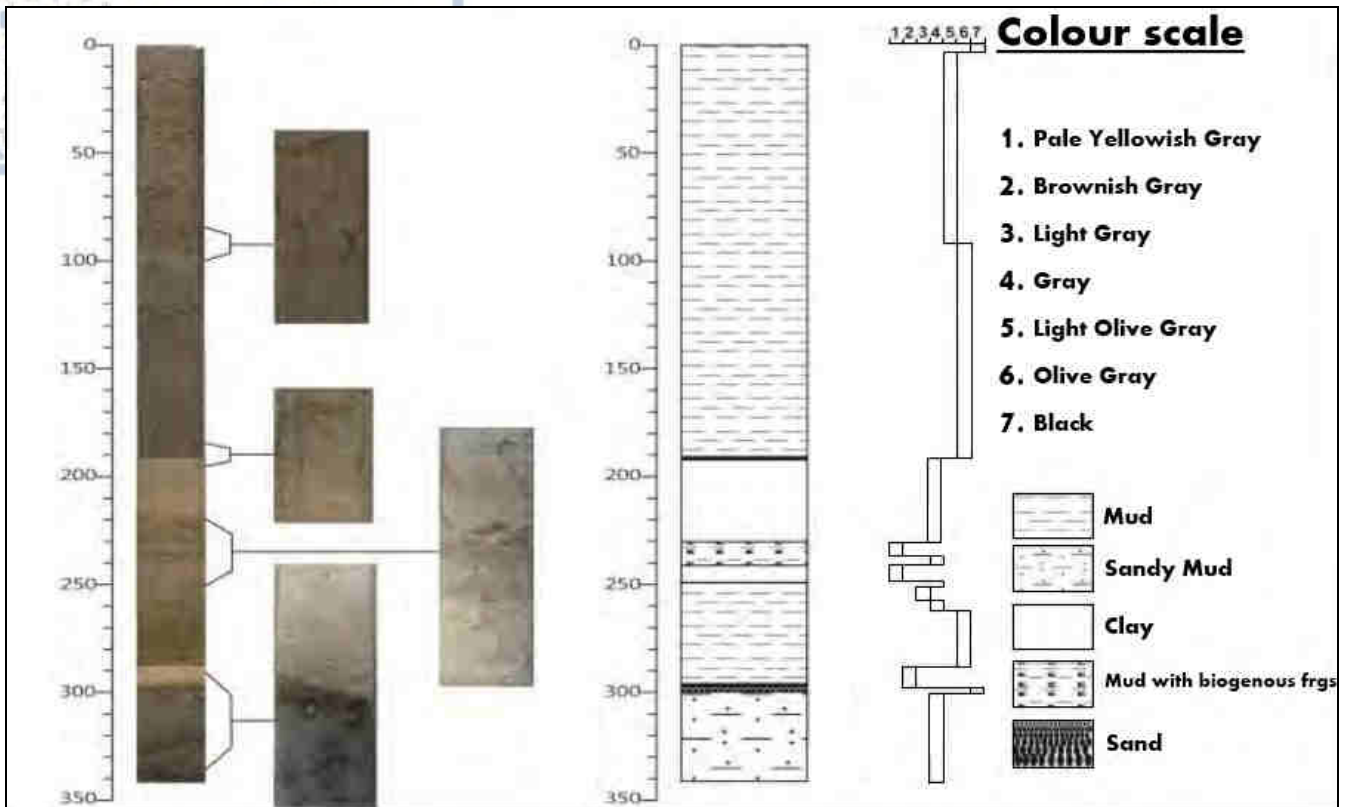


Figure 5.1 Macroscopic description of the S2P core. Left: a synthesis of photos showing the whole core with photos of important details from parts of the core. Right: sediment characteristics of the core and its color variation (using the SSCC). Modified after Petropoulos et al. (2013)

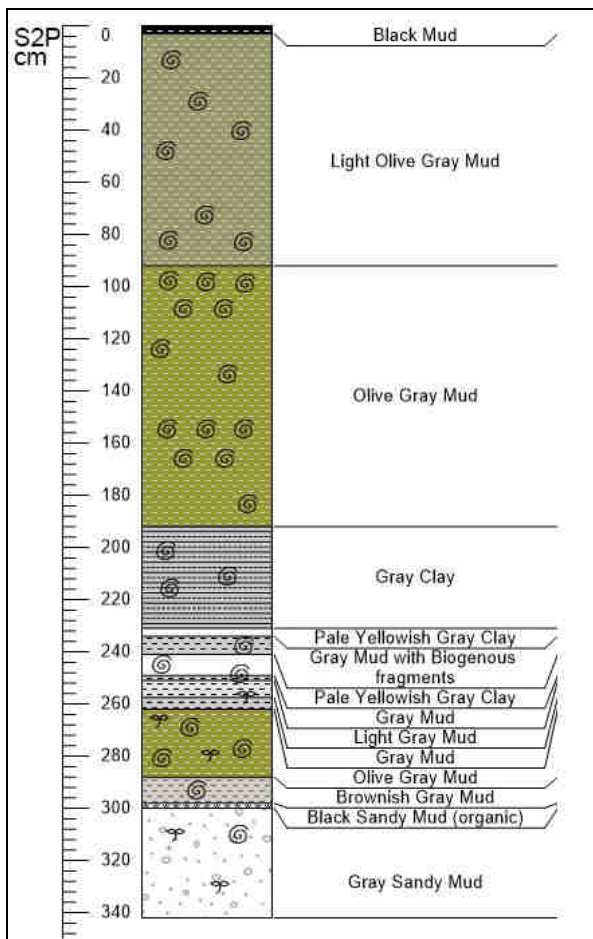


Figure 5.2 Detailed stratigraphic column of the S2P core lithology (data after Petropoulos et al., 2013). Invertebrate specimens are present on all layers of the core aside of layers 296,8-300 cm. Invertebrates are symbolized with a spiral here. The plant symbol signals the presence of plant remnants (below 300 cm) and occurrence of perolithosis (above 300 cm).

5.1.2 S2P Core Sand/Mud Percentages

The sand / mud (silt + clay) content of each sample was estimated after the weight difference between initial and washed samples. Results are presented according depth in Table 9.1 (*Appendix*). The fluctuations of the sand / mud percentages can be seen in Figure 5.3. We can notice the dominance of mud on almost the whole extent of the S2P core. Starting from downcore (342 cm), sand and mud are equally mixed, which can be noted between layers 342-300 cm and 270-251 cm. Layers 300-270 cm have fluctuating values with less or more dominant mud and evident presence of sand. At 251 cm the sand content drops sharply and remains low till 190 cm. Between layers 190-72 cm the mud dominance is quite stable, while after 72 cm till the upper end of the core the layers have fluctuating values with occasional increased values of sand content.

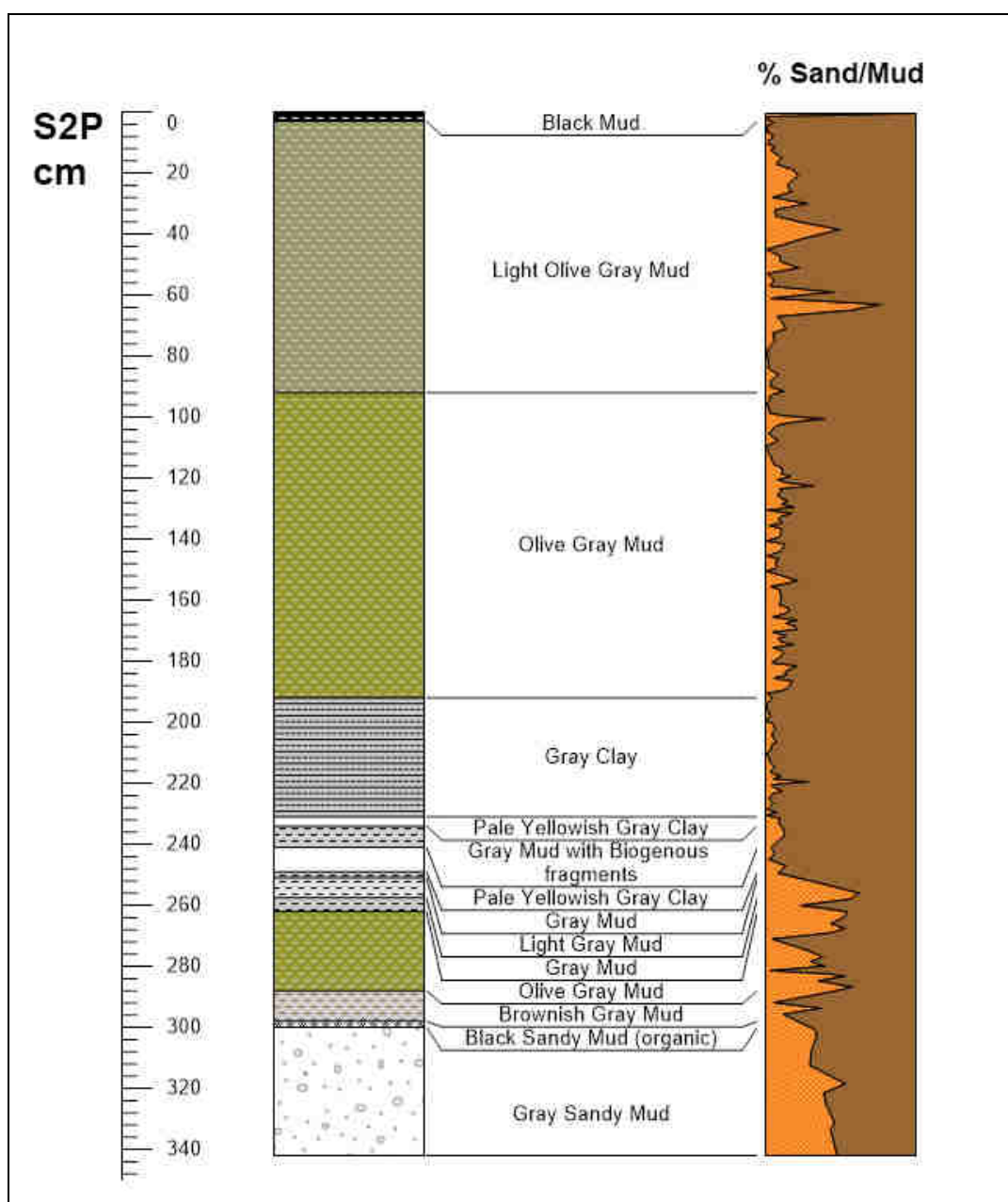


Figure 5.3 Stratigraphic column of the S2P core alongside the sand and mud percentages column.

5.2 Radiocarbon dating

The resulted ages from the AMS ^{14}C dating can be seen in Table 5.A and Figure 5.4.

Table 5.A Radiocarbon dating ages of selected S2P core samples. Data provided from Kyrikou (2016), Kyrikou et al. (2016) and the kind contribution of Professor Maria Triantaphyllou.

Depth (cm)	Dated material	^{14}C age (year BP)	Calibrated age (cal. Year BP)	Calibrated age (BC/AD)
40-42	Mollusc shell	2270 $\pm$ 30	1782.5 $\pm$ 162	A.D. 5-330
109-110	Mollusc shell	3330 $\pm$ 30	3090 $\pm$ 240	A.D. 1380-900
120-121	Mollusc shell	4260 $\pm$ 30	4285 $\pm$ 230	2565-2105 B.C.
242-244	Mollusc shell	10220 $\pm$ 30	11150 $\pm$ 155	9355-9045 B.C.
297-300	Gyttya	11650 $\pm$ 40	13490 $\pm$ 65	11605-11475 B.C.

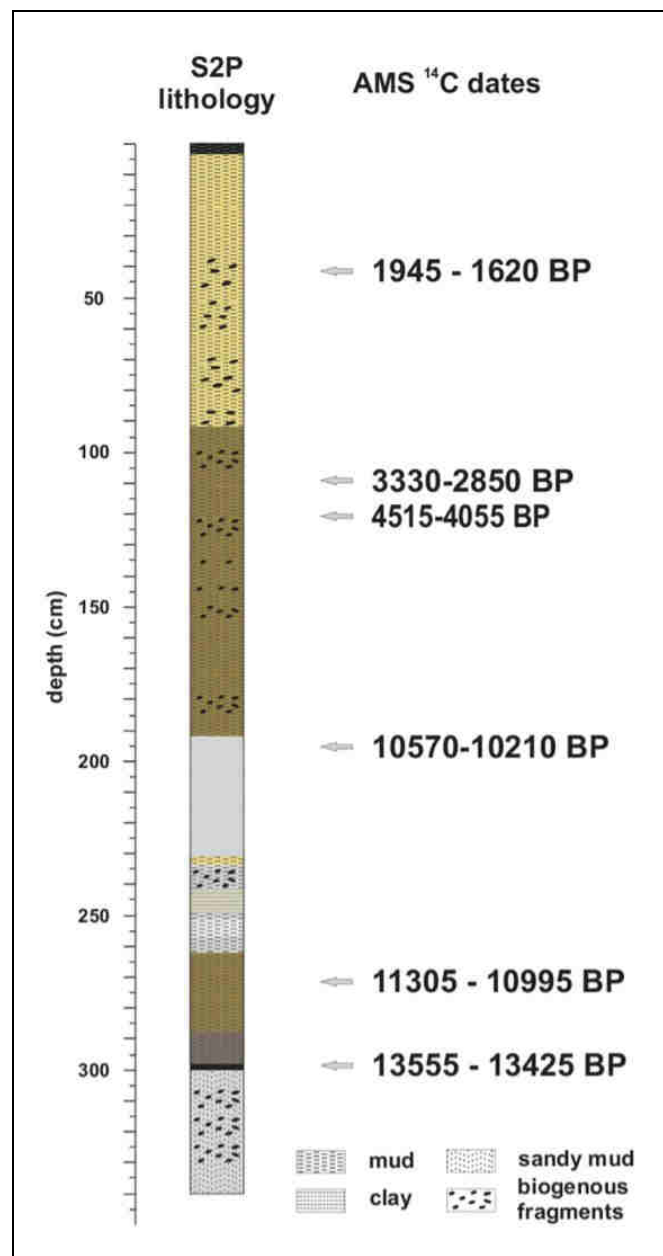


Figure 5.4 Radiocarbon dating ages in the S2P column (from Kyrikou et al., 2016).

5.3 Faunal analysis

As it is presented in Chapter *Taxonomy*, there are several genera/species that are found in the layers of the S2P core. It is possible to set them in various environments, given their usual conditions in which they live. Some taxa are found in the same type of environment, which in turn form groups, or assemblages that can be associated with factors like oxygenation, salinity and surface sediment type.

A quantitative analysis of the specimens retrieved from the samples indicates taxa that are present on particular depths of the core. Furthermore, Taxa (S), Shannon-Wiener (H') and Density indexes were calculated and are presented (Fig. 5.7). More specifically (bottom to top):

1. From the bottom of the core at 342 cm until 300 cm, the layers include coarse sand, pebbles, as well as few mollusk fragments of unknown origin. These fragments are well rounded and possibly "fossilized" (Table 9.3 *Appendix*). Indices and density were not calculated since the macrofauna was excluded of any quantitative analysis; only their number was included into the diagrams (Fig. 5.7, 6.5).
2. As mentioned in the macroscopic description, the layers between 300 cm and 296,8 cm consist of organic material (gyttja) with complete absence of any mollusk faunal element.
3. From 296,8 cm till 253 cm depth there is a monotonous fauna with only 2 species, the gastropods *Hydrobia* sp. (9,1-100%) and *Theodoxus* sp. (2,17-100%), while there is complete absence of any bivalve species. Only the layers between 265-267 cm is an exception, with individuals of *Cerastoderma glaucum* that comprise the 23,07% of the sample's total fauna. The main characteristic of these layers is the presence of biogenous debris, in the form of plant remnants with calcium carbonate perolithosis, probably formed in an environment rich with floral elements, as well as Charophytes (gyrogonites, lime shelled oospores found). In this range, Taxa (S) present with the lowest values (1-2) and the Shannon-Wiener (H') index has very low values (from 0 up to 0,7). Mollusk density is low and represented by gastropods only.
4. Another distinct and simple fauna can be observed between 253 cm and 200 cm. This fauna is consisted mainly by the bivalve species *Cerastoderma glaucum* (1,38-100%), *Mytilaster marioni*. (4,1-52%), and the gastropod *Hydrobia* sp. (5,55-80,5%). The above species are present in this core depth range with percentages between 57 % and 100 % of the total fauna, with a calculated average value of 89 %. The presence of the bivalve *Abra segmentum* is frequent, with average percentages (1,35-40%). Also relatively abundant is the gastropod *Rissoa* sp., with percentages as high as 43 %. The species *Lucinidae* sp., *Bittium reticulatum* and *Nassarius lima* appear in distinguished single samples within this range. This fauna disappears completely at 200 cm. Before that layer, few individuals species of the below described layers (point 5) are also present (bivalve species *Abra segmentum* and few individuals of bivalve species *Corbula gibba*, *Lucinidae* sp. and gastropod species *Bittium reticulatum*, *Nassarius*

lima). Additionally, significant is the barren core sample between 225 cm and 224 cm. Between 253 cm and 236 cm two faunas seem to “collide”, as there are also individuals from species of unit 3 (*Theodoxus* sp.) with decreasing values, till they disappear. Also, from 236 cm and below, etched (corroded) specimens are abundant. Taxa (S) has low-mid values (0-6) and the Shannon-Wiener (H') index has average to low (less than 1) values. Mollusk density is high between 253 cm and 229 cm depth and relatively low between 229 cm and 200 cm depth.

