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Marine invertebrate diversity in Aristotle's zoology

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Abstract

The aim of this paper is to bring to light Aristotle's knowledge of marine invertebrate diversity as this has been recorded in his works 25 centuries ago, and set it against current knowledge. The analysis of information derived from a thorough study of his zoological writings revealed 866 records related to animals currently classified as marine invertebrates. These records corresponded to 94 different animal names or descriptive phrases which were assigned to 85 current marine invertebrate taxa, mostly (58%) at the species level. A detailed, annotated catalogue of all marine *anhaima* (*a* = without, *haima* = blood) appearing in Aristotle's zoological works was constructed and several older confusions were clarified. Some of Aristotle's "genera" were found to be directly correlated to current invertebrate higher taxa. Almost the total of the marine *anhaima* were benthic invertebrates. The great philosopher had a remarkable, well-balanced scientific knowledge of the diversity of the various invertebrate groups, very similar to that acquired by modern marine biologists in the same area of study. The results of the present study should be considered as a necessary starting point for a further analysis of Aristotle's priceless contribution to the marine environment and its organisms.

Contents

Introduction

Aristotle was the one who created the idea of a general scientific investigation of living things. Moreover he created the science of biology and the philosophy of biology, while his animal studies profoundly influenced the origins of modern biology (Lennox, 2001a). His biological writings, constituting over 25% of the surviving Aristotelian corpus, have happily been the subject of an increasing amount of attention lately, since both philosophers and biologists believe that they might help in the understanding of other important issues of his philosophy (Gotthelf and Lennox, 1987) and they may introduce a new generation of biologists to the richness of Aristotle's biological observations and the questions that motivated them (Tipton, 2006).

On the basis of his zoological works, he has been considered as "the founder of zoology" (Pellegrin, 1982) and "the father of zoological classification" (Mayr and Ashlock, 1991). He was the first who gathered information on species of animals, examined their similarities and differences, and attempted to classify them into groups although, as pointed out by various authors (Peck, 1965; Pellegrin, 1982; Mayr and Ashlock, 1991), his aim was not to present an orderly, fully consistent classification of the animal kingdom. This did not prevent Darwin from considering him as "one of the greatest … observers that ever lived", and also as the ancient equivalent of the great systematist Linnaeus by saying, in his famous 1882 letter to W. Ogle, that "Linnaeus and Cuvier have been my two gods … but they are mere school-boys to old Aristotle" (Gotthelf, 1999). His contribution to the classification of animals has been a subject of analysis and evaluation by philosophers such as Lloyd (1961) and Pellegrin (1982). Biologists, on the other hand, have greatly appreciated his contribution to various biological disciplines (Moore, 1987; Kiortsis, 1989; Mayr and Ashlock, 1991; Sofianidou, 2004).

Around 500 animals are examined in his zoological

works. During his stay for about 2 years in Lesbos Island, Aristotle devoted a considerable part of his biological research to marine animals (Thompson, 1913; Lee 1948; Solmsen 1978). Information on the morphology, anatomy, reproduction, development, habitat, diet and behavior of marine invertebrates, fishes, cetaceans and pinnipeds is given in his zoological works and their first classification scheme is presented. Thus, he is fairly considered to be the first marine biologist (Castro and Huber, 1997). Nevertheless, these data have not been paid special attention by modern researchers, with the exception of Aristotle's *malakia,* the current cephalopods (see Scharfenberg, 2001). A few attempts to examine Aristotle's marine animals are included in more general works by non specialists (Thompson, 1947; Louis, 1973) and can serve as a basis for a thorough analysis. However, many descriptions of marine animals have not been conclusively identified, and there is scope for new and interesting discoveries in his work (Balme, 1970).

We think that Aristotle's contribution to the knowledge of marine life needs to be studied in detail and evaluated under the scope of modern marine biology. As Voultsiadou and Tatolas (2005) pointed out, useful zoological information can be derived from the study of classical texts; this, among other benefits, may help historical zoogeographers as a supplement to paleontology, archaeology, and art in the reconstruction of faunas of older epochs. The aim of the present paper is to bring to light Aristotle's knowledge of marine invertebrate diversity as this has been presented in his zoological works 25 centuries ago and set it against current knowledge. This was achieved mainly by presenting a detailed, annotated catalogue of all animals appearing in Aristotle's zoological works, recognized nowadays as marine invertebrates.

Materials and methods

The first step was to go carefully through Aristotle's zoological works searching for records of what we call today "marine invertebrates". The works studied, and their scope as defined by Aristotle himself, are the following:

I. *History of animals (HA)* aiming *"*to determine first of all the differences that exist [among animals] and the actual facts in the case of all of them" because "having done this, we must attempt to discover the causes" (*HA 491a12*). Here, a description of the observed diversity in animal structure, function and behavior is given.
II. *Parts of animals (PA),* the task here being "to consider what are the causes through which each animal is as I described it" [in *Histories of Animals] (PA 646a10).* Structure is herein examined in relation to function, and a long discussion is given on the scientific method and the principles of zoology.
III. *Movement of animals (MA),* examining "the common cause of animal movement of whatever kind and how the soul moves the body and what is the origin of movement in an animal" *(MA 698a4*). The general mechanism of movement in animals is examined mostly theoretically.
IV. *Progression of animals (IA)* discussing "the parts which are useful to animals for their movement… why each part is of the nature which it is and why they possess them … the differences in the various parts of one and the same animals and in those of animals of different species compared with one another" *(IA 700b11).*
V. *Generation of animals (GA)* aiming "to describe those [parts] which subserve animals for the purpose of generation" and to deal with its "motive cause and to explain what it is" *GA (715a12).* This is a study on reproduction, embryology and development of animal characteristics.

The publications of LOEB Classical Library, Harvard University (Peck, 1942, 1961, 1970; Forster, 1961; Balme, 1991) were used for the study of the classical texts and their English translations for the quotations reported in the paper. Additionally, other editions of classical texts (Balme 2002) and translations of Aristotle's zoological works (Lennox, 2001b) were consulted. The results of the detailed examination of all the above texts were crosschecked using the searching machine offered by the Online Thesaurus Linguae Graecae database (TLG E, Edition 2000). TLG and the Liddel and Scott Dictionary of Greek language were used for the estimation of Aristotle's contribution to the nomenclature of modern zoology.

All animal names were carefully examined in order to be correlated to current marine invertebrate taxa. The identification of animals encountered in the texts and their correlation to recent marine invertebrate taxa was not an easy task, since Aristotle's descriptions were very detailed and accurate in some cases, but fragmentary in others. Classical Greek names often proved very helpful, since they embodied information on their morphology or life history; this information was made available thanks to the continuity of Greek language. On the contrary, Latin scientific names inspired by Aristotle's animal names were sometimes confusing,

such as *holothourion, balanos* and *nautilos*, which were given to animals other than the original, possibly due to misunderstanding of Aristotle's descriptions. Moreover, marine invertebrates are a very diverse group of animals including species not very well known, as for example other groups like mammals or birds. Their knowledge requires expertise in a number of totally different taxa belonging to almost all the known animal phyla. So, the personal experience of the authors on the Mediterranean, and more specifically Aegean, diversity of marine invertebrates such as decapod crustaceans (Koukouras *et al.,* 1992), anthozoans (Vafidis *et al*., 1994; 1997), ascidians (Koukouras *et al*., 1995), gastropods (Koutsoubas *et al*., 1997), sponges (Voultsiadou-Koukoura *et al*., 1987; Voultsiadou, 2005), was critical, and their database of all literature on Aegean invertebrate fauna proved very useful. The construction of a complete catalogue was made possible thanks to the conclusive identification of several descriptions for the first time and the clarification of various misidentifications and confusing points found in previous works, such as in the cases of sponges, anthozoans, crinoids, polychaetes, and echiurans. A series of zoological books (Ruppert *et al*., 2004), general zoological publications on Mediterranean invertebrates (Riedl 1963; Fischer *et al*., 1987; Weinberg 1993; Hayward and Ryland 1996), as well as more specialized ones (Ingle 1996; Delamote and Vardala, 1994), were really helpful in the evaluation of the collected information. For details on the identification procedure see Voultsiadou and Tatolas (2005).