5. From 200 cm up to 0 cm a rich variety of species is observed (Fig. 5.5, 5.6), with dominant the bivalves *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata* and the gastropods *Bittium reticulatum* and *Turritella communis*, presenting with high values. These species are present in this core depth range with percentages ranging between 60% and 100% of the total fauna, with a calculated average value of 80 %. Individuals of other species are present with lower percentages fluctuating or appearing only once; bivalves: *Abra segmentum* (0,95-16,6%), *Acanthocardia* sp. (0,6-20%), *Acanthocardia pausicostata* (0,6-11,1%), *Acanthocardia tuberculata* (1,09%), *Anomia* sp. (0,6-4,5%), *Cuspidaria cuspidata* (1,07-11,1%), *Laevicardium* sp. (1-2,56%), *Lucinidae* sp. (0,63-11,1%), *Mytilus* sp. (7,14%), *Nuculana* sp. (1,3-3,7%), *Ostrea* sp. (0,8-10%), *Petricola* sp. (1,07-10%), *Saxicavella* sp. (2,56%), *Solen* sp. (0,62-25%), *Solemya togata* (1,72-2,94%), *Tellina* sp. (0,95-11,1%), *Venus* sp. (0,62-5%); gastropods: *Aporrhais pespelecani* (1,08-9,1%), *Bolinus brandaris* (4,54%), *Chrysallida* sp. (0,82-16,6%), *Cima* sp. (0,98-4%), *Epitonium cf. clathrus* (0,82-3,44%), *Eulima* sp. (0,95-10%), *Fusinus* sp. (1,88%), *Hydrobiidae* indet. (1,07-40%), *Monophorus* sp. (1,07-3,33%), *Nassarius lima* (1,08-4,34%), *Nassarius reticulatus* (1,07-4%), *Natica* sp. (1,07-20%), *Odostomia* sp. (0,92-14,2%), *Pyramidellidae* sp. (0,81-16,6%), *Retusa leptoneilema* (1,7-11,5%), *Rissoa* sp. (4-5,5%), *Sorgenfreispira brachystoma* (0,62-16,6%), *Steromphala adansonii* (1-3,22%), *Turbonilla acuta* (1,53-11,1%). The layers of this core depth range present alternating values in faunal richness. Aside of the most abundant species, minor ones do not appear in all samples within this range. From 199 cm and downcore, the percentages of the above described invertebrates are reduced to values between 20-40%. At the lower part of this depth range (200-191 cm) there appears to be a transition between the faunal assemblages of point 4 and point 5, as the species *Cerastoderma glaucum*, *Mytilaster marioni* and *Hydrobia* sp. (point 4) are still present in the fauna, in restricted numbers. These species slowly diminish and disappear as we reach at 191 cm depth, while the most abundant species of point 5 (200-0 cm) appear at the same layer (191 cm). In this range (200-0 cm), Taxa (S) has average-high values (4-19) and the Shannon-Wiener (H') index has high values (ranging from 1 to 2,2). Mollusk density has the highest value of the S2P core (up to 500 individuals/10g) in this range. High density is observed between 200 cm and 150 cm, while between 150 cm and 77 cm it is lower (excluding layers 100-101 cm). From 77 cm to the uppermost part of the core we can notice high density that has a decreasing trend as we move upwards.

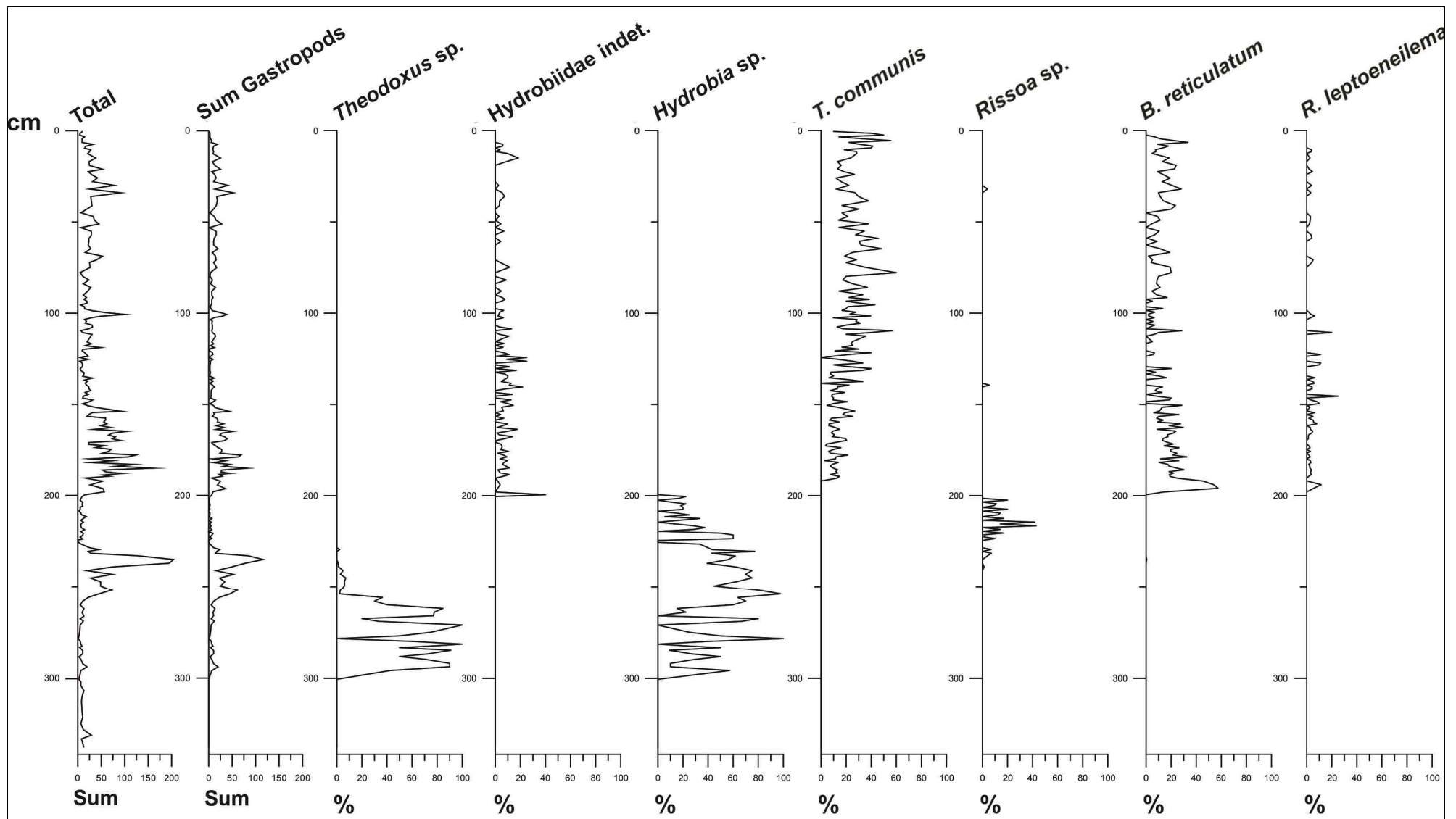


Figure 5.5 Total abundances of mollusks and gastropods, and relative frequencies of the most abundant gastropod species across the S2P core layers.

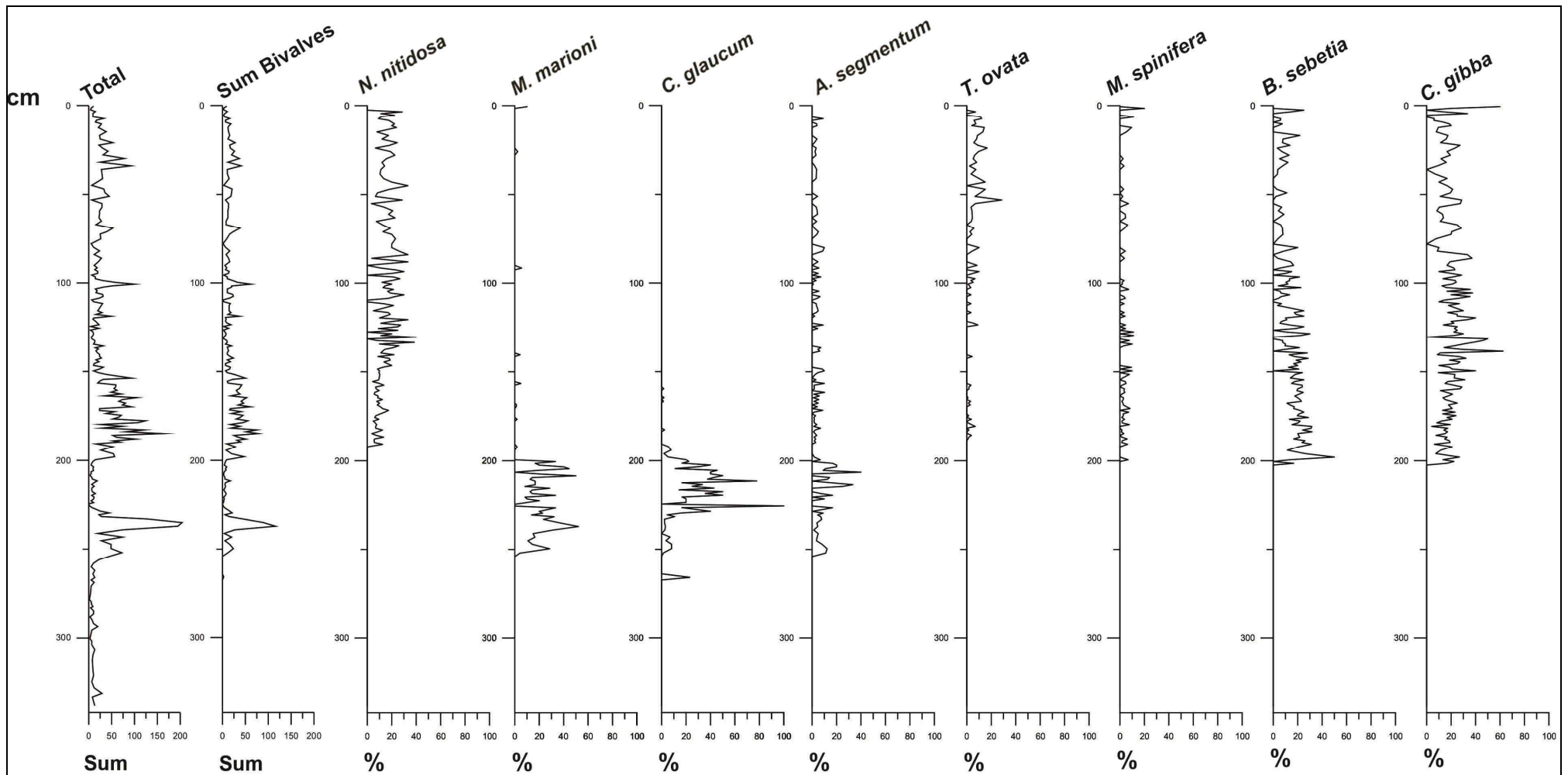


Figure 5.6 Total abundances of mollusks and bivalves, and relative frequencies of the most abundant bivalve species across the S2P core layers.

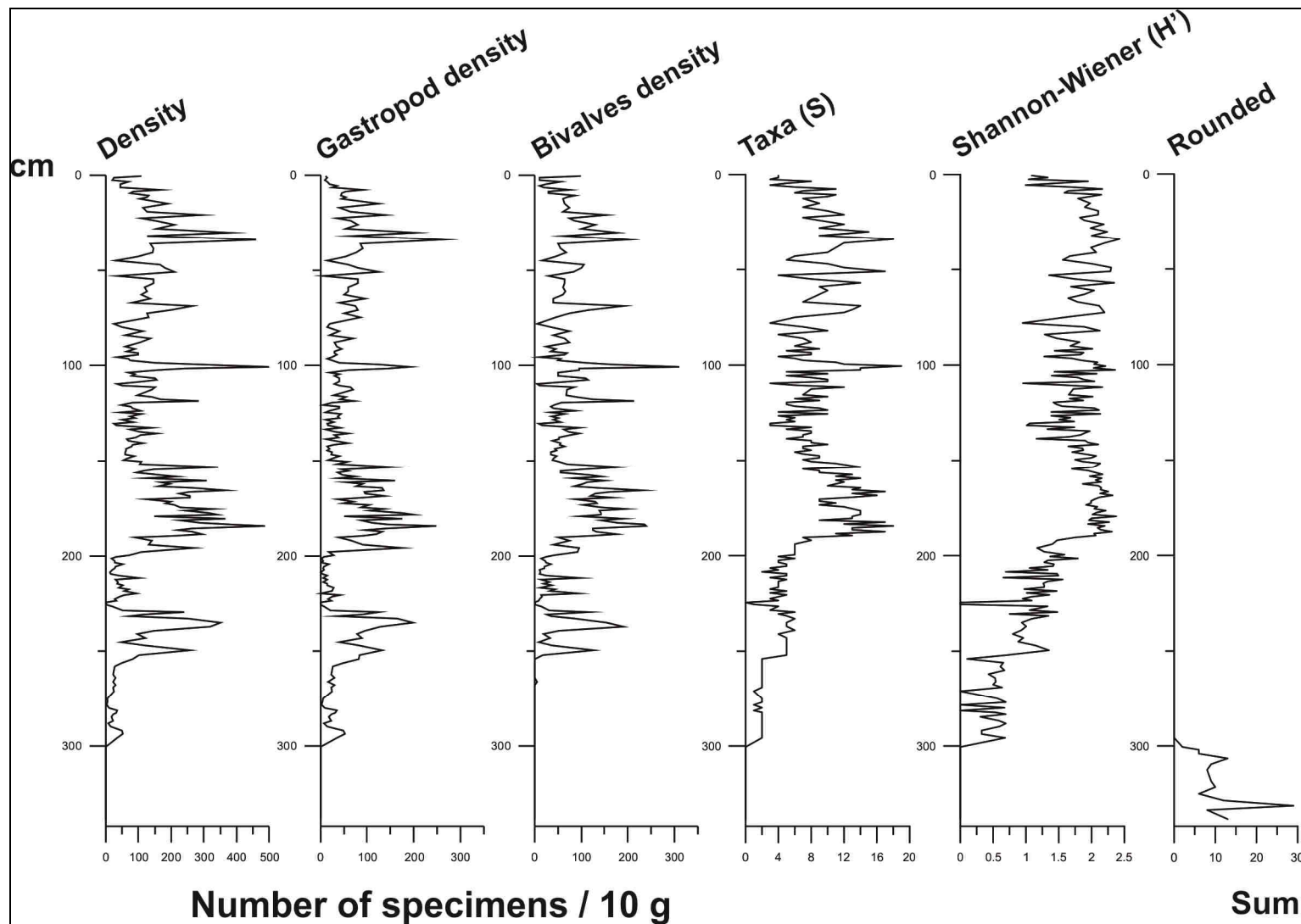


Figure 5.7 Shannon-Wiener H' diversity index in comparison to the number of taxa (S) and rounded specimens. The evident changes in the diversity of the species are also important clues to create the model of the paleoenvironmental reconstruction.

5.4 Statistical Analysis

Using the softwares SPSS, PAST and Grapher, a series of dendrograms, diagrams and graphs were created, using data from the S2P specimens. In order to confirm the validity of the qualitative and quantitative analysis, the data were transformed accordingly to match the needs for the statistical analysis. The processes follow the suggestions of Davis (2002).

First of all, using SPSS, a Q and R mode Cluster Analysis was conducted. The methodology which gave a good result is the Centroid Linkage. Faunal elements with a presence of less than 5 % were not included, to remove as much data noise as possible. We can notice in Figure 5.8 the correlation of species into groups. More specifically, two main groups of mollusks are distinguished. The first group clustered 42 species, while 5 were grouped in second group (Fig. 5.8). The second group is divided in two sub-clusters. The first consists of four species (*Hydrobia* sp., *Mytilaster marioni*, *Rissoa* sp. and *Cerastoderma glaucum*) and the second of an independent species (*Theodoxus* sp.).