Results

Overall 866 records corresponding to animals currently classified as marine invertebrates were encountered in the studied texts. These records were unequally distributed in four of the studied works by Aristotle as follows: the majority -582 records- was found in *History of animals*, 195 in *Parts of animals*, 74 in the *Generation of animals* and 15 in *Progression of animals*. No specific animal records occurred in *Movement of animals*. All these records corresponded to 94 different animal names or descriptive phrases. Notice that Aristotle often needed to report animals that were not given a name up to his age. In such cases, he gave a short description of the animal's characteristic features or life history, *e.g.* γένος ἀστακοῖς μικρὸν ὥσπερ καρκίνοι (a genus similar to lobsters, but small like crabs) or πιννοφύλαξ σπόγγων (pinna-guard of sponges), which is what we report here as "descriptive phrases".

A detailed identification and assignment of all marine *anhaima* (*a* = without, *haima* = blood) to recent marine invertebrate taxa, as these are classified in the groups defined by Aristotle himself, is given below. As is well known, Aristotle divided animals into *anhaima* (ἀναιμα) meaning bloodless and *enhaima* (ἔναιμα) meaning blooded, these two groups corresponding to what we call today invertebrates and vertebrates. Further on, he recognized four groups of bloodless animals: apart from *entoma* (insects) that do not fall into the scope of our study, these were *ostrakoderma* (having a hard shell surrounding the body), *malakia* (having a soft body), and *malakostraka* (having a soft shell) (Fig. 1).

The necessary documentation for the identifications were quoted from the classical texts and comments on etymology and other animal characteristics, helpful for identification, are also cited. The extent of documentation depends on how well known or common an animal is. Therefore, we did not consider it necessary to quote and comment on the identity of animals such as the common edible sea urchin, which is frequently recorded and thoroughly described in the texts. On the other hand, the identification of animals not very common or not easily recognizable was supported by detailed evidence. Animal names were transliterated in Latin for the convenience of the reader. Transliteration was made according to Brown (1979) and Lennox (2001b). All the records of each animal name in the examined texts are given. Superscript numbers in each name or descriptive phrase correspond to the taxa names listed in Table 2. Each number corresponds to one of Aristotle's animal names.

1. Malakia (μαλάκια) (having a soft body)

Malakia[1] (μαλάκια): a general name for Cephalopoda Mollusca. A definition *(HA 523b2)* and a full description *(HA 523b22)* of the group are given: "the fleshy part is exterior and the hard part (if any) interior". Their body "consists of the feet, the head which is continuous with the feet, the sac which contains the internal parts and a skin around it" (*HA 523b35*). It "includes cuttlefish and the squids, which have hard parts inside and the octopuses, which has no hard part at all" *(HA 524b22)*.

HA 487b16, 489b34, 490a23, b12, 494b27, 523b2, b21, b26, 524a21, b8, b14, 525a18, a29, 531a1, b18, 534b14, b15, 535b13, 537a1, b4, b25, 539a11, 541b1, 544a1, 549a19, b29, 567b8, b10, 589b20, 590b20, b33, 591b5, b10, 606a10, 607b6, 621b28, 622a32, b1, PA 644b10, 654a10, a13, a14, 678a27, b7, b25, 679a4, b6, b32, 681b11, b17, 684b6, b17, b19, b34, 685a4, a9, a10, a12, a27, IA 706b1, GA 715b1, 717a4, 720b5, 721a32, 727b2, 732b6, 733a22, a29, 733b10, 741b33, 755b32, 757b31, 758a15, a20, 761b5.

Polypous[2] (πολύπους = having many legs): a general name for the Octopoda Cephalopoda, used also for the common octopus which is the largest, edible kind. Three categories are recognized: the first includes the largest edible octopus and some smaller not edible ones, the second includes the *heledōnē* with "one row of suckers", and the third those "living inside a shell".

HA 490a1, 523b29, 524a3, a20, a21, a28, b28, 525a3, a6, a13, a21, 521b2, b29, 532a2, 534a25, b25, b27, 541b1, b4, 544a6, 549b31, 550a3, b1, b4, b15, 557a23, 590b14, b18, 591a1, 607b7, 621b17, b30, 622a3, a14, a15, a23, a24, a25, a29, a32, b5, PA 642b19, 644b25, 652b25, 654a22, 661a15, 678b28, 679a7, a12, a22, a37, 685a5, a14, a22, a24, b2, b12, b20, b24, GA 720b33, 758a8.

- *Polypodōn megiston genos*[3] (πολυπόδων μέγιστον γένος): the common octopus *Octopus vulgaris* Cuvier, 1797. It is discriminated from other smaller octopuses for its greater size, its habit to approach the water level and because it is edible *(HA 525a14)*.
  HA 525a14.

- *Heledōnē*[4] (ἐλεδώνη) or *bolitaina*[5] (βολίταινα) or *ozolis*[6] (ὄζολις): the musky octopus *Eledone moschata* (Lamarck, 1798). It is discriminated from other octopuses by its longer arms each "bearing one single row of suckers" *(HA 525a19)*. The name *ozolis* (ὀζω = to stink) indicates its characteristic unpleasant smell. Scharfenberg's (2001) opinion that *heledōnē* and *volitaena* or *ozolis* are two different species does not seem to be valid. If such was the case Aristotle would not state that *heledōnē* is the only μαλάκιον with a single row of suckers.
  Heledōnē HA 525a17, volitaina HA 525a19, a26, 621b17, ozolis HA 525a19.

- *Nautilos*[7] (ναυτίλος = sailor) or *pontilos*[8] (ποντίλος) or *ōon polypodos*[9] (ᾠὸν πολύποδος = the egg of the polypous): the paper nautilus *Argonauta argo* Linnaeus, 1758. Although the name has been given to the recent genus *Nautilus,* Aristotle's description indicates the paper nautilus: its shell is described as "a single, deep scallop valve not joining with another" *(HA 525a21)*. The way it moves up and down in the water is described *(HA 622b1-19)*.
  Nautilos HA 525a21, 622b5, pontilos HA 525a21, ōon polypodos HA 525a21.

- *Polypous en ostrakō oion cochlias*[10] (πολύπους ἐν ὀστράκῳ οἷον κοχλίας): the chambered nautilus, a species of the genus *Nautilu*s spp. It is briefly reported as "living inside a shell like a snail, sometimes protruding its tentacles" *(HA 525a26)*. It is obvious that Aristotle had never seen a chambered nautilus; otherwise he would have been impressed by its appearance. It seems that he had rather been informed about its existence by somebody else, possibly someone accompanying Alexander the Great in his expeditions in the vicinity of the Indian Ocean, where the distribution of *Nautilus* species extends. Thompson (1947) suggested that Aristotle had in mind the species *Janthina janthina* (Linnaeus, 1758) and he must have mistaken for tentacles, the masses of eggs released by this floating species. Although *J. janthina* is common in the Aegean, it is very small in size and it could not be mistaken for an octopus.
  HA 525a26.

Sēpia[11] (σηπία) and *sēpidion*[12] (σηπίδιον = the young individual): the cuttlefish *Sepia officinalis* Linnaeus, 1758, described as "having the sepion (σήπιον), a strong and broad internal hard part" *(HA 524b25),* and "the largest ink sac among all malakia" *(HA 524b16)*. The use of ink discharge when the animal is in danger is mentioned *(HA 621b29)*.

Sepia HA 489a33, b35, 490b13, 523b5, b29, 524a25, a27, b16, b17, b22, 525a6, 527a23, 529a4, 534b5, 541b1, b12, 544a2, 549b9, b2, b3, b6, b13, b14, b19, 567b8, b10, 590b33, 607b7, 608b17, 621b29, b33, 622a11, a32, PA 654a20, 661a14, 678b28, 679a5, a9, a15, a20, 685a14, a23, b1, b20, GA 757b32, 758a6, a21, sepidion (young sepia) *HA 550a10, a16, a19, a22, a26, a29, a31, b16.*

Teuthos[13] (τεῦθος): the sagittal squid *Todarodes sagittatus* (Lamarck, 1798). This common Mediterranean species is recognized by several characteristics given in the text *(HA 524a25-33)* in comparison to τευθίς. So, it is "bigger in size, has its sharp part (fin) broader, and its encircling fin goes all around the sac", possibly meaning that the two tentacles are long, almost surrounding the body when extended.

HA 490b13, 523b30, 524a25, a30, 550b14, 610b6.

Teuthis[14] (τευθίς): the long finned squid *Loligo vulgaris* Lamarck, 1798. It is discriminated from *teuthos* by all the above mentioned characteristics and the fact that the "fin" observed in the former "is here absent" *(HA 524a33)*.

HA 489b35, 490b13, 523b29, 524a25, a30, a32, a33, b22, b26, 541b1, b12, 550b12, b16, b17, 590b33, 607b7, 621b30, PA 654a21, 678b30, 679a7, a14, a22, 685a14, a24, b2, b19, GA 758a6.

2. Malakostraka (μαλακόστρακα) *(having a soft shell)*

Malakostraka[15] (μαλακόστρακα): a general name for Malacostraca (mostly Decapoda). It is one of the three γένη (genera) of *anhaima* including animals having "their soft fleshy part inside and their hard part outside" *(HA 523b5)*. The latter "can not be broken by a clean crack, it has to be crushed. It includes lobsters and crabs" *(HA 490b11)*. They include four "major genera" (μέγιστα γένη)*, astakoi* (ἀστακοί), *karaboi* (κάραβοι), *karides* (καρίδες) and *karkinoi* (καρκίνοι), each including several species *(PA 683b26)*.

HA 490b11, 523b5, 525a30, 527b34, 528a3, 529b21, 531b18, 534b14, b16, 535b14, 537a1, b5, b26, 539a10, 541b19, 549a14, 550a32, 589b20, 590b10, b32, 599b28, 601a17, 607b3, b5, PA 654a1, 661a13, 678a27, b10, b24, 679a31, b7, b31, 681b12, b20, 683b25, 684b17, b18, b31, 685b26, GA 715b1, 717a3, 720b5, b9, b26, 727b2, 732b6, 733a20, a29, b10, 743b10, 755b33, 757b32, 761b5, 748b16.

2.1. *Astakoi* (ἀστακοί)

Astakos[16] (ἀστακός): the common lobster *Homarus gammarus* (Linnaeus, 1758). A detailed description and comparison of *astakos* with *karabos* is given *(HA 526a11-b33),* fully discriminating the two species. It is reported that "astakos has longer and more slender antennas, longer and more acute rostrum, smooth and not spiny carapace, as well as massive and unequal pincers".

HA 490b12, 525a32, b11, 526a11, 530a28, 541b20, b25, 549b14, b16, 601a10, PA 683b27, 684a32.

2.2. *Karaboi* (κάραβοι)

Arktos[17] (ἄρκτος): the small European locust lobster *Scyllarus arctus* (Linnaeus, 1758), compared with *karabos* for its spawning season *(HA 549b23)*. The name ἄρκτος (= a bear) indicates the shape of the second antennae which on dorsal view resembles the footprint of a bear.

HA 549b23.

Karabos[18] (κάραβος) or *karabodē*[19] (καραβώδη): the spiny lobster *Palinurus elephas* (Fabricius, 1787). A detailed description is given *(HA 526a11-b33)* and a comparison with the common lobster (see *astakos*).

Karabos HA 487b16, 489a33, 490a2, b11, 525b15, b21, b27, b33, 526a15, a31, a32, b2, b4, b5, b13, b20, b21, b23, b25, b26, 527a1, a9, a11, a14, a16, a28, 529b22, 534b26, 537a1, 541b19, 549a14, b9, b13, b17, b23, b27, b28, 590b12, b14, b16, b16, b20, 601a10, a16, b17, PA 661a13, 679a31, a36, 683b27, 684a1, a16, a26, IA 713b29, b30, GA 757b33, karabodē HA 607b4, PA 683b31, GA 758a12, a16.

2.3. *Karides* (καρίδες)

Karis[20] (καρίς): a general name for Natantia Decapoda and Stomatopoda including shrimps, prawns and mantis shrimps *(HA 525b1)*. The following kinds are distinguished.

HA 525a33, a34, b1, b17, b27, b32, 526b27, 527a9, a20, 541b20, b25, 547a6, 549b12, 591b14, PA 683b27, 684a14.

- *Kyfai karides*[21] (κυφαί καρίδες): hunchback prawns of the family Penaeidae. The description given *(HA 525b17-30)* corresponds to the typical prawns of this family such as the edible, common in the Aegean species *Melicertus kerathurus* (Forskal, 1775). Besides the "hunched back", the "five pairs of slender thoracic legs towards the head in opposition to the abdominal legs which have broad ends and the acute, spine bearing tail (telson)" are pointed out.
  HA 525b1, b17, b28, 549b12.

- *Karidon mikron genos*[22] (καρίδων μικρὸν γένος): the small kind *(HA 525b2),* a species of Natantia Decapoda. It could be any group of small sized shrimps, since no description is given.
  HA 525b2.

- *Krangōn*[23] (κραγγών): the mantis shrimp *Squilla mantis* (Linnaeus, 1758). The body structure of Stomatopoda is described in detail *(HA 525b22-30);* four plus three pairs of legs on the anterior part and a broad spiny tail (telson and two biramous uropods).
  HA 525b2, b21, b29.

- *Karidion*[24] (καρίδιον): the shrimp *Pontonia pinnophylax* (Otto, 1821). The information given *(HA 547b17)* on the symbiotic relationship of this shrimp with the fan mussel (*Pinna)* indicates this species. Besides this specific meaning, the term *karidion* was used for a small *karis*.
  HA 547b17.