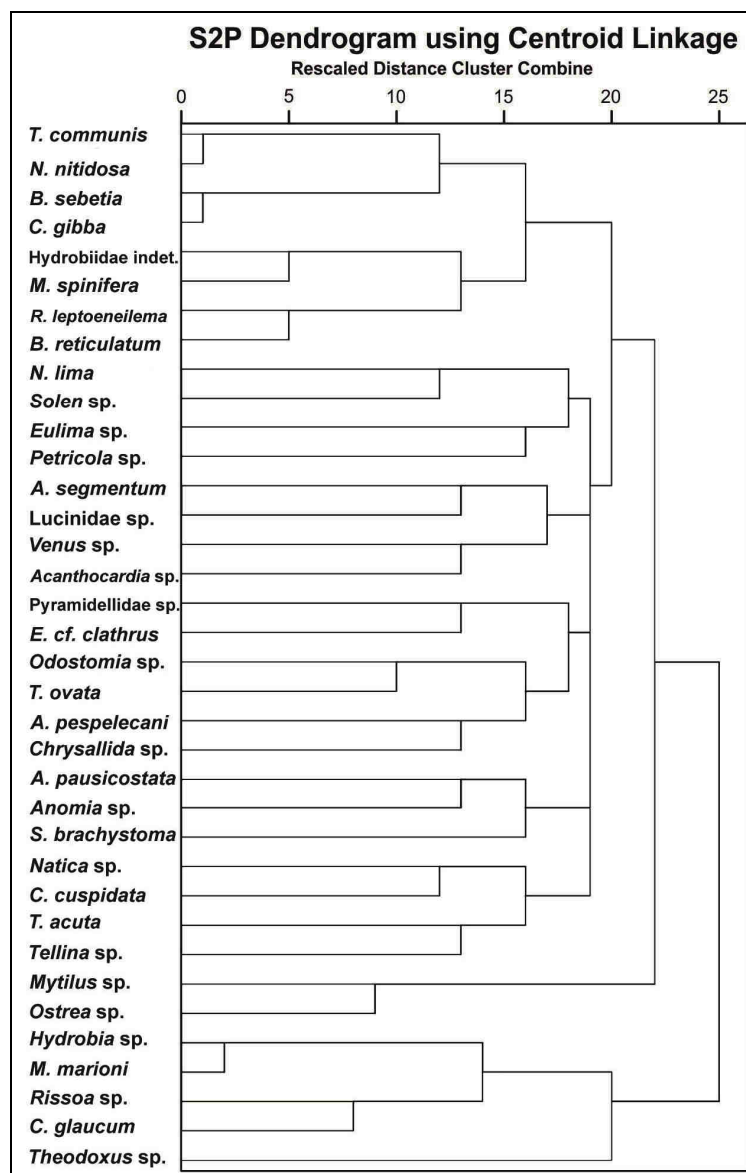


Figure 5.8 The R-mode Cluster Analysis using Centroid Linkage shows that there is indeed a distinction between species into groups.

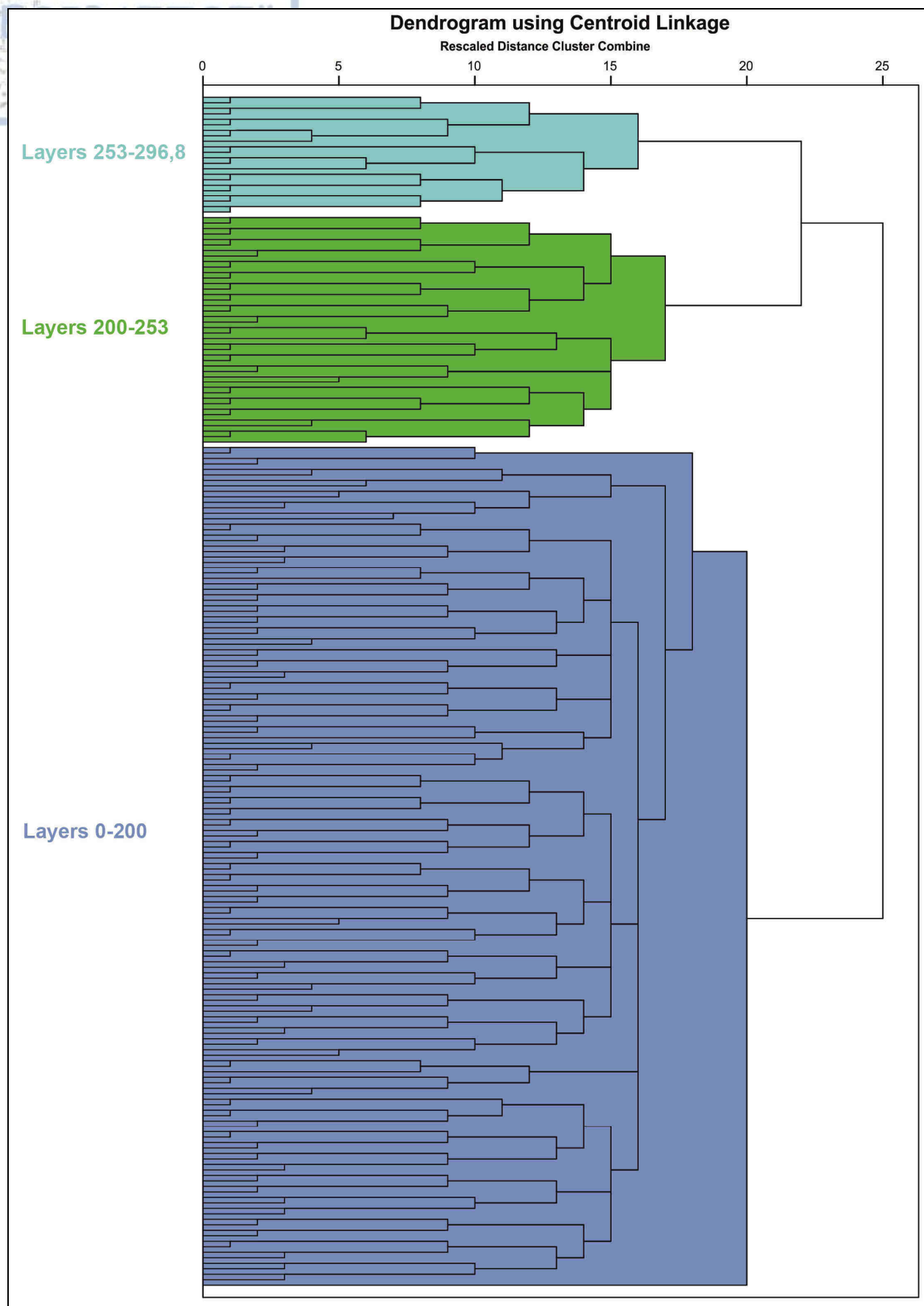


Figure 5.9 The Q-mode Cluster Analysis using Centroid Linkage shows the grouping of layers of the S2P core.

Q-mode cluster analysis divided studied samples in two main groups, with the first one having two well distinguished sub-groups. The first sub-group consists of 24 samples representing the core depth layers 253-296,8 cm (cyan in Fig. 5.9). The second sub-cluster groups 41 samples which comprise depth layers of 200-253 cm (green in Fig. 5.9). Finally, the second main group which is the largest one (153 samples) and is very well distinguished from the other one (rescaled distance of 25) clusters together the core depth layers of 0-200 cm (blue in Fig. 5.9).

In order to confirm the above analysis and distinguish different species and layers, two PCA scatter plots were designed (Fig. 5.10, 5.11). As seen in Figure 5.10, the main species are divided into the same 3 different faunal groups. **Green** (*Hydrobia* sp., *Mytilaster marioni*, *Abra segmentum* and *Cerastoderma glaucum*) and **Blue** (*Turritella communis*, *Nucula nitidosa*, *Corbula gibba*, *Timoclea ovata*, *Bornia sebetia*, *Bittium reticulatum*) polygons show two distinct groups, while **Cyan** corresponds only to *Theodoxus* sp. Figure 5.11 shows an evident grouping of layers within polygon-groups, which are affected by certain species, seen here as biplot (green lines). Green layers (200-253 cm) depend on *Hydrobia* sp., *Mytilaster marioni* and *Cerastoderma glaucum*, while Cyan layers (253-296,8 cm) depend more to *Theodoxus* sp. and less to *Hydrobia* sp. Blue layers (0-200 cm) depend on *Abra segmentum*, *Timoclea ovata*, *Turritella communis*, *Nucula nitidosa*., *Myrtea spinifera*, *Corbula gibba*, *Bittium reticulatum*, *Bornia sebetia* and less on *Cerastoderma glaucum*. The dependence to the species can also be noted on the PCA loadings of Figure 5.11 (Fig. 5.12). We can note that the value for *Abra segmentum* is close to zero, indicating that the layers are not much dependent on this species. The species *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata*, *Bittium reticulatum*, *Turritella communis* have positive values and are distinguished from *Cerastoderma glaucum*, *Mytilaster marioni*, *Hydrobia* sp. and *Theodoxus* sp., which have negative values.

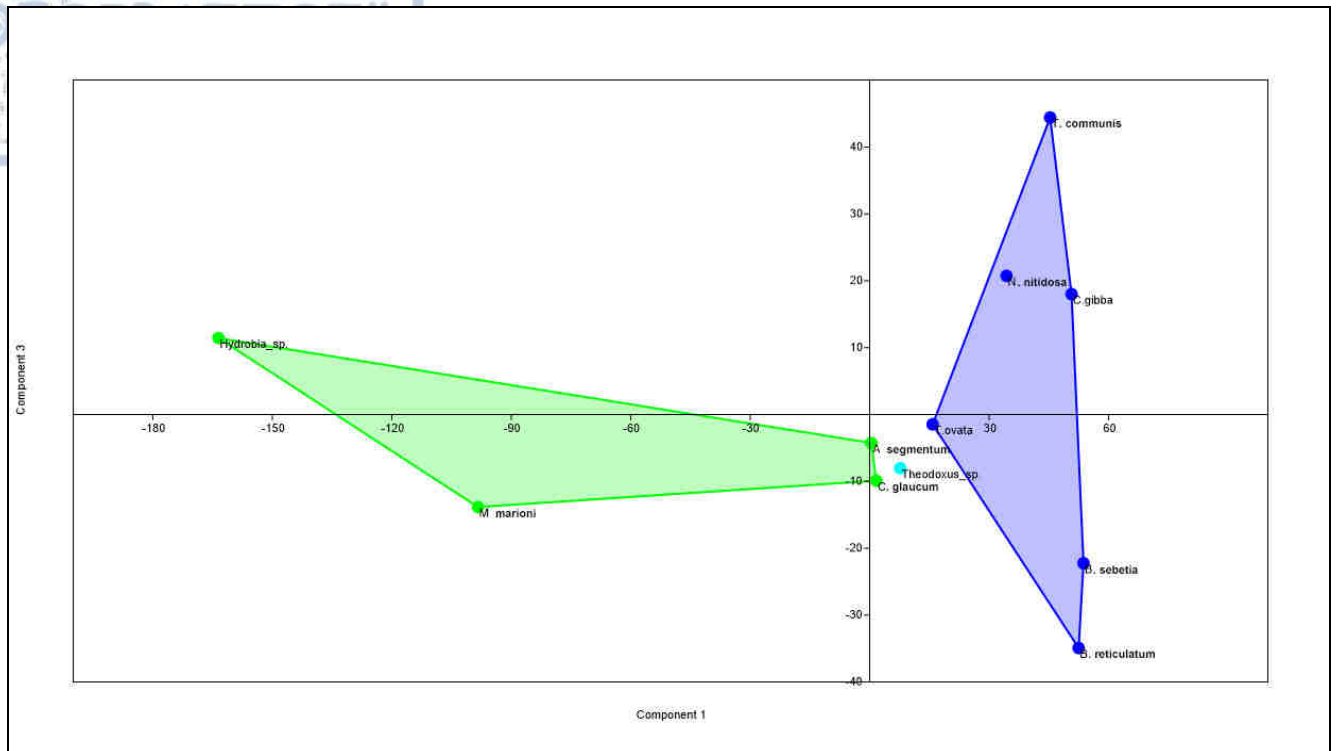


Figure 5.10 PCA scatter plot of components 1 and 3 showing the grouping of species.

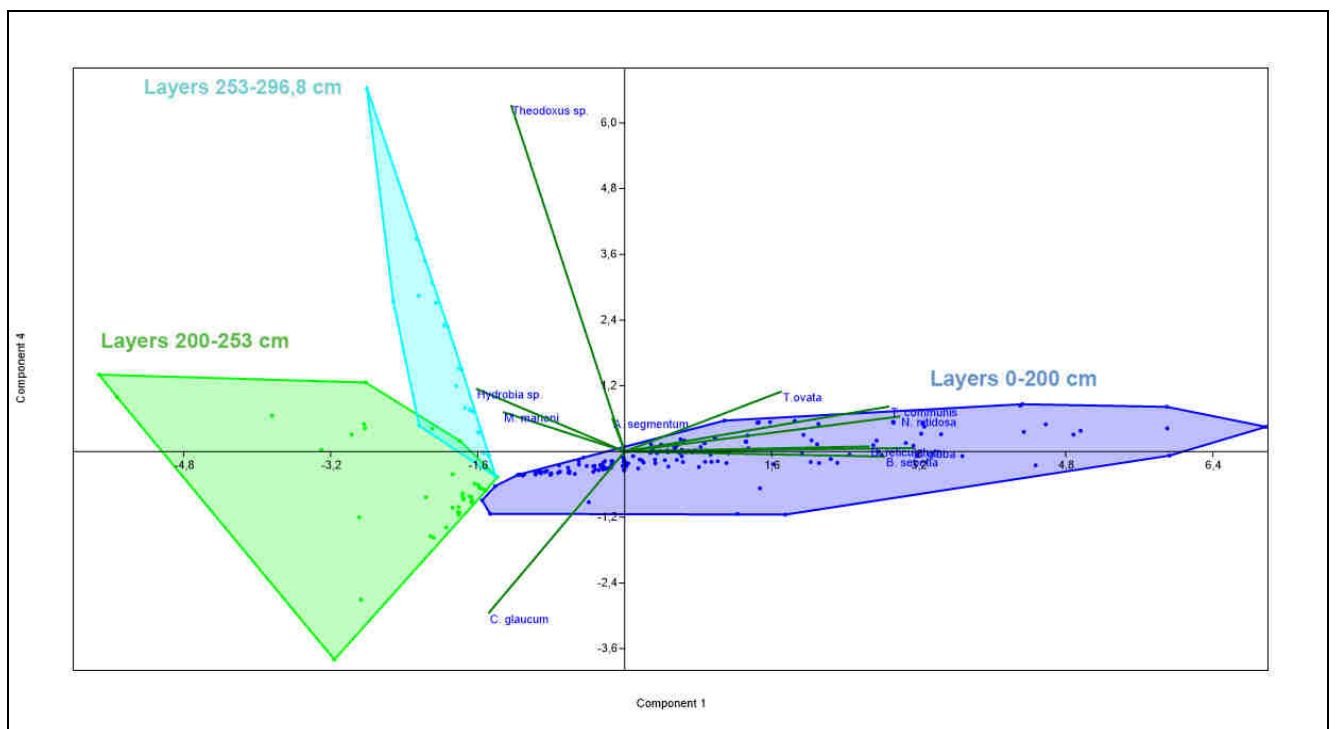


Figure 5.11 PCA scatter plot of components 1 and 4 showing the grouping of layers.

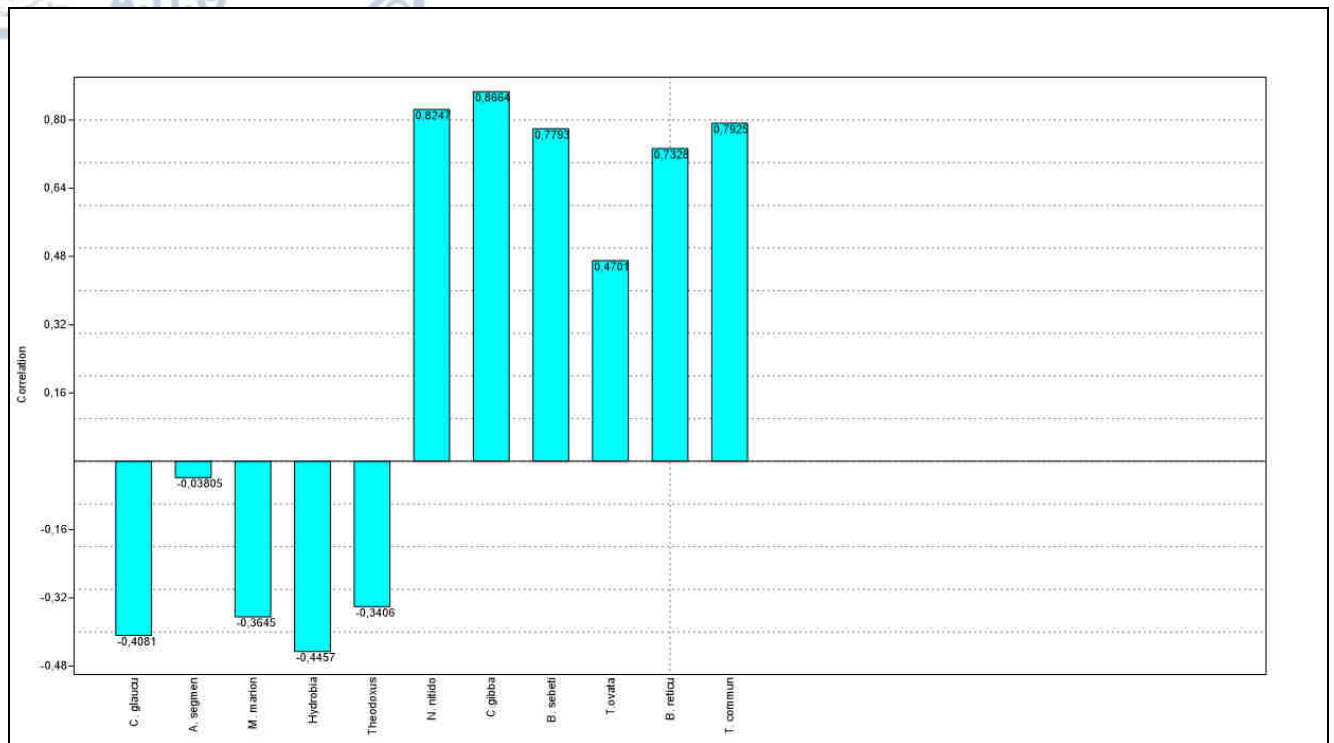


Figure 5.12 Loadings depending on Component 1 from the PCA of Figure 5.11.