- *Pinnofylax spongōn*[25] (πιννοφύλαξ σπόγγων = pinnaguard of sponges): shrimps of the family Alpheidae. They are "similar to those guarding the fan mussel, but growing in sponge canals" *(HA 548a28)*. Common species of this family living inside Aegean sponges and similar to those of the genus *Pontonia* are *Synalpheus gambarelloides* (Nardo, 1847), *Alpheus dentipes* Guerin, 1832 and *Typton spongicola* Costa, 1844.
  HA 548a28.

2.4. *Karkinoi* (καρκίνοι)

Karkinos[26] (καρκίνος): a general name for Brachyura Decapoda. They are distinguished from lobsters and prawns by having a "rounded body" and by the "absence of a tail" *(HA 525b31)*. They are considered as a "variable group including numerous species" *(HA 525b5)*.
HA 525b5, b10, b16, b31, 526a10, a20, a28, 527a10, b4, 541b25, b28, 547b26, 549b27, 590b25, 601a16, a20, PA 654a2, 679a32, 683b28, 684a2, a4, a8, a11, a15, a23, a26, 686a1, 691b16, b20, IA 712b13, b20, 713b11, 714b17.

- *Karkinoi mikroi*[27] (καρκίνοι μικροί): the blue-leg swim crab *Polybius (Liocarcinus) depurator* (Linnaeus, 1758). They are described as "little tiny crabs having their hindmost walking legs flattened like fins or oars, to make them useful for swimming, usually found among the catch with small fish" *(PA 684a11)*.
PA 684a11.

- *Hippos*[28] (ἵππος = horse): the ghost crab *Ocypode cursor (= O. hippeus)* (Linnaeus, 1758) which is said to live in Phoenicia running fast on the beach *(HA 525b7)*. It is a common species on the eastern coasts of the Levantine basin.
HA 525b7.

- *Maia*[29] (μαῖα = midwife): the spiny spider crab *Maja squinado* (Herbst, 1788). The information given for this crab is that it is "the biggest among all crabs" *(HA 525b4),* "it lives in the deep and moves little about" *(PA 684a8),* "has a very hard shell" *(HA 601a19)* and "owe its safety to it, having for this reason thin feet, considerably less effective for locomotion" *(PA 684a10)*. Moreover, it is said to "have its eyes in the middle and close together", in contrast to most other crabs "in which eyes are placed a long way apart from each other" *(HA 527b7)*. *M. squinado* has all the above characteristics.
HA 525b4, b14, 601a19, PA 684a8, a10.

- *Pagouros*[30] (πάγουρος): possibly the edible crab *Cancer pagurus* Linnaeus, 1778, according to older identifications (see Thompson 1947). No description exists but it is said to be "one of the biggest crabs in size" *(HA 525b5)*.
HA 525b5.

- *Herakleotikos karkinos*[31] (ἡρακλεωτικὸς καρκίνος): the shamefaced crab *Calappa granulata* (Linnaeus, 1758). It is described as "being in size next to maia" *(HA 525b5),* having also "a hard shell" for protection *(HA 601a19),* its eyes "in the middle and close together" *(HA 527b12),* and "short legs not effective for locomotion" *(PA 684a10)*.
HA 525b5, 527b12, 684a8, a10.

- *Pinnotērēs*[32] (πιννοτήρης) or *pinnophylax*[33] *(*πιννοφύλαξ*):* the crab (or shrimp, see *karidion*) "guarding the fan mussel" *(HA 547b16)*. It may "exist inside" other bivalves such as "the scallops and the oysters" *(HA 547b28)*. Their "white color" indicates the species *Pinnotheres pisum* (Linnaeus, 1758).
HA 547b16, b28.

2.5. Unclassified *malakostraka*

Karkinion[34] (καρκίνιον): the hermit crab. A general name for Anomura Decapoda of the family Paguridae. It is considered to dualize (*epamfoterizein,* ἐπαμφοτερίζειν*)*, since it looks like *karabos* but lives inside a shell like *ostrakoderma* do *(HA 529b20-530a27),* "carries it about with, feeds inside it, and as it grows it moves on again into a larger one" *(HA 548a14-21)*. Besides this specific meaning, the term *karkinion* was used for a small *karkinos (HA 547b17)*.
HA 529B20, 530A17, 547B17, 548A14.

Kyllaros[35] (κύλλαρος): Paguridae sp. A species of Anomura living inside *Nēreitēs*, a small gastropod. It is characterized by having "the right pincer smaller than the left one" *(HA 530a12)*. It is difficult to identify a certain species, since there exist some small sized common species of hermit crabs with obviously smaller right pincer.
HA 530a12.

Mikron genos ōsper karkinoi, to eidos homoion tois astakois[36] (μικρὸν γένος ὥσπερ οἱ καρκίνοι, τὸ εἶδος ὅμοιον τοῖς ἀστακοίς): the squat crabs of the family Galatheidae belonging to Anomura. They are a kind "small like crabs but in appearance similar to lobsters" *(HA 525b10)*.
HA 525b10.

*3. Ostrakoderma (*ὀστρακόδερμα*) (having a hard shell surrounding the body)*

Ostrakoderma[37] (ὀστρακόδερμα) or *Ostrea*[38] (ὄστρεα): a general name for animals protected inside a hard exoskeleton, identified as the current Bivalvia, Gastropoda, Asteroidea, Echinoidea and Ascidiacea. They are described *(HA 528a1-20)* as "having their fleshy part inside and their hard part outside; the latter would brake

by cracking but does not crush; there is no hard part inside". They are divided into *dithyra* (δίθυρα*)*, those "enclosed in two shells", *monothyra* (μονόθυρα*),* "those enclosed in one, with the fleshy part exposed, e.g. the limpet" and *strombōdē* (στρομβώδη), those "having their flesh invisible, except for the head "enclosed in a spiral shell as indicated by their name. The *tēthya* (τήθυα)*,* modern ascidians are "completely enveloped by their shell and no portion of their flesh is exposed to the outside", while *echinoi* (εχίνοι)*,* the sea urchins, "have no fleshy part inside the shell".

Ostrakoderma HA 466b21, 489b14, 490b10, 491b27, 523b9, 527b35, 528b9, 529b21, b23, 531a32, 531b19, 532a7, 534b15, 535a6, a23, 537b25, b31, 538a18, 539a9, 544a16, 546b17, b23, b27, 547b26, 548a22, 549a12, 588b16, 590a19, 599a10, 601a18, 603a12, a24, 606a11, a12, 607b2, b5, 621b9, PA 661a17, a21, 678a30, b11, b22, 679b2, b15, b30, b31, b35, 680a4, a19, a30, 681a32, b1, b12, b31, 683b4, b18, 684b15, b16, b34, 685a5, b26, IA 706a13, b2, 714b8, b14, GA 715b17, 720b6, 731b8, 743b10, 758a28, 761a13, a21, a28, a30, 761b4, b23, 762a29, 763a8, a20, a26, Ostrea HA 487a26, b9, b14, 490b10, 523b12, 525a20, a24, 528a1, 531a15, b5, 547b20, b33, 548a12, 568a8, 590a29, a31, a32, 591a13, PA 644b10, 645a3, 680b7, b10, b22, b23, 681b10, GA 761a31, 763a33, b1, b13.

3.1. *Echinoi* (Ἐχῖνοι) (sea urchins)

Echinos[39] (ἐχῖνος = having spines): the sea urchin (Echinoidea, Echinodermata). A complete description of the sea urchin is given *(HA 530a32-531a7* and *PA 680a5-681a9)* and six different species are reported.

HA 528a7, 530a32, b10, b19, b24, 531a4, a6, a15, b8, 535b24, PA 679b28, b34, 680a4, a5, b3, b8, b9, b10, b33, 681a2.

- *To esthiomenon genos*[40] (τὸ ἐσθιόμενον γένος): the edible stony sea urchin *Paracentrotus lividus* Lamarck, 1816. It is described as "the edible kind, in which the so-called eggs are large and edible, in large and small ones alike: the eggs are present in them even while still quite small" *(HA 530b1)*. The habit of the species to "always have something fixed on its spines" is pointed out *(HA 530b17)*.
  HA 530b1, b17.

- *Spatangēs*[41] (σπατάγγης): Echinoidea sp. It is reported *(HA 530b5)* as a "deep sea and rare species".
  HA 530b5.

- *Bryssos*[42] (βρύσσος): Echinoidea sp. It is reported *(HA 530b5)* as a "deep sea and rare species".
  HA 530b5.

- *Genos mikron*[43] (γένος μικρόν): the species *Cidaris cidaris* (Linnaeus, 1758). It is "a kind small in size, bearing large, hard spines … living in the area of Toronē, several fathoms deep, and some use it as a remedy for strangury" *(HA 530b7)*. *C. cidaris,* which thrives in sandy bottoms deeper than 30 m, fits with the above description.
  HA 530b7, GA 783a20.

- *Leukos echinos*[44] (λευκὸς ἐχῖνος): the heart urchin *Brissus unicolor* (Leske, 1778). They are described as *(HA 530b10)* "white sea urchins -shells, spines and eggs are all white- longer than the ordinary ones, the spines neither large nor strong, but rather limp". The species *B. unicolor*, living in sandy bottoms, like in the area of Toroni mentioned in the text, is exactly as described above having a test diameter of up to 13 cm.
  HA 530b10.

- *Echinomētra*[45] (ἐχινομήτρα = mother of sea urchins): the violet sea urchin *Sphaerechinus granularis* (Lamarck, 1816). It is "the largest of all in size" *(HA 530b6)*. This common Aegean species is very similar to the common urchins but reaches 15 cm in test diameter. The species *Echinus melo* that has been suggested by some authors is yellowish in color and lives in deeper waters, characteristics which have been indicated by Aristotle for the discrimination of other sea urchin species.
  HA 530b6.

3.2. Asteres (ἀστέρες) (Sea stars)

Astēr[46] (ἀστήρ = star): the sea star (Asteroidea, Echinodermata). Most possibly it is one of the very common Aegean species, the normally star-shaped *Astropecten aurantiacus* (Linnaeus, 1758) or *Echinaster sepositus* (Retzius, 1783), since Aristotle mentions that "it resembles in shape the stars seen in drawings" *(HA 548a7)*. The predatory activity of the sea star against mollusks is indicated *(HA 548a7, PA 681b9)*.

HA 548a7, PA 681b9.

3.3. *Tēthya* (Τήθυα)

Tēthyon[47] *(*τήθυον*):* the sea squirt (Ascidiacea, Chordata). It is described *(HA 531a9-31)* as "the most extraordinary of all these animals, being the only ones whose body is completely hidden inside the shell, the texture of which is between that of skin and shell, and

consequently cut like hard leather. The animal clings to the rock by its shelly part and has two passages some distance apart". Two kinds are distinguished according to their colour.

HA 528a20, 531a8, a18, a29, 535a24, 547b21, 588b20, PA 680a5, 681a10, a25, GA 763b14.

- *Tēthyon ōchron*[48] (τήθυον ὠχρόν): the white sea squirt *Phallusia mammilata* Muller, 1776. This common species has an *ochron* (ωχρόν = pale, white-yellow), leathery tunic.
  HA 531a30.

- *Tēthyon erythron*[49] (τήθυον ἐρυθρόν): the red sea squirt *Halocynthia papillosa* (Linnaeus, 1767). This common, sciaphilic species is easily recognized by its characteristic *erythron* (ερυθρόν = red) color.
  HA 531a30.

3.4. *Monothyra* (μονόθυρα) (enclosed in one shell)

Lepas[50] (λεπὰς): the limpet *Patella caerulea* Linnaeus, 1758. It is described as a "univalve, having its fleshy part exposed" *(HA 528a14)* "releasing its hold in order to search for food" (*HA 528b1*) and "living near the surface of the water with Nēreitēs" *(HA 547b22)*.

HA 528a14, b2, 529a31, 530a19, b22, 547b22, 548a27, 590a32, PA 679b25, 680a23.

Lepas agria[51] (λεπὰς ἀγρία) or *thalattion ous*[52] (θαλάττιον οὖς): the abalone or ear shell, *Haliotis tuberculata* Linnaeus, 1758. It is mentioned as "the wild limpet, which is called the ear of the sea and its shell is perforated" *(HA 529b15)*.

Lepas agria HA 529b15, Thalattion ous HA 529b15.

Monothyra[53] (μονόθυρα): a general name for Haliotidae, Patellidae and allied families of Gastropoda, i.e. those "enclosed in one shell, having their fleshy part exposed" (*HA 528a12*).

HA 528a12, a13, b3, b14, 529a25, 603a27, PA 679b17, b23, b27, 680a22, 683b11.

3.5. Strombōdē (στρομβώδη) (spiral-shelled)

Haimorrhois[54] (αἱμορροΐς): a gastropod species (Gastropoda, Mollusca). Its name, coming from *haima* (αἷμα = blood) and *rheo* (ῥέω = flow, spring) implies that it produces a purple dye. However, it is discriminated from *porphyra*, with which it is reported in a general description of spiral-shelled animals *(HA 530a19)*. Possibly it was a separate name for one of the three species assigned to the name *porphyra* (see bellow).

HA 530a19, a24.

Kēryx[55] (κῆρυξ): the triton *Charonia tritonis* (Linnaeus, 1758) and related species. It is usually reported with *porphyra* (πορφύρα) as a common species, possibly due to the fact that both were widely used, not only as food. It has "a rough shell" *(HA 528a24),* is "long-lived" *(HA 547b8)* and "the smallest individuals may host hermit cabs" *(HA 548a19)*. It was used in antiquity as food, for the construction of trumpets and as jars, after removing its internal axis.

HA 524b12, 527a24, a28, 528a10, a24, a30, 529a7, 530a5, a14, 544a15, 546b25, b26, 547b2, b8, 548a19, 549a17, PA 679b14, b20, 683b13, IA 706a16, GA 761b31, 763b9.

Kochlos[56] (κόχλος): a group of marine gastropods, other than the well known species such as the πορφύρα, the κήρυξ, etc. (…the purpura, the trumpet-shell, the sea snail and the other spiral-shelled…) *(HA 528α10)*.

HA 528a1, a10, 529a2, a17, a24, b3, 530a27, PA 678b24, 679b4, b14.

Nēreitēs[57] (νηρείτης): the gastropod *Monodonta turbinata* (Born, 1780) and related species. It is described as "having a smooth, large and rounded shell, resembling to keryx" *(HA 530a12)*. It is said to "live near the surface with the limpets, moving about when the sea is calm" *(HA 530a12)* and that "they can host small karkinia" *(HA 530a7)*. *M. turbinata* is the largest of all the Trochidae species (of the genera *Monodonta* and *Gibbula*) living in the mediolittoral zone and it has been used for food since the neolothic period.