6.1 S2P Faunal Evolution Model

It is quite evident, given their grouping under specific limits, that the taxa present in the S2P core depths are adapted to different environments; else there would be a wider interaction between species. Hence why, according to both the qualitative (determination, taxonomy) and quantitative analysis (PCA, Cluster analysis) presented before, we can sum up these faunal elements, from top to bottom, into the following Assemblages:

Assemblage A (Shallow marine assemblage)

Typical species: *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata*, *Bittium reticulatum*, *Turritella communis*

Layers: 0 - 200 cm

Fauna of exclusive marine living, benthonic, usually on soft bottoms (mud or sandy mud), with possible presence of hard surfaces (i.e., scattered rocks, algae), as there are also present some species prone to attach on (*Anomia* sp., *Mytilus* sp., *Ostrea* sp., *S. adansonii*), which can also attach on floral elements) or perforate such surfaces (*Petricola* sp.) (Sakellariou, 1957; Riedl, 1991; Di Rita et al., 2011). Rich in variety, these species have a stenohaline adaptation, where some of them need specific depth habitats. Important is the typical habitat depth of species like *A. pausicostata*, *N. nitidosa*, *Nuculana* sp., *C. cuspidata*, *A. pespelecani*, *Epitonium cf. clathrus*, which can be summed up to a range between 10 and 70 m (estimated after data from Riedl, 1991). Especially due to the presence - even if limited - of *C. cuspidata*, we can imply that average depths of about 30 m or more in the Gulf of Elefsina existed before present times. Furthermore, there are also a lot of biological interactions between species, such as parasite living (*Eulima* sp., *Chrysallida* sp., *Turbonilla acuta*) or predation (*Natica* sp., *B. brandaris*). Borings on shells show the presence of specific predator species (i.e., Naticoid and Muricid gastropods) and a predator-prey relationship between these taxa, even if no specimens of the said species are found. Additionally, Scaphopods (*Dentalium* sp.), Serpulids (*Serpula* sp., *Ditrupa* sp.), remnants of Echinoid species, mostly Irregular (Irregularia) ones adapted on endobenthic living (soft substrates), but also fragments of decapod Arthropods. All the above are indicative species of a marine environment. Also, very important information is given from the high presence of species like *C. gibba* and *M. spinifera*, who are noted in the literature (Büyükeriç et al., 2016, and references) to be able to live on dysoxic muddy bottoms, and

especially *C. gibba* is considered one of the most tolerant to reduced oxygen habitats, even at depths between 25-40 m. The nowadays oxygenation issue of the Gulf of Elefsina is known from researches in this area (Sklivagkou, 2003; Paraskevopoulou, 2009; Prifti et al., 2012; Prifti and Kaberi, 2014; Karageorgis et al., 2016). Taxa (S) average-high values, Shannon-Wiener (H') index high values and mollusk density average-high values indicate an abundant and diversified fauna, with occasional fluctuations. Therefore, we can sum up the Assemblage A to be a typical marine environment, with mid-low oxygenation events caused possibly by the reduced saltwater exchange between the Gulf of Elefsina and the open sea.

Assemblage B (Open lagoon assemblage)

Typical species: *Cerastoderma glaucum*, *Mytilaster marioni*, *Hydrobia* sp.

Layers: 200 - 253 cm

Species resistant to lower salinities and/or salinity fluctuations (Riedl, 1991; Di Rita et al., 2011; Büyükmeriç et al., 2016). The absence of marine species (found in Assemblage A) is remarkable. In addition, the chemical etching of some specimens is frequent. The species *Mytilaster marioni* indicates the presence of hard surface elements (plants, or possibly rocks) in a brackish environment with sandy sediments (euryhaline species *Cerastoderma glaucum* is common in them) (Riedl, 1991; Öztürk et al., 2002; Barbieri et al., 2011). Serpulids are occasionally present and are known to withstand lower salinities as well. The species *Hydrobia* sp., present in this but also in Assemblage C, is known to live in salinity levels that range from brackish to freshwater environments (mostly the latter), like *Cerastoderma glaucum* when is found in great abundances (Riedl, 1991; Di Rita et al., 2011). The species *Theodoxus* sp. (Assemblage C), which usually lives in freshwater, is basically absent in the layers that are characterized by the presence of Assemblage B, with few individuals present only in the transitional layers. This difference of Assemblages B and C is essential for the paleoenvironmental reconstruction, since the presence or absence of *Theodoxus* sp. indicates two different salinity environments from 200 cm till 296,8 cm. Taxa (S) low-mid values, Shannon-Wiener (H') index average-low values (less than 1) and mollusk density low-high values (low in layers between 200 and 229 cm, high in layers between 229 and 253 cm), indicate a less diversified but still abundant fauna. Considering the above, Assemblage B is characterized by a meso-oligohaline, brackish environment of low energy, common of shallow marine to open lagoonal conditions, with important freshwater input in the system.

Assemblage C (Freshwater – oligohaline environment assemblage)

Typical species: *Hydrobia* sp., *Theodoxus* sp.

Layers: 253 - 296,8 cm

Only 2 species of gastropods present. *Theodoxus* sp. indicates low salinity levels to (mostly) freshwater conditions (Riedl, 1991; Antczak, 2014). Furthermore, according to Antczak (2014), this species is present in rich in calcium (or “hard”) water. The Charophytes and the high amounts of perolithosis fragments also indicate calcium rich water. The very low values of Taxa (S) and Shannon-Wiener (H') indexes as well as the low values of mollusk density low values indicate a scarcely diversified fauna. So Assemblage C can be attributed to oligohaline conditions that were established into an initial fresh water environment that gradually shifted to a closed lagoon, possibly due to the increasing marine influence.

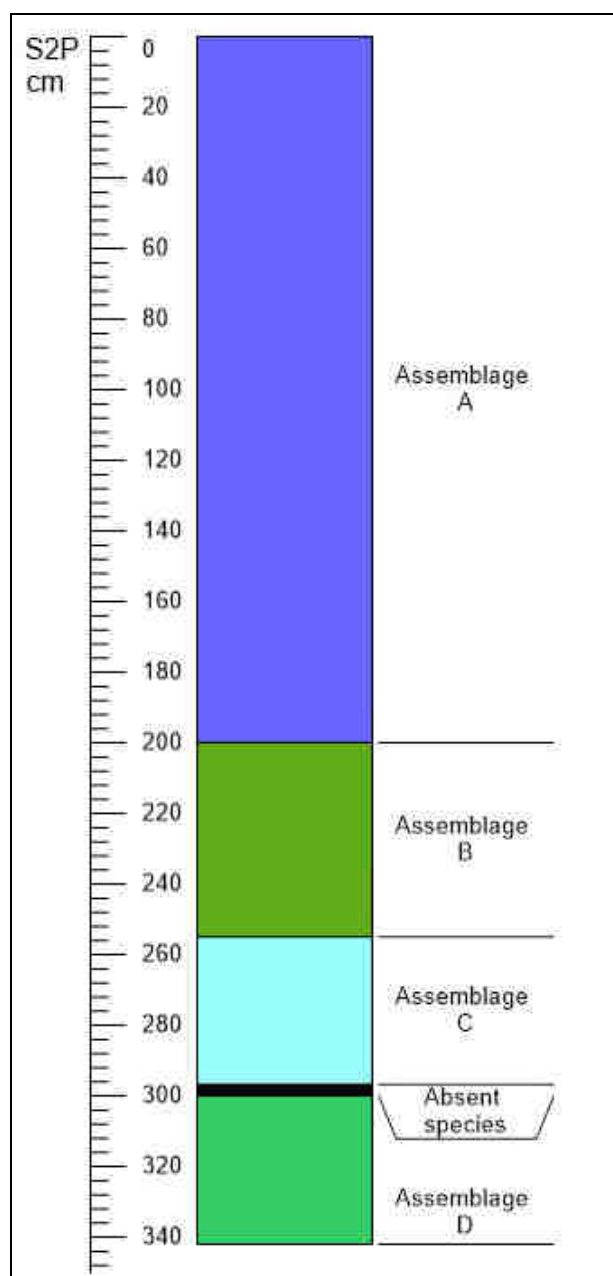


Figure 6.1 Simplified column that shows the faunal assemblages of the S2P core.

Assemblage D (“Fossil” assemblage)

Typical species: well rounded specimens

Layers: 300 – 342 cm

A sandy facies containing several well rounded mollusk fragments, foraminifera and ostracods with calcareous perolithosis. This is a problematic Assemblage to be identified, as the well rounded specimens don't allow precise determination. However these fragments represent inherited faunal remnants of unclear origin. We can imply that these specimens are not contemporary to the coarse sediment present in these layers, as they are mostly fossilized, and they may have been transported through erosion from older sedimentary deposits. As a result they were not included in any quantitative or statistical analysis, but only plotted as indicative accumulations in figures 5.7, 6.5.

The faunal assemblages (A, B, C, D) described above can be seen in the simplified column of Figure 6.1. A comparative picture between the stratigraphic column of the S2P core and Fig. 6.1 column can be seen in Figure 6.2. By viewing the latter figure, we can note a consistency between lithological units and palaeoenvironments. This makes sense, especially if we consider that any environmental change that involved the input of water of variable salinity (freshwater and marine) and the supply of different clastic elements triggered certain sedimentary processes (clastic, biogenous, chemical sedimentation).

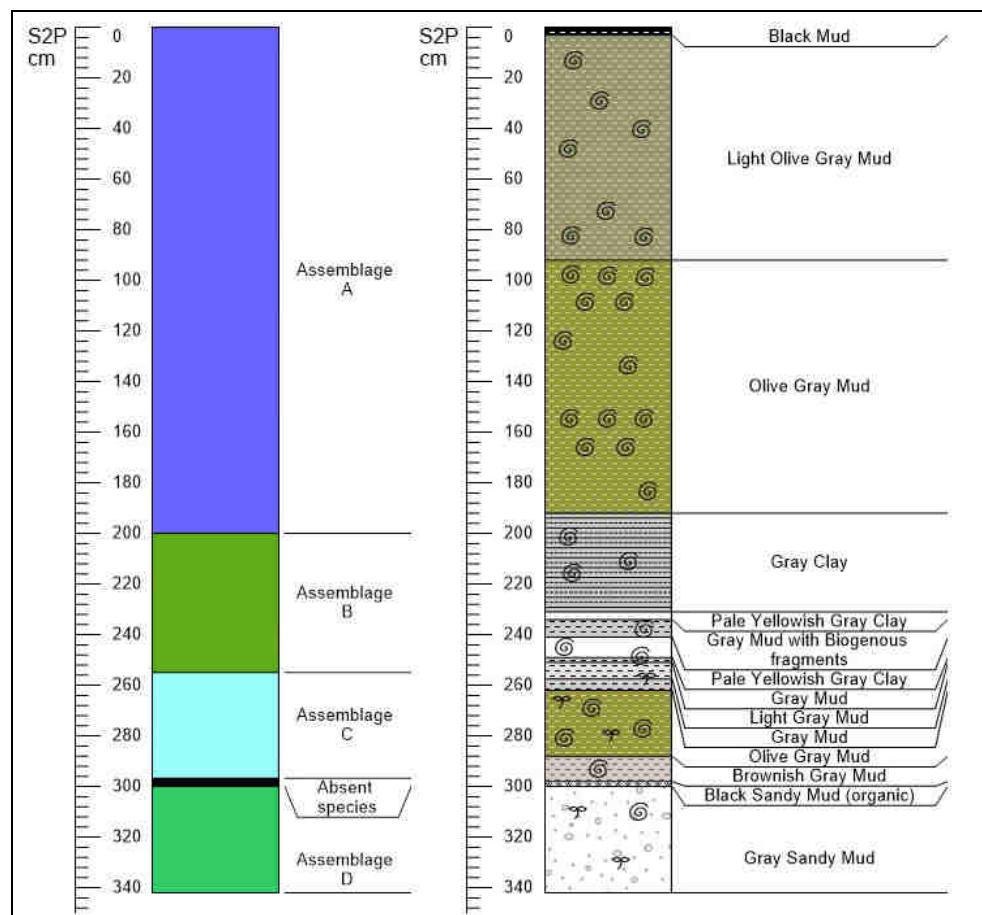


Figure 6.2 Synthesis of the mollusk assemblages and stratigraphy columns of the S2P core.

Considering the relevant presence of some species as mentioned above, two distinct groups of taxa was proposed (Fig. 6.3), a Marine-exclusive one, including the species *B. sebetia*, *C. gibba*, *N. nitidosa*, *T. ovata*, *Venus* sp., *B. reticulatum*, *T. communis*, and an Oligohaline group, with the species *A. segmentum*, *C. glaucum*, *M. marioni* and *Hydrobia* sp. The freshwater living species *Theodoxus* sp. was used separately, as an indicator of closed environmental conditions. The graphs presented below show the total sum, bivalves and gastropods sums, marine and oligohaline groups sums, and *Theodoxus* sp. sum, in comparison between them (Fig. 6.3). The distinction of zones where specific faunal assemblages prosper is evident, giving us a representative picture of the environmental changes.

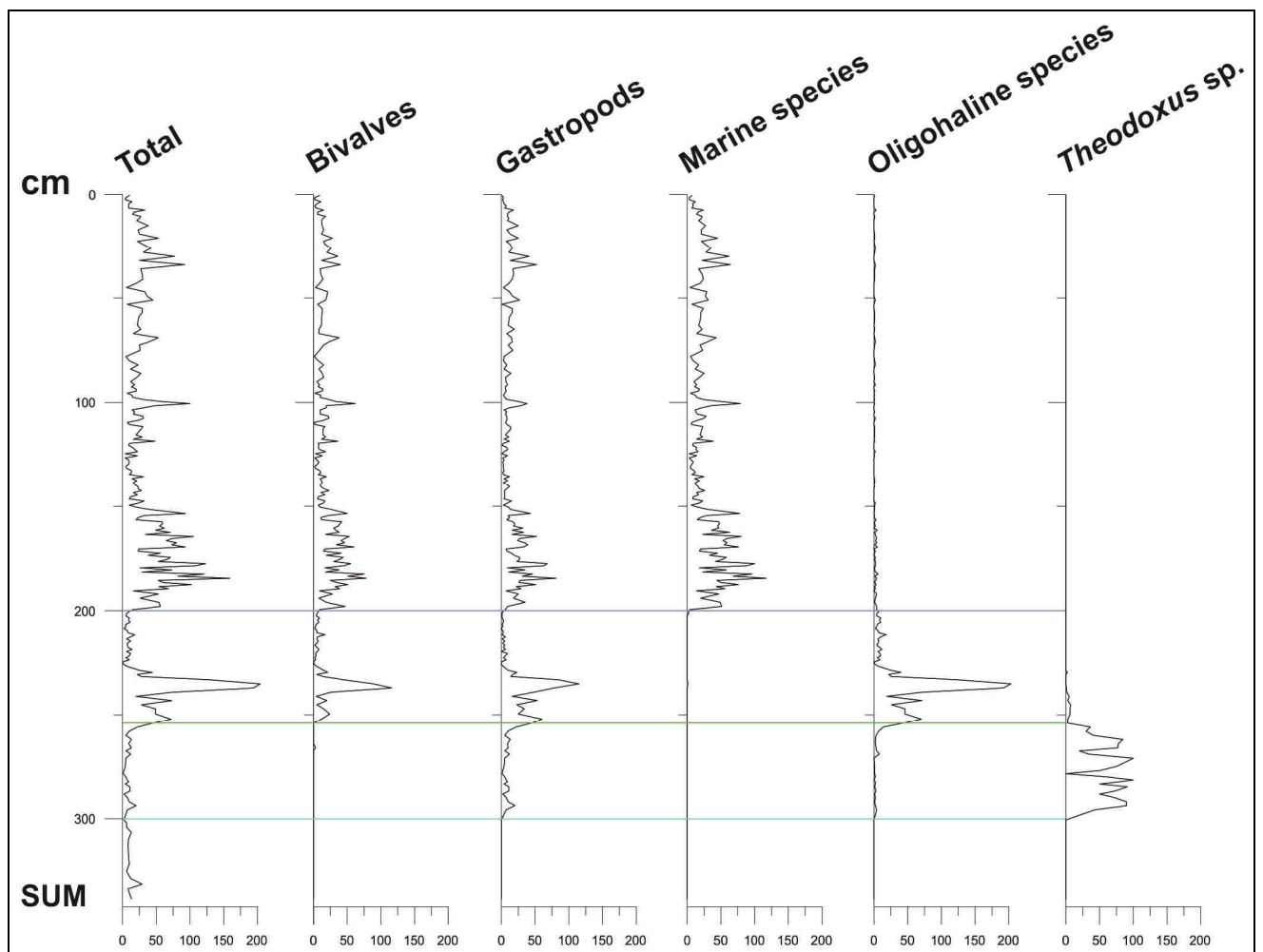


Figure 6.3 Total amount of specimens (rounded shells included), Bivalves, Gastropods, Marine, Oligohaline species and *Theodoxus* sp.. The drawn lines indicate the faunal differentiation.

Moreover, graphs showing the cumulative percentages of the said faunal groups depending on the S2P core depth were designed, presenting the Marine species, Oligohaline species and *Theodoxus* sp. percentages (Fig. 6.4). The resulting differentiation of Figure 6.4 is more evident than in Figure 6.3.

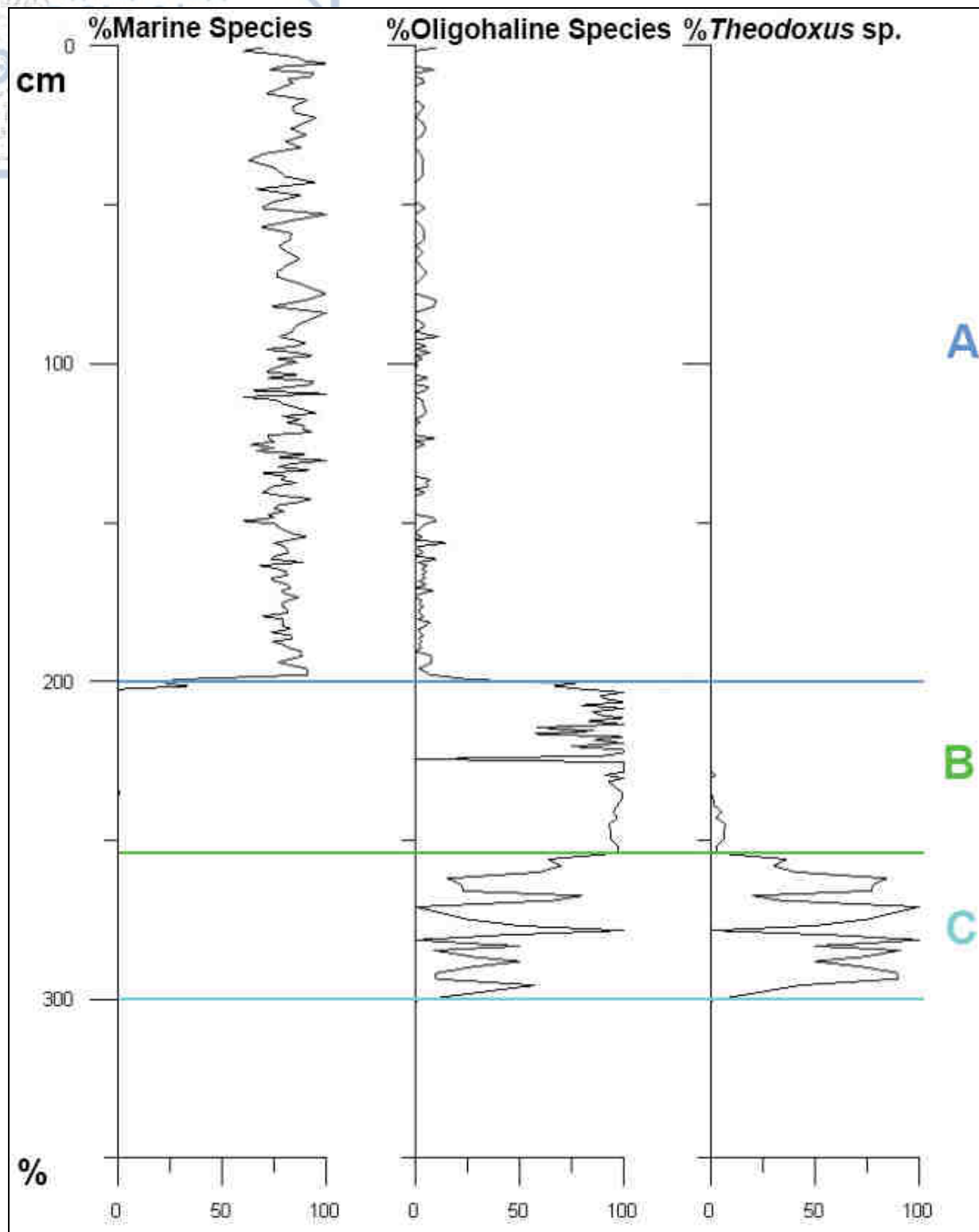


Figure 6.4 Cumulative percentage graphs showing the presence of Marine, Oligohaline species as well as *Theodoxus* sp. across the whole core depth. Lines differentiate the environments into the proposed Assemblage models (A, B, C).

Additionally, Figure 6.5 compares the assemblages' column with the cumulative percentages of Marine, Oligohaline species, *Theodoxus* sp. and rounded specimens sum.

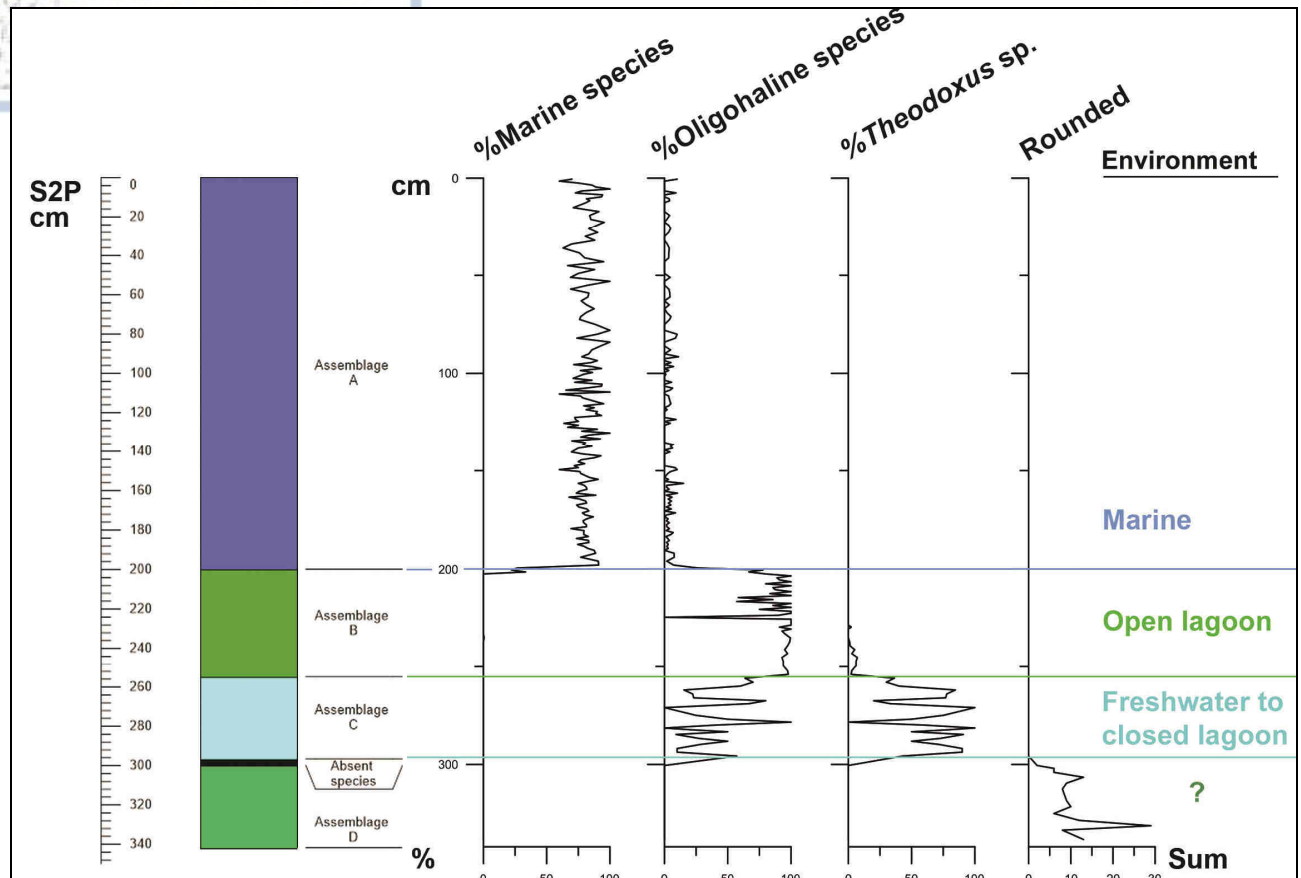


Figure 6.5 Comparison between proposed faunal assemblages, percentage sum graphs of Marine, Oligohaline species, *Theodoxus* sp. and rounded specimens sum. The drawn lines show the differentiation of the environment.

A well observable change of the faunas across the core depths are presented in Figure 6.5. Starting from the bottom of the core, and considering first the dubious nature of Assemblage D with rounded specimens, we notice afterwards a spread of oligohaline and *Theodoxus* sp. species within the freshwater to closed lagoon Assemblage C range. The latter species diminishes as mentioned above, to completely disappear when we reach the layers corresponding to open lagoon Assemblage B. The Oligohaline group blooms, a good indicator of a radical change, with better conditions for the fauna to prosper, in a brackish environment. Afterwards, the marine fauna dominates, which testifies an increase of saline water input in the system, to a complete change into marine conditions.

The faunal assemblages proposed are further confirmed from the Cluster analysis carried out. In Figure 6.6, the marine environment species (blue) are distinctly separated from the oligohaline (green) and freshwater (cyan) species.

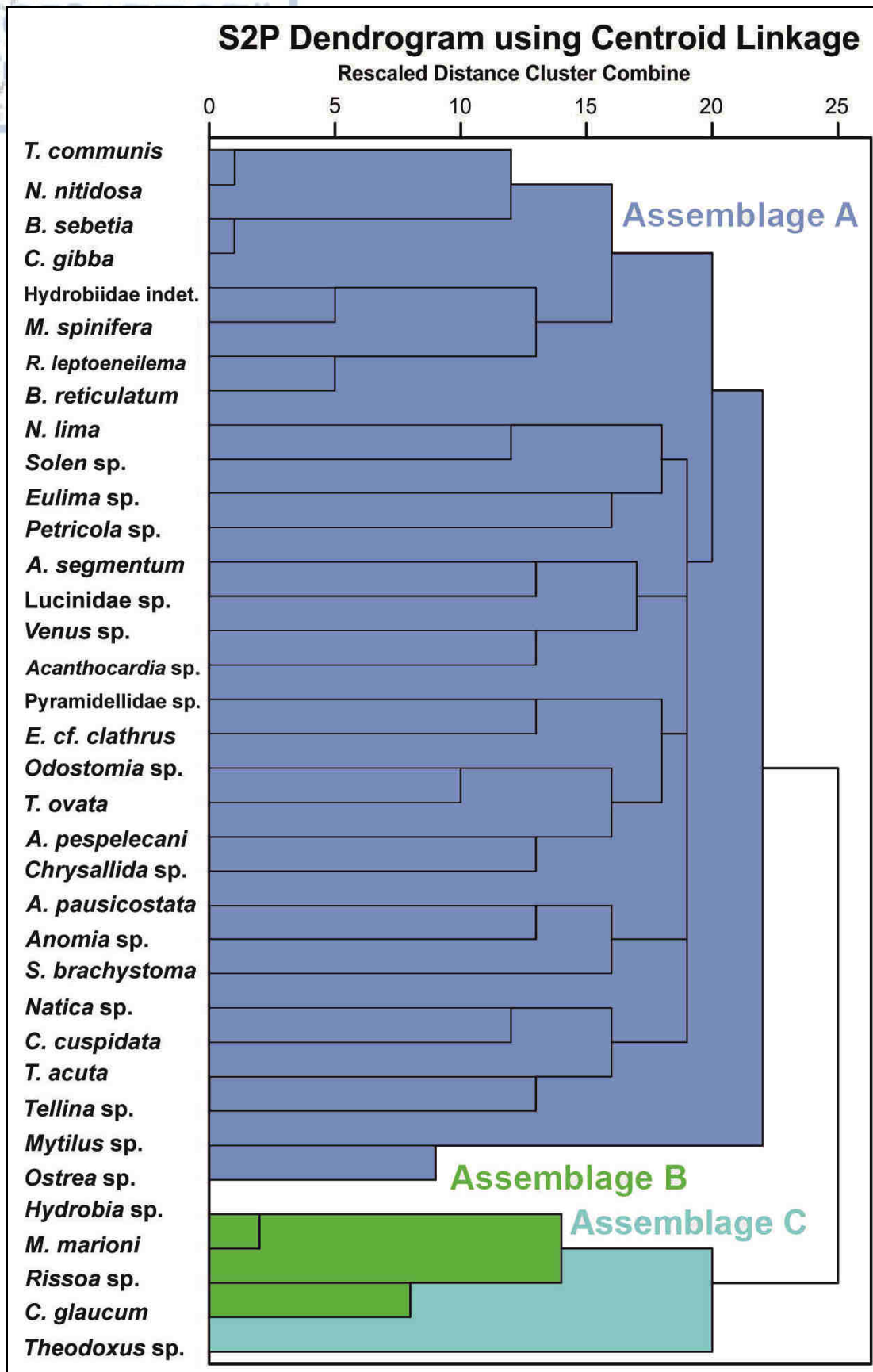


Figure 6.6 The R-mode Cluster Analysis using Centroid Linkage shows that there is indeed a distinction between marine (assemblage A) and oligohaline species (assemblage B) into groups. The latter create 2 distinguishable sub-groups, one of a brackish-open lagoonal environment (B) and one that indicates a freshwater to closed lagoonal environment (C).

6.2 Paleoenvironmental reconstruction of the Gulf of Elefsina

Valuable data retrieved from the analysis of the macrofaunal invertebrates present in the S2P core can help us determine, in combination with data provided from other researchers on the area, an accurate environmental representation of the Gulf of Elefsina in the Quaternary and more precisely during Holocene.

The most important factor that contributes to the evolution of the coasts of the Aegean Sea and the Saronic Gulf with the end of the Pleistocene is undoubtedly the postglacial sea level rise. Generally, sea-level change in the Mediterranean Sea during glacial cycles is determined by the temporally variable eustatic change and by the spatially variable glacio-hydro-isostatic response of the earth and ocean to the growth and decay of ice sheets (Lambeck and Purcell, 2005). For areas without (neo)tectonic activity, all suggested curves indicate a rapid and stable sea level rising in the Holocene till 6000 years BP, a point from which the sea level rise is slower (Lambeck and Purcell, 2005). For the Aegean, the environmental changes are well documented in the coastal areas from biological and other proxies (e.g., Syrides, 1996; Koskeridou and Ioakim, 2009; Syrides, 2008; Syrides et al., 2009a; Syrides et al., 2009b; Pavlopoulos et al., 2010; Triantaphyllou et al., 2010; Koukousioura et al., 2012; Karadimou et al., 2016; Triantaphyllou et al., 2016).

The Saronic Gulf has been studied recently for the purpose of creating a specific, Western Saronic related average sea level curve of the Upper Holocene (Fig. 6.7) by Kolaiti and Mourtzas (2016).

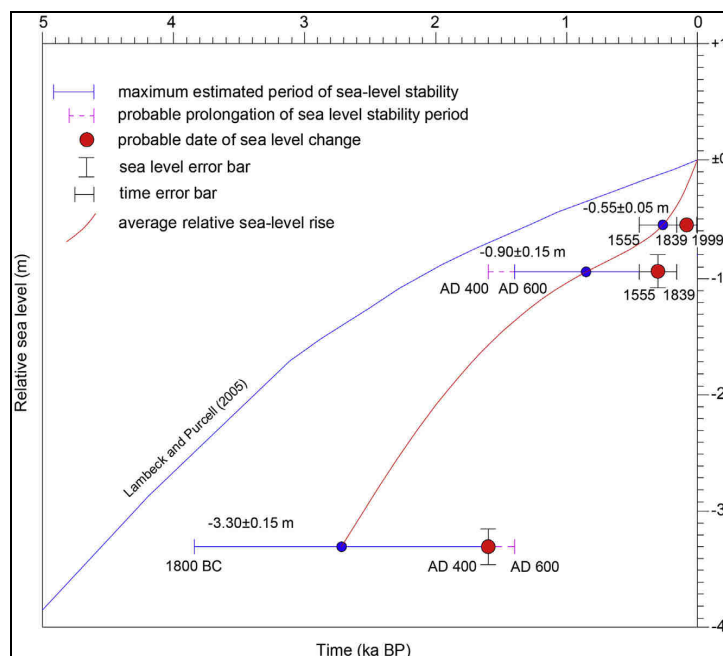


Figure 6.7 Relative sea level rise in the Upper Holocene of Western Saronic Gulf in comparison to the RSL curve proposed by Lambeck and Purcell (2005) for the Mediterranean. The steady rise is increased the last hundreds of years (from Kolaiti and Mourtzas, 2016).

These researchers mention the absence of tectonic displacements along the extensive seismically active fault zones that are known to be present in the area (Lekkas, 2001) for the last 3000 years BP. It must be taken into account nonetheless, that the neotectonic activity in the Saronic Gulf has

possibly altered the way that the post-glacial sea level rise has changed the environment in the Gulf of Elefsina as well, but unfortunately such data was not available for this thesis.