HA 530α7, a12, a18, a27, 535a19, 547b23, 548a17, PA 679b20.

Porphyra[58] (πορφύρα = purpura): the purple dye murex *Bolinus brandaris* (Linnaeus, 1758), the banded murex *Hexaplex trunculus* (Linnaeus, 1758) and the red-mouth purpura *Stramonita (= Thais) haemastoma* (Linnaeus, 1767). All these species were used in antiquity for food but mainly as sources for the extraction of the purple dye. Aristotle gives a lot of information on these valuable animals: he says that "there are several species differing in external morphology and in the color of the dye" *(HA 547a4);* he gives a detailed description of the way the dye is extracted and prepared for use *(HA 547a 15);* he mentions the egg-masses they lay, considering them as kind of refuse *(HA 546b19),* etc.

HA 528a10, 529a6, 530a5, a25, 532a9, 535a7, 544a15, 546b18, b23, b32, b33, 547a4, a21, b1, b2, b6, b8, b9, b24, b32, 568a9, 590b2, 599a11, a17, 603a13, a15, 621b11, 661a21, PA

679b14, b19, IA 706a15, GA 761b31, 763b9, 794a21, 795b11, 797a5.

Strombos[59] (στρόμβος): the common cerith *Cerithium vulgatum* Bruguiere, 1792 and related species. It is reported in comparison with *Nēreitēs* concerning its size: the hermit crabs living in *strombos* are more elongated than those living in *nēreitēs (HA 530a6)*. It was "used as bait for porphyra, the latter having the strength to bore through its shell" *(PA 661a21)*. Common ceriths, which are very common in the mediolittoral and upper sublittoral of the Aegean, have been widely consumed as food since the Neolithic period.

HA 492a17, 530a6, α26, 548a18, 621a23, PA 685a18.

Strombōdē[60] (στρομβώδη) or *stromboeidē*[61] (στρομβοειδή): a general name for spiral-shelled marine animals (Gastropoda Mollusca). "They move and creep about" *(HA 528a33),* and "they have an operculum which serves the purpose of the second valve in the bivalves" *(HA 530a22)*. There are several kinds "the porphyres, the kērykes and the remaining spiral-shelled" *(HA 528a11)*.

Strombōdē HA 528a11, a33, b5, b8, b13, 529a15, 530a22, b21, 531a1, 547b4, PA 679b14, b16, b17, b26, 680a22, 683b12, 684b16, b20, b34, 685a10, a11, IA 706a13, b1, GA 763a22. stromboeidē HA 528b17.

3.6. *Dithyra* (δίθυρα) (enclosed in two shells, bivalves)

Balanos[62] (βάλανος): the bivalve *Pholas dactylus* Linnaeus, 1758. It is only reported as a stationary animal "living in rock cavities or crevices along with the sea squirts" *(HA 547b22)*. The name βάλανος, attributed originally to the oak acorn, indicates this species, which resembles in various aspects this fruit; it has an externally sculptured shell bearing concentric and radiating ribs which are roughest in front in order to assist drilling into the substrate; the siphons protruding from the shell, like the oak fruit from its cup, are long, united, covered by a horny sheath.

HA 535a25, 547b22.

Chēmē[63] (χήμη): the common Noah's arc shell *Arca noae* Linnaeus, 1758 and the related species. The name ch*ē*m*ē* (χήμη from χάσμα = gap, chasm) indicates the space existing between the umbones which are far apart in dorsal view. They are reported once by Aristotle as "taking their rise in sandy places together with conchai, sōlēnes and ktenes" *(HA 547a13)*. He does not give any further information of these animals, but Xenocrates in his work Περὶ τῆς ἀπὸ τῶν ἐνύδρων τροφῆς (xxxi) [on food from aquatic animals] writes that the coarser of them are "elongated, having a roughness when opened, just like the cup of the acorn", obviously indicating the straight hinge with the numerous small teeth and that "they are radially ribbed, with extra roughness, on their shell", just like *Arca*.

HA 547a13.

Conchē[64] (κόγχη): a general name for smooth-shelled bivalves, such as tellins (Tellinidae), trough shells (Mactridae) or wedge shells (Donacidae). They are listed with razor shells and mussels as examples of *ostrakoderma* "having a smooth shell" *(HA 528a21-27)* and they are reported to "take their rise in sandy places" *(HA 547a13)*.

HA 528a22, 530a11, 547b13, b20, 548a5, 614a28, 622b2.

- *Galax*[65] (γάλαξ): a species belonging to one of the families Donacidae, Tellinidae and Mactridae. It is not possible to discriminate which of the three was known under this certain name, since it is just reported as "a kind of conchai, called by some galakes". The name itself indicates a milky white shell but such morphs exist in all the above groups which present a great variation in shell colour *(HA 528a23)*.

  HA 528a23.

Conchos[66] (κόγχος): a general name for rough-shelled bivalves, i.e. cockles (Cardiidae), venus clams (Veneridae), and allied species.

HA 528a24, a25, a26.

- *Conchos rhabdōtos trachyostrakos*[67] (κόγχος ῥαβδωτὸς τραχυόστρακος): bivalve species with "rough, radially ribbed shells", such as the cockles of the family Cardiidae *(HA 528a25)*.

  HA 528a25.

- *Conchos arrhabdōtos trachyostrakos*[68] (κόγχος ἀρράβδωτος τραχυόστρακος): bivalve species with "rough, not radially ribed shells", such as the venus clams of the family Veneridae *(HA 528a26)*.

  HA 528a26.

Conchylion[69] (κογχύλιον): a general name for bivalves (Bivalvia, Mollusca). They are usually mentioned as food for other marine organisms such as the purple shellfish *(HA 547b7),* the marine turtles *(HA 590b4),* and the octopuses *(HA 591a1)*.

HA 519b21, 547b7, 590b4, 591a1, 622a7, b17, PA 661a22.

Dithyra[70] (δίθυρα): a general name for bivalves (Bivalvia, Mollusca). They are *ostrakoderma* "enclosed in two shells" *(HA 528α12)* which may be "smooth" or "rough, ribbed, thick or thin, moving or stationary" *(HA 528a22-34)*.

HA 528a11, a12, a14, a17, b4, b15, 529a25, a31, 530a22, 603a27, PA 679b16, b17, b24, b25, b27, 680a23, a25, 683b11, b14.

Kteis[71] (κτείς = comb): the scallops of the family Pectenidae. It is emphasized that "it has a radially ribbed shell" *(HA 528a25),* "it can actually fly, because it often jumps out of the device in which it was caught" *(HA 528a30),* and that "they take their rise in sandy places" *(HA 547b16)*.

HA 528a15, a25, a31, 531b8, 535b26, 547b14, b24, b32, 599a14, a18, 603a21, a22, 607b2, PA 679b25, 680b23, 683b15, 621b10, GA 763b12.

Limnostreon[72] (λιμνόστρεον): the edible oyster *Ostrea edulis* Linnaeus, 1758. It is described as "rough-shelled and thick-lipped" *(HA 528a23),* "being born in muddy places" *(HA 547b12),* and hosting little shrimps or crabs *(HA 547b29)*.

HA 528a23, a30, 547b11, b29, GA 763a30, b12.

Mys[73] (μῦς): the Mediterranean mussel *Mytilus galloprovincialis* Lamarck, 1819. It is a "thin lipped bivalve, unlike the oysters" *(HA 528a29),* and "they grow, like onions, by side-shoots, the smaller ones growing on the sides of the original ones" *(GA 761b31)*. Here the formation of mussel beds is well described.

HA 528a15, a22, a29, 547b11, PA 679b26, 683b25, GA 761b30, 763b12.

Pinna[74] (πίννα): the noble pen shell *Pinna nobilis* Linnaeus, 1758. It is a "rough-shelled bivalve" *(HA 528a24),* "they grow up erect held by their byssos, in sandy and muddy places; they have inside a pinna-guard, some of them a small shrimp and other a small crab; and if they are deprived of it they quickly perish" *(HA 547b15)*.

HA 528a24, a26, a33, 547b15, b28, 548a5, 588b15, GA 763b8.

Sōlēn[75] (σωλήν = tube): the razor shells of the family Solenidae. They "have a smooth shell" *(HA 528a18)* and in contrast to scallops, which are closed at the one end and opened at the other, "they are closed at both sides" *(PA 683b17),* possibly indicating the adductor muscle which is located by the mantle cavity, near the end of the each valve. Moreover, they "take their rise in sandy places" *(HA 547b13)*.

HA 528a18, a22, 535a14, 547b13, 548a5, 588b15, PA 683b17.

4. Other marine anhaima (ἄναιμα) not classified in the above major groups

Acalēphē[76] (ἀκαλήφη) or *cnidē*[77] (κνίδη, κνίζω = to irritate): the sea anemones (Actiniaria, Anthozoa, Cnidaria). A detailed description is given *(HA 531a31)* and two species are distinguished.

Akalēphē HA 487a25, b12, 531a31, b10, 588b20, 590a27, a31, cnide HA 548a23, a24, 681a36.

- *Akalēphē edōdimos*[78] (ἀκαλήφη ἐδώδιμος): the species *Anemonia viridis* (Forskal, 1775) described as "small, edible, living on smooth, broad and flat surfaces, able to detach and move around".
  HA 531b10, 548a22.

- *Akalēphē sklērē*[79] (ἀκαλήφη σκληρή): the species *Actinia equina* (Linnaeus, 1758) described as "bigger and harder, living in rocks crevices and never detached from the rock".
  HA 531b10, 548a22.

Aidoion andros[80] (αἰδοῖον ἀνδρός) (looking like *aidoion andros*)*:* the echiuran *Bonnelia viridis* Rolando, 1821 (Echiura). It is mentioned as a "rare species not easily classified, although observed by experienced fishermen; … it is similar in shape and size to the male penis having two fins instead of the testicles" *(HA 532b23)*. The female of *B. viridis* reaches 15 cm in length and its proboscis has a forked tip, the two branches of which must have been called *fins* by Aristotle, just like the tentacles of the cuttlefish.

HA 532b23.

Aspis[81] (ἀσπίς) (looking like *aspis*)*:* the feather-star *Antendon mediterranea* (Lamarck, 1816) (Crinoidea, Echinodermata). It is described as a "rare species not easily classified, although observed by experienced fishermen; … it looks like aspis (ασπίς meaning here a poisonous snake species well known at that age), it is red in colour and bears densely arranged fins" *(HA 532b22)*. The common Mediterranean crinoid *A. mediterranea* must have been associated with a snake due to the waving movement of its arms that bear many branches.

HA 532b22.

Dokias[82] (δοκίας) (looking like *dokias*): the black sea-cucumber *Holothuria forskali* Delle Chiaje, 1823

(Holothurioidea, Echinodermata). It is mentioned along with *aidoion* and *aspis* as a "rare species not easily classified, although observed by experienced fishermen; … it is like a relatively long and stout bar, black, round and has the same thickness throughout its length" *(HA 532b21)*. The description fits perfectly to this common Mediterranean species of sea-cucumbers, which may reach 40 cm in length.

HA 532b21.

Holothourion[83] (ὁλοθούριον): the soft coral species *Veretillum cynomorium* (Pallas, 1766) (Anthozoa, Cnidaria). According to Aristotle it is "an unattached, though not moving animal, not having any power of sensation, living like a plant unattached to the soil" *(HA 487b14)*. Moreover, "it differs from sponges only slightly in being unattached" *(HA 681a17)*. This description fits well with the above common species which resembles sponges actually in having a spongy internal structure and lives in sandy bottoms loosely held in the sediment. Its elongated shape and erect habit lies behind the name *holothourion,* ὁλοθούριον made of ὁλος (= whole, entire) and θούριος (= male, acute, fierce).

HA 487b15, PA 681a17.

Oistros o tōn thynnōn[84] (οἶστρος, ὁ τῶν θύννων): the parasitic copepods (Copepoda, Crustacea) of the genus *Caligus* commonly found on tuna fish. According to the description it is "found around the fins of tuna, it is like a scorpion and about the size of a spider*" (HA 557a27)*. The species of the genus *Caligus* conform to this description.

HA 557a27, 602a28.

Phtheir thalattia[85] (φθεὶρ θαλαττία): the isopods of the family Cymothoidae (Isopoda, Crustacea). Their description as "lices (φθείρες) found on fishes, resembling woodlice, except that they have a flat tail, and they are mostly found on the red mullet" *(HA 557a21)* indicates these common fish parasites. The most common species in the Mediterranean are *Nerocila bivittata* (Risso, 1816) and *Anilocra physodes* (Linnaeus, 1758).

HA 537a5, 557a22, a25, 602b29.

Pneumōn[86] (πνεύμων): the dead man's finger *Alcyonium palmatum* Pallas, 1766 (Anthozoa, Cnidaria). It is only mentioned once *(PA 681a18)* along with *holothourion* as "differing only slightly from sponges in being unattached. They have no power of sensation but they live just as if they were plants unattached to the soil". As mentioned for *holothourion* it has a spongy internal structure as well, justifying the name πνεύμων (= lung) and lives loosely held in sandy bottoms.

HA 548a11, PA 681a17.

Psyllos thalattios[87] (ψύλλος θαλάττιος): the amphipods (Amphipoda, Crustacea). They are mentioned as attacking in great numbers the fish caught by the fishermen when they are left in the water for a while before brought on the surface, or even crowding together around the bait, provided that it consist of fish, forming a ball around it *(HA 537a8)*. The above information and the name ψύλλος (= flea), borrowed from the known insects, indicates the marine amphipods, which besides an external superficial similarity, share the ability of jumping (at least the littoral species of the group).

HA 537a6.

Scolopendra thalattia[88] (σκολόπενδρα θαλαττία): the fire-worm *Hermodice carunculata* (Pallas, 1766) (Polychaeta, Annelida). It is mentioned that "there exist marine scolopendras similar to the terrestrial ones but slightly smaller in size, occurring in rocky places" which "compared to the land millipedes, they are redder and have more numerous and more delicate feet" *(HA 505b14)*. They are said to "bite, not with the mouth, but apparently with the whole body, like the sea anemone, and to turn its inside out when it swallows the hook, in order to expel it" *(HA 621a6)*. This warm water polychaete, very common in the Eastern Mediterranean, but missing from the western basin, may reach 30 cm in length. It has numerous parapodia, bearing red gills at their base. It can easily extent and retract its pharynx and when touching the skin it causes a burning irritation.

HA 505b14, 621a6.