Thanks to all the data gathered, we can accurately reconstruct the paleoenvironmental evolution of the study area during the Holocene. Such evolution can be related to certain ages of the Quaternary thanks to the radiocarbon dating. According to the AMS analysis, the high organic content in the S2P core depth between 296,8-300 cm resulted to a calibrated age of 13555 – 13425 years BP (Late Pleistocene). Before that age and downcore, there should have been a freshwater environment, with coarse sand and mud sediments, which gradually changed for a short time into a marshy environment, rich in organic material, like peat. During that period, there was no connection to the sea. From that point and afterwards the sea level rises and begins influencing the Gulf of Elefsina with marine overflow intrusions, which are mixed with the freshwater inputs from the wider area, creating a closed, freshwater to oligohaline environment at first with species of the faunal Assemblage C (freshwater – oligohaline environment assemblage) and muddy sand sediments. This process doesn't supply the Gulf with high quantities of sediments, in a period of at least more than ~2400 years. Surely sometime after ~11000 years BP (242-244 cm) during the early Holocene the environment turns into an open lagoon with species of the faunal Assemblage B and mud-sandy mud sediments. During this time the sea starts to overpass the geomorphological barrier and gains access to the Gulf of Elefsina. Worth noting is how the creation of the open lagoon in the study area precedes chronologically similar environmental changes on areas such as on the Eastern Saronic Gulf. A multiproxy research on the area of Piraeus done by Goiran et al. (2011) and Triantaphyllou et al. (2016) found the oldest influence of the sea in a lagoonal environment with an age maximum from radiocarbon data of 8700 years BP. Between ~11000 and ~10200 years BP (less than millennia) the sedimentation rate seems to be very high and the environment turns fast from a closed lagoon to an open lagoon with freshwater inputs and clear influence of the sea to a marine environment with the presence of the faunal Assemblage A and muddy sediments. Between ~10200 and ~4000 years BP the marine fauna reaches the highest values observed in the S2P, a signal of prosperity that could be due to the providing of newly available nutrition resources for the species. During the last thousand of years of the Holocene the Gulf of Elefsina's marine environment has been formed. We know that the sea level did continue to rise constantly till about 6000 years BP (Lambeck and Purcell, 2005) and afterwards it did and continues nowadays at a slower and steady pace. At that point both straits that lead to the Gulf of Elefsina provide the enclosed area with saltwater from the open sea. However, the water exchange is very restricted and combined with the freshwater input it created in the past anoxic episodes that influenced the marine species' diversity (notable by the occasional decrease of species). Not only that, the recent (in geological time) presence of the human civilization had a serious impact on the environmental conditions of the Gulf (Sklivagkou, 2003; Paraskevopoulou, 2009; Prifti et al., 2012; Prifti and Kaberi, 2014; Karageorgis

et al., 2016). Furthermore, the sedimentation rate varies a lot, which can be related to how much material is provided to Elefsina from torrents, rivers and the Saronic Gulf itself (Hatzianestis et al., 2004).

In conclusion, this study's observations agree, in general, with the results from different approach analyses carried out on the S2P core (Petropoulos et al., 2013; Kyrikou, 2016; Kyrikou et al., 2016). Petropoulos et al. (2013) analyzed the carbonate and organic carbon content of the S2P core, concluding that the Gulf of Elefsina was a paleolake environment, followed by a lagoonal environment which then transited to a normal marine environment; Kyrikou (2016) and Kyrikou et al. (2016) assessed through palynological data from the S2P “*the Holocene marine transgression in the area of Elefsis and its successive steps from a fresh water lake to a lagoon and finally to a shallow marine bay*”, with correlatable results (Fig. 6.8). More specifically, between 295 cm and 245 cm they observed the “*remarkable presence*” of green algae *Botryococcus* with a continuous presence of hydrophilous vegetation, indicative of shallow fresh water to very oligohaline lacustrine conditions; between 245 cm and 195 cm the high abundances of the euryhaline dinoflagellate cyst *Lingulodinium machaerophorum* showed the occurrence of a lagoonal environment; from 195 cm till the top of the core, the retreat of *L. machaerophorum* signaled the establishment of the modern marine environment. The present work compared to the data of Kyrikou (2016), and Kyrikou et al. (2016) reveal close similarities among the layers and the environmental changes (Fig. 6.8), The slight offset (2-8 cm) among depths that is noted can be explained due to different “reaction” hysteresis period between macrofauna, microfauna and flora.

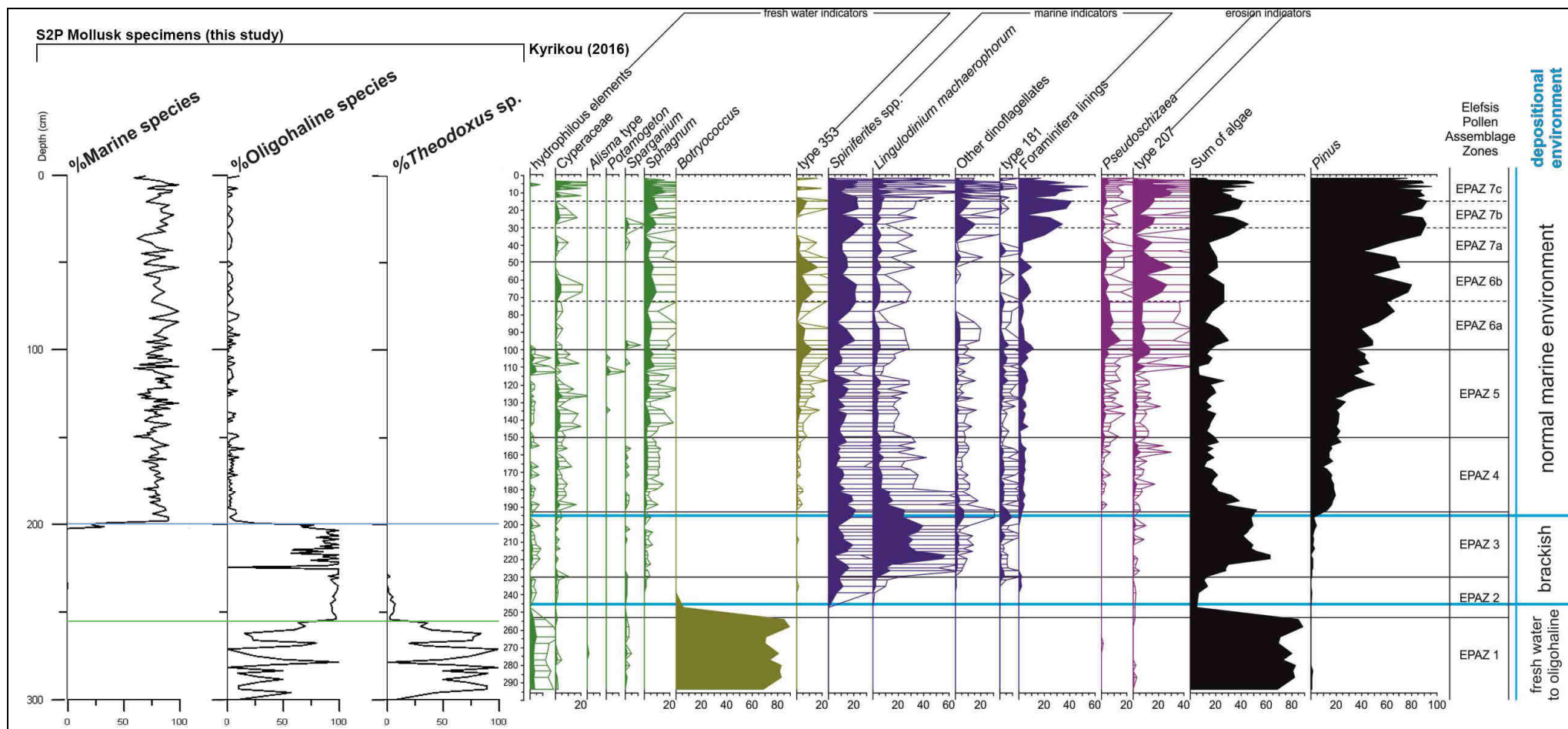
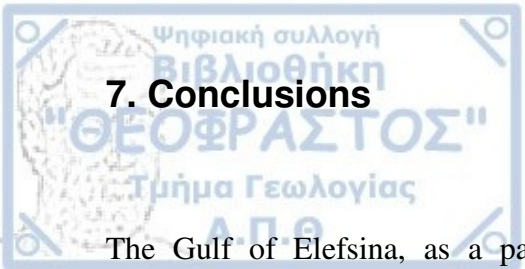


Figure 6.8 Comparison of this study's results (left part of figure) and results from Kyriku (2016) (right part of figure).



7. Conclusions

The Gulf of Elefsina, as a part of the Saronic Gulf, is a geomorphological embayment that communicates through two narrow straits, and has depths ranging from 35 m to 10 m.

The restricted communication of the Gulf with the open sea, the freshwater inputs and the industrial pollution cause nowadays issues to the marine fauna, with anoxia/hypoxia and the presence of toxic elements and compounds (Sklivagkou, 2003; Paraskevopoulou, 2009; Prifti et al., 2012; Prifti and Kaberi, 2014; Karageorgis et al., 2016).

In order to gain knowledge of the environmental evolution of the Gulf of Elefsina, a sample core with the codename S2-Perseus was retrieved from the deep western area of the Gulf. The core was prepared for multiproxy analyses, of which the present thesis carried out the study of the macrofaunal elements present in it. The methodology used for the study of the S2P core included laboratory methods, AMS radiocarbon dating, description of the sediments and sand/mud percentages, qualitative identification of the invertebrates (classification, ecology, faunal assemblages), quantitative analysis of the mollusk fauna and confirmation of the results through statistical analysis.

A total of 10500 specimens were retrieved, from a total of 231 core samples. The Mollusca were the focus of this thesis, as the presence, rich variety of species and diversity within the core layers was evident. The Bivalvia and Gastropoda gave out the most important data. The number of well preserved bivalves and gastropods reached a total amount of 6661 individuals. Aside of the latter number, 590 more specimens, that were either etched or rounded, were observed and elaborated as environmental indices but were not taken into account for quantitative analyses. The classification of the fauna revealed the presence of 48 species of mollusks (23 gastropods, 24 bivalves and 1 scaphopod). The species were grouped within the core depths into well distinguished faunal Assemblages that were attributed to different environmental conditions. The transition between environments was gradual and documented with assemblages coexistence.

Four different assemblages were distinguished:

The oldest observable **Assemblage D** (“fossil” assemblage) consists of rounded specimens of dubious nature, calcified and possibly fossilized.

Assemblage C (freshwater – oligohaline environment assemblage) includes freshwater-oligohaline living species such as *Theodoxus* sp. and *Hydrobia* sp. Taxa (S) (1-2), Shannon-Wiener H' (0-0,7) and Density present very low values.

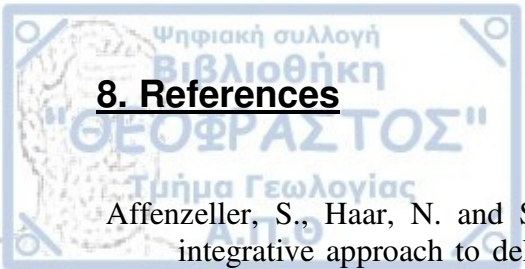
Assemblage B (open lagoon assemblage) consists of the brackish living species *Cerastoderma glaucum*, *Mytilaster marioni*, *Hydrobia* sp. Taxa (S) (0-6), Shannon-Wiener H' (<1) and Density get relatively intermediate values.

Assemblage A (marine assemblage) comprises marine living species (mainly *Bornia sebetia*, *Corbula gibba*, *Myrtea spinifera*, *Nucula nitidosa*, *Timoclea ovata*, *Bittium reticulatum* and *Turritella communis*). Taxa (S) (4-19), Shannon-Wiener H' (1-2,2) and Density (up to 500) present high values.

The mollusk analysis concluded that in the Late-Pleistocene and Holocene, during the last 13,5 ka, the Gulf of Elefsina evolved from a dubious depositional system to a fresh water oligohaline environment, which due to the constant sea level rise turned into an open lagoon and later became completely marine. The period of such environmental changes can be put between 13,5 ka and about 10,5 ka BP. This agrees with other researches focused on answering the same question. The fauna changed accordingly and showed periods of decadence or prosperity, probably depending to the documented anoxic episodes of the Gulf, due to the restricted communication with the open sea, and/or the lack of nutrition for the invertebrates.

This study proved that the use of Holocene molluscan assemblages to access paleoenvironmental evolution is a useful and reliable method that should be taken into account. The well distinguished faunal assemblages described herein gave important ecological data, as it confirmed the trend of certain mollusk species to live in certain environments and environmental conditions. In turn, these environments can be expected to host these specific faunas. Therefore, this analysis gave out a series of environmental indices in the form of faunal assemblages, which can be applied to future projects and research for (paleo)environmental studies.

Further sampling and study of the Gulf of Elefsina with multiproxy analyses could confirm the model of the present thesis and a more thorough study of the wider Saronic Gulf can give insight to the environmental past of this area of the Aegean Sea.



8. References

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- <http://www.wikipedia.com> | Scientific vocabulary source

The tables showing the species present in the S2P core sample and their corresponding amounts based on core depth are provided separately in A3 sized sheets. There are 4 of these. The tables were split due to size according to depth (0 to 200 m, 200 to 342 m) and Class (Bivalvia, Gastropoda). Each species has the amount and faunal participation percentage per depth recorded and placed side by side for comparison.

Table 9.1 S2P Sand/Mud Percentages according to depth. The sand / mud (silt + clay) content of each sample were estimated after the weight difference between washed and residual material.

S2P	Washed	Residual	%Mud	%Sand	S2P	Washed	Residual	%Mud	%Sand
0-1	0,91	0,85	6,47	93,53	52-54	2,00	0,03	98,60	1,40
1-2	2,00	0,02	99,00	1,00	54-56	2,00	0,12	94,15	5,85
2-3	2,00	0,03	98,65	1,35	56-58	2,00	0,06	97,00	3,00
3-4	2,00	0,11	94,60	5,40	58-60	2,00	0,90	54,85	45,15
4-5	2,00	0,02	99,15	0,85	60-62	1,83	0,06	96,56	3,44
5-6	2,00	0,02	98,85	1,15	62-64	2,00	1,52	23,80	76,20
6-7	2,00	0,02	98,90	1,10	64-66	2,00	1,12	44,10	55,90
7-8	2,00	0,10	95,00	5,00	66-68	2,00	0,15	92,30	7,70
8-9	2,00	0,09	95,70	4,30	68-70	2,00	0,22	88,80	11,20
9-10	2,00	0,04	98,10	1,90	70-72	1,98	0,27	86,57	13,43
10-11	2,06	0,04	97,96	2,04	72-73	2,00	0,09	95,35	4,65
11-12	2,00	0,13	93,40	6,60	73-77	2,00	0,12	93,95	6,05
12-13	2,00	0,07	96,55	3,45	77-79	2,00	0,02	98,80	1,20
14-16	2,00	0,21	89,40	10,60	79-81	2,00	0,03	98,75	1,25
16-18	2,00	0,14	92,85	7,15	81-83	2,00	0,04	97,90	2,10
18-20	2,00	0,38	81,20	18,80	83-85	2,00	0,04	98,20	1,80
20-22	1,81	0,39	78,45	21,55	85-87	2,00	0,17	91,60	8,40
22-23	2,00	0,35	82,60	17,40	87-89	2,00	0,08	96,20	3,80
23-25	2,00	0,29	85,65	14,35	89-91	2,00	0,07	96,75	3,25
25-27	2,00	0,35	82,70	17,30	91-92	2,00	0,25	87,75	12,25
27-29	2,00	0,10	95,00	5,00	92-93	2,00	0,10	95,10	4,90
29-31	2,03	0,57	72,08	27,92	93-94	2,00	0,05	97,60	2,40
31-33	2,00	0,13	93,65	6,35	94-95	2,00	0,06	96,85	3,15
33-35	2,00	0,13	93,35	6,65	95-96	2,00	0,01	99,30	0,70
35-37	2,00	0,46	76,85	23,15	96-97	2,00	0,04	98,05	1,95
37-40	2,00	0,98	50,85	49,15	97-98	2,00	0,05	97,45	2,55
40-43	2,07	0,51	75,36	24,64	98-99	2,00	0,05	97,65	2,35
42-44	2,00	0,30	84,90	15,10	99-100	2,00	0,25	87,75	12,25
44-46	2,00	0,02	99,10	0,90	100-101	2,00	0,79	60,75	39,25
46-48	2,00	0,18	91,15	8,85	101-102	2,00	0,41	79,70	20,30
48-50	2,00	0,20	90,00	10,00	102-103	2,00	0,18	90,90	9,10
50-52	2,15	0,48	77,86	22,14	103-104	2,00	0,11	94,70	5,30
					104-105	2,00	0,08	96,00	4,00

S2P	Washed	Residual	%Mud	%Sand	S2P	Washed	Residual	%Mud	%Sand
105-106	2,00	0,05	97,70	2,30	165-166	2,00	0,09	95,30	4,70
106-107	2,00	0,09	95,40	4,60	166-167	2,55	0,53	79,10	20,90
107-108	2,00	0,16	91,85	8,15	167-168	3,55	0,48	86,54	13,46
108-109	2,00	0,11	94,70	5,30	168-169	2,85	0,55	80,60	19,40
109-110	2,00	0,01	99,70	0,30	169-170	3,61	0,75	79,36	20,64
110-111	2,00	0,03	98,40	1,60	170-171	1,94	0,10	95,00	5,00
111-112	2,00	0,04	98,10	1,90	171-172	1,16	0,16	86,10	13,90
112-113	2,00	0,06	97,20	2,80	172-173	3,06	0,26	91,43	8,57
115-116	2,09	0,12	94,34	5,66	173-174	1,82	0,19	89,82	10,18
116-117	2,05	0,22	89,42	10,58	174-175	3,11	0,58	81,30	18,70
117-118	0,96	0,11	88,52	11,48	175-176	2,00	0,10	94,80	5,20
118-119	1,68	0,18	89,55	10,45	176-177	2,16	0,23	89,57	10,43
119-120	1,23	0,21	83,28	16,72	177-178	3,88	0,46	88,09	11,91
120-121	1,93	0,16	91,79	8,21	178-179	3,16	0,32	89,83	10,17
121-122	1,98	0,29	85,27	14,73	179-180	1,75	0,12	93,02	6,98
122-123	2,23	0,72	67,92	32,08	180-181	2,00	0,09	95,70	4,30
123-124	2,07	0,19	90,61	9,39	181-182	1,27	0,26	79,29	20,71
124-125	0,87	0,10	89,09	10,91	182-183	4,23	0,71	83,32	16,68
125-126	2,02	0,16	92,27	7,73	183-184	2,17	0,28	87,32	12,68
126-127	0,54	0,05	89,91	10,09	184-185	3,27	0,45	86,15	13,85
127-128	1,00	0,15	85,34	14,66	185-186	2,00	0,12	94,20	5,80
128-129	1,99	0,21	89,42	10,58	186-187	2,72	0,49	82,11	17,89
129-130	1,08	0,21	80,97	19,03	187-188	3,85	0,63	83,64	16,36
130-131	2,05	0,02	98,88	1,12	188-189	1,83	0,28	84,53	15,47
131-132	1,88	0,33	82,63	17,37	189-190	3,17	0,37	88,23	11,77
132-133	0,94	0,10	89,60	10,40	190-191	1,80	0,02	98,72	1,28
133-134	1,74	0,15	91,64	8,36	191-193	3,74	0,17	95,58	4,42
134-135	0,97	0,11	88,96	11,04	193-195	2,00	0,01	99,30	0,70
135-136	2,00	0,05	97,45	2,55	195-197	2,00	0,03	98,70	1,30
136-137	1,32	0,14	89,30	10,70	197-199	5,09	0,17	96,76	3,24
137-138	2,30	0,23	90,12	9,88	199-200	2,11	0,00	99,86	0,14
138-139	2,52	0,27	89,36	10,64	200-201	2,76	0,13	95,15	4,85
139-140	2,64	0,22	91,70	8,30	201-202	3,46	0,20	94,31	5,69
140-141	2,00	0,02	99,25	0,75	202-203	1,79	0,12	93,58	6,42
141-142	2,77	0,36	87,16	12,84	203-204	3,72	0,16	95,67	4,33
142-143	3,56	0,42	88,36	11,64	204-205	1,71	0,08	95,43	4,57
143-144	2,56	0,28	89,11	10,89	205-206	3,83	0,21	94,41	5,59
144-145	3,57	0,27	92,57	7,43	206-207	1,88	0,13	92,88	7,12
145-146	2,00	0,03	98,75	1,25	207-208	2,62	0,10	96,06	3,94
146-147	1,69	0,15	90,91	9,09	208-209	1,70	0,06	96,35	3,65
147-148	3,67	0,23	93,76	6,24	209-210	4,76	0,14	97,08	2,92
148-149	3,75	0,29	92,31	7,69	210-211	2,01	0,01	99,55	0,45
149-150	1,86	0,12	93,32	6,68	211-212	1,76	0,05	97,33	2,67
150-151	1,92	0,01	99,27	0,73	212-213	4,03	0,10	97,47	2,53
151-152	3,78	0,31	91,77	8,23	213-214	1,63	0,06	96,14	3,86
153-154	2,71	0,57	78,84	21,16	214-215	3,52	0,22	93,75	6,25
154-155	2,18	0,31	86,02	13,98	215-216	1,34	0,06	95,68	4,32
155-156	2,00	0,07	96,45	3,55	216-217	1,72	0,06	96,63	3,37
156-157	2,13	0,20	90,78	9,22	217-218	1,15	0,12	89,74	10,26
157-158	3,59	0,34	90,60	9,40	218-219	2,43	0,13	94,80	5,20
158-159	2,70	0,29	89,17	10,83	219-220	0,64	0,18	71,97	28,03
159-160	4,40	0,44	90,08	9,92	220-221	2,11	0,08	96,16	3,84
160-161	2,00	0,21	89,75	10,25	221-222	2,44	0,16	93,60	6,40
161-162	2,93	0,27	90,96	9,04	222-223	1,79	0,19	89,16	10,84
162-163	3,65	0,54	85,22	14,78	223-224	3,07	0,15	95,28	4,72
163-164	2,10	0,33	84,30	15,70	224-225	1,72	0,04	97,50	2,50
164-165	3,92	0,47	87,93	12,07	225-226	3,76	0,11	97,02	2,98

S2P	Washed	Residual	%Mud	%Sand
226-227	2,88	0,14	95,08	4,92
228-229	4,87	0,05	98,89	1,11
229-230	1,84	0,14	92,23	7,77
230-231	1,92	0,01	99,48	0,52
231-232	3,96	0,38	90,31	9,69
232-234	5,10	0,45	91,25	8,75
234-236	5,80	0,69	88,15	11,85
236-238	6,08	0,77	87,34	12,66
238-240	4,98	0,41	91,76	8,24
240-242	2,06	0,08	96,36	3,64
242-244	6,01	0,37	93,78	6,22
244-246	5,80	0,14	97,66	2,34
246-248	4,12	0,55	86,62	13,38
248-251	1,90	0,16	91,42	8,58
251-253	7,14	2,18	69,46	30,54
253-255	5,68	2,61	54,03	45,97
255-257	4,66	2,89	37,95	62,05
257-259	3,76	2,08	44,62	55,38
259-261	1,98	0,46	76,63	23,37
261-263	5,57	3,01	46,00	54,00
263-265	3,04	1,57	48,47	51,53
265-267	6,10	2,63	56,96	43,04
267-268	1,62	0,86	47,26	52,74
268-270	5,25	2,28	56,68	43,32
270-272	2,00	0,09	95,35	4,65
274-275,9	6,74	1,96	70,94	29,06
275,9-277,9	4,74	1,79	62,20	37,80
277,9-278,9	3,43	1,03	70,06	29,94
278,9-280,9	5,00	1,98	60,50	39,50
280,9-281,9	1,98	0,07	96,66	3,34
281,9-282,8	2,86	1,16	59,44	40,56
282,8-283,8	1,76	0,93	47,25	52,75
283,8-285,6	5,94	2,06	65,28	34,72
285,6-287,8	4,71	2,71	42,42	57,58
287,8-288,5	2,94	1,32	54,90	45,10
288,5-291	4,90	1,43	70,86	29,14
290,9-292,8	2,04	0,12	94,36	5,64
292,8-294,6	3,82	1,40	63,30	36,70
294,6-296,8	1,97	0,23	88,24	11,76
300-301	2,95	0,94	68,12	31,88
301-303	5,07	1,71	66,18	33,82
303-305	7,71	2,54	67,00	33,00
305-308	11,46	3,54	69,12	30,88
308-311	10,53	3,14	70,15	29,85
311-314	10,24	3,01	70,59	29,41
317-320	2,05	1,08	47,10	52,90
320-323	10,61	4,07	61,62	38,38
323-327	10,13	4,04	60,14	39,86
327-330	10,25	4,41	57,00	43,00
330-332,5	10,01	4,56	54,42	45,58
332,5-334,5	2,02	0,87	57,09	42,91
334,5-342	10,06	4,75	52,72	47,28

Table 9.2 Table showing the number of individuals, the density/10g of total mollusks, bivalves and gastropods, etched and rounded specimens amount, number of taxa and Shannon-Wiener index.

S2P	Individuals	Total/10g	Gastropods/10g	Bivalves/10g	Etched	Rounded	Taxa	Shannon-Wiener	S2P	Individuals	Total/10g	Gastropods/10g	Bivalves/10g	Etched	Rounded	Taxa	Shannon-Wiener
0-1	10	110	11	98,7	0	0	4	1,09	96-97	14	70	15	55	0	0	6	1,70
1-2	5	25	15	10	1	0	4	1,33	97-98	15	75	25	50	0	0	7	1,84
2-3	4	20	10	10	0	0	3	1,04	98-99	30	150	40	110	0	0	11	2,09
3-4	14	70	15	55	0	0	8	1,95	99-100	58	290	125	165	0	0	12	2,04
4-5	9	45	20	25	0	0	5	1,47	100-101	100	500	190	310	0	0	19	2,21
5-6	9	45	35	10	0	0	3	1,00	101-102	48	240	145	95	0	0	14	2,03
6-7	9	45	25	20	0	0	6	1,68	102-103	31	155	60	95	0	0	14	2,36
7-8	33	165	90	75	0	0	11	2,16	103-104	14	70	20	50	1	0	5	1,43
8-9	17	85	55	30	0	0	7	1,64	104-105	18	90	40	50	0	0	10	2,08
9-10	15	75	45	30	0	0	6	1,59	105-106	16	80	30	50	0	0	5	1,39
10-11	27	131	43,7	87,4	0	0	11	2,15	106-107	30	150	40	110	2	0	8	1,79
11-12	25	125	55	70	0	0	10	1,98	107-108	31	155	40	115	0	0	10	1,88
12-13	21	105	45	60	0	0	7	1,79	108-109	23	115	40	75	0	0	10	2,04
14-16	38	190	125	65	0	0	9	1,98	109-110	7	35	30	5	0	0	3	0,96
16-18	23	115	40	75	2	0	7	1,90	110-111	10	50	40	10	1	0	6	1,61
18-20	25	125	65	60	0	0	10	2,10	111-112	30	150	65	85	0	0	12	2,17
20-22	53	294	139	155	0	0	12	2,10	112-113	28	140	70	70	0	0	8	1,72
22-23	22	110	35	75	1	0	7	1,82	115-116	20	96	29	67	0	0	7	1,65
23-25	30	150	65	85	0	0	9	1,89	116-117	29	141	54	88	0	0	10	2,02
25-27	42	210	80	130	3	0	12	2,19	117-118	16	167	42	125	0	0	6	1,67
27-29	31	155	55	100	0	0	9	1,99	118-119	48	285	71	214	0	0	9	1,87
29-31	77	380	202	178	0	0	15	2,24	119-120	10	82	24	57	0	0	5	1,42
31-33	25	125	65	60	1	0	9	2,00	120-121	9	47	5	42	0	0	5	1,47
33-35	92	460	260	200	0	0	18	2,43	121-122	15	76	40	35	0	0	6	1,55
35-37	27	135	85	50	1	0	12	2,21	122-123	18	81	40	40	0	0	9	2,04
37-40	29	145	90	55	2	0	11	1,99	123-124	22	106	19	87	0	0	10	2,11
40-42	30	145	77,1	67,5	0	0	10	2,07	124-125	4	46	11	34	0	0	4	1,39
42-44	20	100	55	45	3	0	6	1,67	125-126	22	109	45	64	0	0	10	2,13
44-46	6	30	15	15	0	0	5	1,56	126-127	4	75	37	37	0	0	4	1,39
46-48	33	165	60	105	0	0	10	2,00	127-128	9	90	40	50	0	0	6	1,68
48-50	36	180	80	100	0	0	12	2,30	128-129	10	50	10	40	0	0	5	1,51
50-52	45	209	126	83,7	0	0	17	2,29	129-130	9	84	28	56	0	0	6	1,74
52-54	7	35	5	30	3	0	4	1,35	130-131	5	24	15	9,8	0	0	3	1,06
54-56	29	145	80	65	1	0	8	1,74	131-132	6	32	16	16	0	0	3	1,01
56-58	29	145	80	65	0	0	14	2,35	132-133	13	138	42	96	0	0	8	1,74
58-60	24	120	60	60	0	0	9	1,69	133-134	13	75	12	63	0	0	5	1,33
60-62	23	125	60	65,4	2	0	10	2,04	134-135	10	103	31	72	0	0	8	1,97
62-64	22	110	50	60	0	0	9	1,89	135-136	31	155	60	95	0	0	8	1,90
64-66	27	135	95	40	1	0	8	1,64	136-137	14	106	30	76	0	0	7	1,83
66-68	16	80	40	40	0	0	7	1,79	137-138	21	91	39	52	0	0	7	1,66
68-70	53	265	75	190	0	0	14	2,12	138-139	16	64	12	52	0	0	5	1,16
70-72	39	197	80,8	116	0	0	13	2,16	139-140	18	68	30	38	0	0	8	1,90
72-73	25	125	50	75	0	0	12	2,20	140-141	23	115	60	55	0	0	8	1,95
73-77	26	130	85	45	0	0	6	1,59	141-142	23	83	29	54	0	0	10	2,10
77-79	5	25	20	5	0	0	3	0,95	142-143	28	79	14	65	0	0	7	1,65
79-81	10	50	15	35	0	0	7	1,89	143-144	16	62	20	43	0	0	7	1,86
81-83	23	115	40	75	0	0	10	2,13	144-145	22	62	14	48	0	0	8	1,87
83-85	12	60	20	40	0	0	4	1,29	145-146	12	60	25	35	0	0	6	1,71
85-87	27	135	70	65	0	0	7	1,47	146-147	10	59	24	35	0	0	7	1,89
87-89	21	105	30	75	0	0	8	1,82	147-148	32	87	41	46	0	0	9	2,07
89-91	12	60	35	25	0	0	6	1,68	148-149	24	64	24	40	0	0	9	2,00
91-92	18	90	45	45	0	0	9	2,01	149-150	10	54	16	38	0	0	7	1,75
92-93	13	65	30	35	0	0	5	1,44	150-151	21	109	57	52	0	0	8	1,86
93-94	20	100	30	70	0	0	8	1,88	151-152	39	103	34	69	0	0	11	2,13
94-95	20	100	35	65	0	0	8	1,83	153-154	93	343	158	184	0	0	14	2,03
95-96	7	35	25	10	0	0	4	1,28	154-155	32	147	46	101	0	0	7	1,70

S2P	Individuals	Total/10g	Gastropods/10g	Bivalves/10g	Etched	Rounded	Taxa	Shannon-Wiener	S2P	Individuals	Total/10g	Gastropods/10g	Bivalves/10g	Etched	Rounded	Taxa	Shannon-Wiener
155-156	23	115	60	55	0	0	9	1,95	219-220	6	94	0	94	0	0	3	1,01
156-157	20	94	38	56	0	0	9	2,06	220-221	12	57	43	14	0	0	5	1,36
157-158	59	165	47	117	0	0	13	2,17	221-222	10	41	25	16	0	0	4	1,09
158-159	59	219	74	145	0	0	11	1,97	222-223	5	28	17	11	0	0	3	0,95
159-160	55	125	41	84	0	0	14	2,15	223-224	10	33	23	10	0	0	4	1,09
160-161	62	310	160	150	0	0	11	2,06	224-225	0	0	0	0	0	0	0	0,00
161-162	49	167	55	113	0	0	12	2,15	225-226	1	3	0	3	0	0	1	0,00
162-163	71	194	90	104	0	0	11	1,87	226-227	6	21	7	14	0	0	4	1,33
163-164	34	162	76	86	0	0	10	2,11	228-229	25	51	21	31	0	0	3	1,06
164-165	105	268	133	135	0	0	14	2,15	229-230	44	239	125	114	0	0	6	1,48
165-166	73	365	135	230	0	0	13	2,14	230-231	22	115	89	26	0	0	4	0,75
166-167	65	255	94	161	2	0	17	2,26	231-232	28	71	35	35	0	0	5	1,34
167-168	80	226	96	130	0	0	13	2,13	232-234	128	251	165	86	4	0	6	1,09
168-169	73	256	137	119	1	0	16	2,32	234-236	204	352	198	154	23	0	5	0,94
169-170	93	258	91	166	0	0	13	2,12	236-238	194	319	128	191	27	0	5	1,00
170-171	24	124	36	88	0	0	9	2,05	238-240	74	149	96	52	14	0	6	0,93
171-172	23	199	69	130	0	0	9	1,99	240-242	20	97	78	19	9	0	4	0,80
172-173	56	183	49	134	0	0	11	1,99	242-244	73	121	88	33	23	0	5	0,96
173-174	38	209	105	105	0	0	9	1,92	244-246	28	48	40	9	11	0	5	0,88
174-175	71	228	87	141	0	0	12	2,09	246-248	49	119	83	36	26	0	5	1,15
175-176	66	330	135	195	0	0	13	2,04	248-251	49	258	132	126	30	0	5	1,35
176-177	53	246	107	139	0	0	14	2,22	251-253	72	101	84	17	161	0	5	0,71
177-178	123	317	175	142	3	0	14	2,08	253-255	46	81	81	0	72	0	2	0,10
178-179	108	342	200	143	0	0	14	2,01	255-257	22	47	47	0	14	0	2	0,66
179-180	26	149	52	97	0	0	13	2,38	257-259	10	27	27	0	5	0	2	0,61
180-181	73	365	175	190	0	0	13	2,00	259-261	5	25	25	0	1	0	2	0,67
181-182	29	228	87	142	0	0	9	1,96	261-263	13	23	23	0	0	0	2	0,43
182-183	121	286	109	177	0	0	17	2,27	263-265	9	30	30	0	0	0	2	0,53
183-184	82	378	143	235	0	0	12	1,95	265-267	13	21	16	5	1	0	2	0,54
184-185	159	486	248	239	0	0	18	2,20	267-268	5	31	31	0	0	0	2	0,50
185-186	53	265	140	125	0	0	13	2,09	268-270	12	23	23	0	2	0	2	0,64
186-187	60	220	96	125	0	0	13	2,14	270-272	5	25	25	0	0	0	1	0,00
187-188	102	265	133	133	0	0	17	2,31	274-275,9	4	6	6	0	0	0	2	0,56
188-189	54	295	120	175	0	0	11	2,04	275,9-277,9	2	4	4	0	0	0	2	0,69
189-190	68	215	91	123	0	0	13	2,06	277,9-278,9	1	3	3	0	0	0	1	0,00
190-191	16	89	39	50	0	0	7	1,75	278,9-280,9	5	10	10	0	0	0	2	0,67
191-193	53	142	67	75	0	0	8	1,47	280,9-281,9	7	35	35	0	1	0	1	0,00
193-195	26	130	90	40	0	0	6	1,40	281,9-282,8	9	32	32	0	1	0	2	0,53
195-197	54	270	175	95	1	0	6	1,17	282,8-283,8	4	23	23	0	0	0	2	0,69
197-199	56	110	18	92	0	0	6	1,28	283,8-285,6	11	19	19	0	0	0	2	0,30
199-200	15	71	28	43	0	0	6	1,59	285,6-287,8	11	23	23	0	0	0	2	0,59
200-201	9	33	7	25	0	0	4	1,37	287,8-288,5	2	7	7	0	0	0	2	0,69
201-202	6	17	3	14	0	0	6	1,79	288,5-291	7	14	14	0	1	0	2	0,60
202-203	5	28	6	22	0	0	4	1,33	290,9-292,8	10	49	49	0	1	0	2	0,33
203-204	10	27	3	24	0	0	4	1,28	292,8-294,6	20	52	52	0	0	0	2	0,33
204-205	9	53	18	35	0	0	5	1,43	294,6-296,8	7	36	36	0	0	0	2	0,68
205-206	11	29	8	21	0	0	5	1,41	300-301	0	0	0	0	0	2	0	0,00
206-207	5	27	5	21	0	0	3	1,06	301-303	0	0	0	0	0	6	0	0,00
207-208	5	19	8	11	0	0	4	1,33	303-305	0	0	0	0	0	6	0	0,00
208-209	2	12	0	12	0	0	2	0,69	305-308	0	0	0	0	0	13	0	0,00
209-210	7	15	4	11	0	0	5	1,48	308-311	0	0	0	0	0	9	0	0,00
210-211	8	40	15	25	0	0	5	1,49	311-314	0	0	0	0	0	8	0	0,00
211-212	18	102	6	97	0	0	3	0,65	317-320	0	0	0	0	0	9	0	0,00
212-213	12	30	15	15	0	0	5	1,56	320-323	0	0	0	0	0	10	0	0,00
213-214	6	37	6	31	0	0	4	1,33	323-327	0	0	0	0	0	6	0	0,00
214-215	12	34	14	20	0	0	4	1,27	327-330	0	0	0	0	0	12	0	0,00
215-216	7	52	15	37	0	0	4	1,28	330-332,5	0	0	0	0	0	29	0	0,00
216-217	7	41	29	12	0	0	4	1,28	332,5-334,5	0	0	0	0	0	8	0	0,00
217-218	8	70	26	43	0	0	3	0,97	334,5-342	0	0	0	0	0	13	0	0,00
218-219	14	58	25	33	0	0	5	1,47									

S2P	<i>Abra segmentum</i>	<i>Acanthocardia</i> sp.	<i>Acanthocardia tuberculata</i>	<i>Acanthocardia paucicostata</i>	<i>Anomia</i> sp.	<i>Bornia sebetia</i>	<i>Cerastoderma glaucum</i>	<i>Corbula gibba</i>	<i>Cuspidaria cuspidata</i>	<i>Laevicardium</i> sp.	<i>Lucinidae</i> sp.	<i>Myrtea spinifera</i>	<i>Mytilaster marioni</i>	<i>Mytilus</i> sp.	<i>Nucula nitidosa</i>	<i>Nuculana</i> sp.	<i>Ostrea</i> sp.	<i>Pericoma</i> sp.	<i>Saxicavella</i> sp.	<i>Solen</i> sp.	<i>Solenya togata</i>	<i>Tellina</i> sp.	<i>Timoclea ovata</i>	<i>Venus</i> sp.
0-1	0	0,00	2	20,00	0	0,00	0	0,00	0	0,00	0	0,00	1	10,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
1-2	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	20,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
2-3	0	0,00	0	0,00	0	0,00	0	0,00	1	25,00	0	0,00	0	0,00	0	0,00	0	0,00	1	25,00	0	0,00	0	0,00
3-4	0	0,00	0	0,00	0	0,00	0	0,00	2	14,29	0	0,00	0	0,00	1	7,14	4	28,57	0	0,00	0	0,00	1	7,14
4-5	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	11,11	0	0,00	0	0,00	0	0,00	1	11,11
5-6	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	22,22	0	0,00	0	0,00	0	0,00	0	0,00
6-7	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	11,11	1	11,11	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
7-8	3	9,09	1	3,03	0	0,00	0	0,00	2	6,06	0	0,00	0	0,00	0	0,00	3	9,09	0	0,00	0	0,00	0	0,00
8-9	0	0,00	0	0,00	0	0,00	0	0,00	1	5,88	0	0,00	0	0,00	0	0,00	3	17,65	0	0,00	0	0,00	0	0,00
9-10	0	0,00	0	0,00	0	0,00	0	0,00	2	13,33	0	0,00	0	0,00	3	20,00	0	0,00	0	0,00	0	0,00	0	0,00
10-11	1	3,70	0	0,00	0	0,00	0	0,00	2	7,41	0	0,00	5	18,52	0	0,00	0	0,00	0	0,00	0	0,00	1	3,70
11-12	1	4,00	0	0,00	0	0,00	0	0,00	1	4,00	0	0,00	5	20,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,00
12-13	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	9,52	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
14-16	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	7,89	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
16-18	0	0,00	0	0,00	0	0,00	0	0,00	5	21,74	0	0,00	4	17,39	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
18-20	1	4,00	0	0,00	0	0,00	0	0,00	2	8,00	0	0,00	4	16,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
20-22	1	1,89	0	0,00	0	0,00	1	1,89	0	0,00	4	7,55	0	0,00	6	11,32	0	0,00	0	0,00	0	0,00	0	0,00
22-23	0	0,00	0	0,00	0	0,00	0	0,00	3	13,64	0	0,00	6	27,27	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
23-25	1	3,33	0	0,00	0	0,00	0	0,00	1	3,33	1	3,33	0	0,00	7	23,33	0	0,00	0	0,00	0	0,00	0	0,00
25-27	1	2,38	1	2,38	0	0,00	0	0,00	1	2,38	3	7,14	0	0,00	7	16,67	0	0,00	0	0,00	0	0,00	0	0,00
27-29	1	3,23	0	0,00	0	0,00	0	0,00	4	12,90	0	0,00	6	19,35	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
29-31	0	0,00	0	0,00	0	0,00	1	1,30	0	0,00	4	5,19	0	0,00	9	11,69	0	0,00	0	0,00	0	0,00	2	6,45
31-33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	12,00	0	0,00	4	16,00	0	0,00	0	0,00	0	0,00	0	0,00
33-35	2	2,17	3	3,26	1	1,09	0	0,00	0	0,00	7	7,61	0	0,00	8	8,70	0	0,00	0	0,00	0	0,00	0	0,00
35-37	1	3,70	1	3,70	0	0,00	0	0,00	1	3,70	0	0,00	0	0,00	1	3,70	0	0,00	0	0,00	0	0,00	1	3,70
37-40	1	3,45	0	0,00	0	0,00	0	0,00	1	3,45	0	0,00	2	6,90	0	0,00	0	0,00	0	0,00	0	0,00	3	10,34
40-42	1	3,33	1	3,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	13,33	0	0,00	0	0,00	0	0,00	0	0,00
42-44	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	10,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
44-46	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	16,67	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
46-48	0	0,00	0	0,00	0	0,00	0	0,00	1	3,03	0	0,00	7	21,21	0	0,00	0	0,00	0	0,00	0	0,00	1	3,03
48-50	0	0,00	2	5,56	0	0,00	0	0,00	4	11,11	0	0,00	7	19,44	0	0,00	0	0,00	0	0,00	0	0,00	4	11,11
50-52	2	4,44	2	2,22	0	0,00	0	0,00	1	2,22	0	0,00	5	11,11	1	2,22	0	0,00	0	0,00	0	0,00	1	2,22
52-54	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	28,57	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
54-56	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	27,59	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
56-58	1	3,45	0	0,00	0	0,00	1	3,45	2	6,90	0	0,00	3	10,34	0	0,00	0	0,00	0	0,00	0	0,00	1	3,45
58-60	1	4,17	1	4,17	0	0,00	0	0,00	1	4,17	1	4,17	0	0,00	2	8,33	0	0,00	0	0,00	0	0,00	0	0,00
60-62	1	4,35	0	0,00	0	0,00	0	0,00	2	8,70	0	0,00	3	13,04	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
62-64	0	0,00	0	0,00	0	0,00	0	0,00	1	4,55	0	0,00	3	13,64	0	0,00	0	0,00	0	0,00	0	0,00	1	4,55
64-66	1	3,70	0	0,00	0	0,00	0	0,00	1	3,70	0	0,00	0	0,00	3	11,11	0	0,00	0	0,00	0	0,00	0	0,00
66-68	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	6,25	0	0,00	4	25,00	0	0,00	0	0,00	0	0,00	0	0,00
68-70	1	1,89	1	1,89	0	0,00	0	0,00	4	7,55	0	0,00	15	28,30	0	0,00	0	0,00	0	0,00	0	0,00	1	1,89
70-72	2	5,13	0	0,00	0	0,00	0	0,00	3	7,69	0	0,00	8	20,51	0	0,00	1	2,56	0	0,00	0	0,00	1	2,56
72-73	1	4,00	0	0,00	0	0,00	0	0,00	2	8,00	0	0,00	5	20,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,00
73-77	0	0,00	0	0,00	0	0,00	0	0,00	1	3,85	0	0,00	2	7,69	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
77-79	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
79-81	1	10,00	0	0,00	0	0,00	0	0,00	2	20,00	0	0,00	1	10,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
81-83	2	8,70	0	0,00	0	0,00	0	0,00	1	4,35	2	8,70	0	0,00	2	8,70	0	0,00	0	0,00	0	0,00	0	0,00
83-85	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	33,33	0	0,00	0	0,00	0	0,00	0	0,00
85-87	0	0,00	0	0,00	0	0,00	0	0,00	1	3,70	0	0,00	10	37,04	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
87-89	1	4,76	0	0,00	0	0,00	0	0,00	3	14,29	0	0,00	4	19,05	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
89-91	0	0,00	0	0,00	0	0,00	0	0,00	2	16,67	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
91-92	1	5,56	0	0,00	0	0,00	0	0,00	1	5,56	0	0,00	4	22,22	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
92-93	0	0,00	0	0,00	0	0,00	1	7,69	0	0,00	0	0,00	3	23,08	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
93-94	0	0,00	0	0,00	0	0,00	1	5,00	0	0,00	3	15,00	0	0,00	2	10,00	0	0,00	0	0,00	0	0,00	2	10,00
94-95	1	5,00	0	0,00	0	0,00	1	5,00	0	0,00	2	10,00	0	0,00	4	20,00	0	0,00	0	0,00	0	0,00	0	0,00
95-96	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	28,57	0	0,00	0	0,00	0	0,00	0	0,00
96-97	1	7,14	0	0,00	0	0,00	1	7,14	0	0,00	3	21,43	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00
97-98	0	0,00	0	0,00	0	0,00	1	6,67	0	0,00	2	13,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	6,67
98-99	1	3,33	0	0,00	0	0,00	0	0,00	4	13,33	0	0,00	7	23,33	0	0,00	0	0,00	0	0,00	0	0,00	1	3,33
99-100	0	0,00	0	0,00	0	0,00	0	0,00	6	10,34	0	0,00	14	24,14	0	0,00	0	0,00	0	0,00	1	1,72	0	0,00
100-101	1	1,00	0	0,00	0	0,00	2	2,00	1	1,00	12	12,00	0	0,00	21	21,00	0	0,00	1	1,00	1	1,00	1	1,00
101-102	0	0,00	0	0,00	0																			

S2P	<i>Aporhais pespelecani</i>	<i>Bytium reticulatum</i>	<i>Bolinus brandaris</i>	<i>Chrysallida</i> sp.	<i>Cina</i> sp.	<i>Epilium cf. cetrinus</i>	<i>Eulima</i> sp.	<i>Fusinus</i> sp.	<i>Hydrobia</i> sp.	Hydrobiidae Indet.	<i>Monophorus</i> sp.	<i>Nassarius lima</i>	<i>Nassarius reticulatus</i>	<i>Naica</i> sp.	<i>Obostomia</i> sp.	Pyramidellidae sp.	<i>Retusa leptoneilama</i>	<i>Rissoa</i> sp.	<i>Sorgenfreiella brachystoma</i>	<i>Seromphala dansonii</i>	<i>Theodoxus</i> sp.	<i>Turbonilla acuta</i>	<i>Turritella communis</i>		
0-1	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	10,00	
1-2	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	20	0	0,00	0	0,00	0	0,00	2	40,00	
2-3	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	50,00	
3-4	0	0,00	1	7,14	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	14,29	
4-5	0	0,00	1	11,11	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	33,33	
5-6	0	0,00	2	22,22	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	5	55,56	
6-7	0	0,00	3	33,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	22,22	
7-8	0	0,00	3	9,09	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	6,06	0	0,00	0	0,00	0	0,00	10	30,30	
8-9	0	0,00	3	17,65	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	7	41,18	
9-10	0	0,00	2	13,33	0	0,00	1	6,67	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	6	40,00	
10-11	0	0,00	2	7,41	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	3,70	0	0,00	0	0,00	5	18,52	
11-12	0	0,00	2	8,00	0	0,00	0	0,00	1	4,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	7	28,00	
12-13	0	0,00	1	4,76	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	6	28,57	
14-16	0	0,00	7	18,42	0	0,00	1	2,63	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	9	23,68	
16-18	0	0,00	3	13,04	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	13,04	
18-20	1	4,00	6	24,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,00	0	0,00	0	0,00	0	0,00	1	4,00	
20-22	1	1,89	12	22,64	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	3,77	2	3,77	1	1,89	0	0,00	0	13,21	
22-23	0	0,00	2	9,09	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	18,18	
23-25	0	0,00	4	13,33	0	0,00	1	3,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	8	26,67	
25-27	0	0,00	8	19,05	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	5	11,90	
27-29	0	0,00	4	12,90	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	5	16,13	
29-31	0	0,00	16	20,78	0	0,00	2	2,60	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	17	22,08	
31-33	0	0,00	7	28,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	12,00	
33-35	1	1,09	9	9,78	0	0,00	4	4,35	2	2,17	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	25	27,17	
35-37	0	0,00	3	11,11	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	11,11	
37-40	1	3,45	4	13,79	0	0,00	1	3,45	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	11	37,93	
40-42	0	0,00	7	23,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	3,33	1	3,33	0	0,00	0	0,00	5	16,67	
42-44	0	0,00	4	20,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	6	30,00	
44-46	0	0,00	0	0,00	0	0,00	1	16,67	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	16,67	
46-48	0	0,00	3	9,09	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	7	21,21	
48-50	3	8,33	4	11,11	0	0,00	1	2,78	0	0,00	0	0,00	0	0,00	0	0,00	1	2,78	1	2,78	0	0,00	0	13,89	
50-52	0	0,00	2	4,44	0	0,00	1	2,22	0	0,00	0	0,00	0	0,00	0	0,00	1	2,22	0	0,00	0	0,00	1	2,22	
52-54	0	0,00	2	6,67	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	14,29	
54-56	0	0,00	3	10,34	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	10	34,48	
56-58	1	3,45	2	6,90	0	0,00	0	0,00	1	3,45	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	8	27,59	
58-60	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	11	45,83	
60-62	0	0,00	2	8,70	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,35	0	0,00	0	0,00	0	0,00	7	30,43	
62-64	2	9,09	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,55	0	0,00	0	0,00	0	0,00	7	31,82	
64-66	0	0,00	3	11,11	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	11,11	0	0,00	0	0,00	0	0,00	13	48,15	
66-68	0	0,00	3	18,75	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	6,25	0	0,00	0	0,00	0	0,00	4	25,00	
68-70	0	0,00	1	1,89	0	0,00	0	0,00	1	1,89	0	0,00	0	0,00	2	3,77	0	0,00	0	0,00	0	0,00	10	18,87	
70-72	0	0,00	2	5,13	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	2,56	0	0,00	2	5,13	0	0,00	0	11	28,21
72-73	0	0,00	1	4,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	4,00	0	0,00	1	4,00	0	0,00	5	20,00	
73-77	0	0,00	5	19,23	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	9	34,62	
77-79	0	0,00	1	20,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	60,00	
79-81	0	0,00	1	10,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	20,00	
81-83	0	0,00	2	8,70	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	8,70	0	0,00	0	0,00	0	0,00	4	17,39	
83-85	0	0,00	1	8,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	25,00	
85-87	0	0,00	3	11,11	0	0,00	1	3,70	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	10	37,04	
87-89	0	0,00	1	4,76	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	33,33	
89-91	0	0,00	1	8,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	16,67	0	0,00	
91-92	0	0,00	3	16,67	0	0,00	1	5,56	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	22,22	
92-93	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	5	38,46	
93-94	0	0,00	1	5,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	4	20,00	
94-95	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	6	30,00	
95-96	0	0,00	0	0,00	0	0,00	1	14,29	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	42,86	
96-97	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	21,43	
97-98	0	0,00	2	13,33	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	3	20,00	
98-99	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	1	3,33	0	0,00	0	0,00	0	0,00	5	16,67	
99-100	0	0,00	4	6,90	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	2	3,45	0	0,00	1	1,72	0	0,00	0	16	27,59
100-101	0	0,00	2	2,00	0	0,00	1	1,00	0	0,00	0	0,00	0	0,00	3	3,00	0	0,00	0	0,00	0	0,00	2	2,00	
101-102	0	0,00	1																						

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