Spongos[89] (σπόγγος): the sponges of the order Dictyoceratida (Porifera) including the commercial bath species. They are described as "living attached on the substrate, being black when alive, before cleaned and washed, providing home for animals like worms and crustaceans, being able to grow up again in case it gets broken off" *(HA 548b1-549a13)* as well as being the most primitive animals "resembling very much the plants" *(HA 588b21)*, "having however, a sort of sensation" *(HA 548b10)* and "receiving food through the big passages on its upper part" *(HA 548a30)*. Five different kinds are distinguished (*HA 548b1-549a13*).

*HA 487b9, 548a23, a28, a32, 549a7, a10, a10, a12, 588b20, 616a30, 630a7, PA 681a11, a15, spongeis (*σπογγείς = the sponge fishermen) *HA 620b34.*

- *Aplysias*[90] (ἀπλυσίας): the black Ircinia *Sarcotragus muscarum* Schmidt, 1864, called "wild sponge" by the sponge fishermen. The description given *(HA 549a4)* fits perfectly to this species, since it can not be cleaned and used as a bath sponge, though it looks very much like the common bath sponges while it is black and in cross section it has large canals, and dense skeleton. Moreover, "compared to the bath sponges it is stickier and more difficult to be torn, looking like a lung".
  HA 549a4.

- *Manos*[91] (μανός): the honey comb *Hippospongia communis* (Lamarck, 1813). It is only mentioned by its name *(*μανός = loose*) (HA 548b1)* indicating the loose structure of this species which bears numerous and large canals, and for "reaching the largest size of all kinds" *(HA 548b19),* which is true for this species sometimes passing 30 cm in diameter.
  HA 548b1, b19.

- *Pycnos*[92] (πυκνός): the Greek bathing sponge *Spongia officinalis* Linnaeus, 1759. The name (πυκνός = dense, close-textured) and the comment that "they become the softest in the area around Lycia" indicates the best quality bath sponge of the species *S. officinalis.*
  HA 548b1, b9, b20, b25.

- *Achilleios*[93] (Ἀχίλλειος): the elephant ear *Spongia agaricina* Pallas, 1766. It is mentioned as "the finest, most closely textured and strongest and the rarest species of all, used for lining helmets and greaves for protection, deadening the noise of blows on them" *(HA 548b1)*. This thin, cup-shaped, strong and delicate sponge fits well to the description.
  HA 548b1, b20.

- *Tragos*[94] (τράγος): the leather sponge *Spongia zimocca* Schmidt, 1862. It is mentioned as "close-textured sponges which are specially hard and rough, called τράγοι (= goats)".
  HA 548b5.

Discussion

Aristotle's major genera and higher taxa

All marine *anhaima* encountered in Aristotle's zoological works are correlated with current marine invertebrate taxa. As a result, a generalized correlation of Aristotle's *major genera* of marine *anhaima* (Fig. 1) with current higher taxa was obtained (Table 1).

Obviously, there was not a direct correlation, since the main taxonomic character he used for their delimitation was the arrangement of the soft and hard parts in the animal body. However, he distinguished current cephalopods (his *Malakia*) and decapods (his *Malakostraka*) as separate groups (including stomatopods in the latter). *Malakostraka* was not homogenous, including some

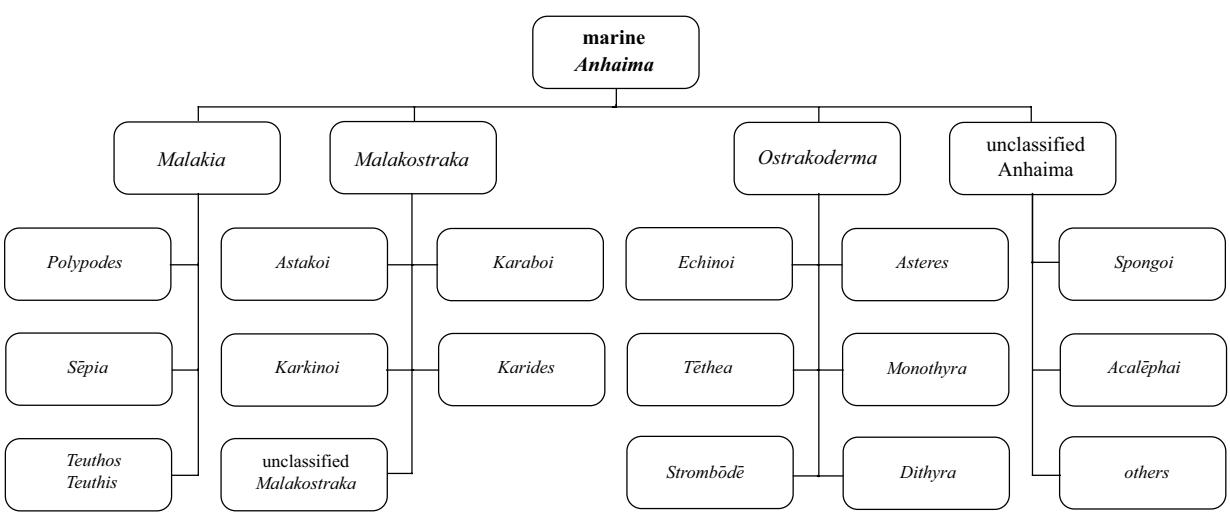

Fig. 1. Aristotle's classification of marine bloodless animals.

major genera itself *(PA 683b26),* such as *astakoi*, *karaboi*, *karides* and *karkinoi* corresponding to the current Macrura Reptantia (the first two), Natantia and Brachyura respectively. Echinoderms were not recognized as a group, since two of their classes (Echinoidea and Asteroidea) were put in *Ostrakoderma* and other two (Crinoidea and Holothourioidea) remained unclassified. Several marine bloodless animals remained out of the three major genera; some of these unclassified *anhaima,* i.e. the sessile sponges, anthozoans and ascidians were distinguished for their resemblance to plants and ranked at the early stages of "nature's transition from plants to animals" *(PA 681a10-b9)*. Aristotle's principle of downward classification, to which Linnaeus largely adhered, dominated in taxonomy up to the eighteenth century (Mayr and Ashlock, 1991).

Classical animal names and their assignment to current taxa

The 94 different animal names or descriptive phrases encountered were assigned to 85 current marine invertebrate taxa at different category levels (Table 2, Figure 2). The number of taxa is lower in comparison to the number of animal names mostly because some animals appeared in the texts with more than one name, e.g. *heledōnē* and *nautilos*. The majority of the animals (58%) were assigned to species level taxa and the remaining to supraspecific taxa. In *malakia*, a group including mostly incessant commercial species, species level taxa were almost exclusively identified.

Table 1. Correlation of Aristotle's groups with current higher taxa, based on the identification of all marine *anhaima* encountered in his zoological works.

Aristotle's major marine *Anhaima* groups	**Current marine invertebrate higher taxa**
Ostrakoderma	Mollusca (Bivalvia and Gastropoda), Echinodermata (Echinoidea and Asteroidea) Ascidiacea
Malakia	Mollusca (Cephalopoda)
Malakostraka	Malacostraca (Decapoda and Stomatopoda)
other marine *Anhaima*	Porifera
	Cnidaria
	Echiura
	Polychaeta
	Copepoda
	Malacostraca (Amphipoda and Isopoda) Echinodermata (Crinoidea and Holothurioidea)

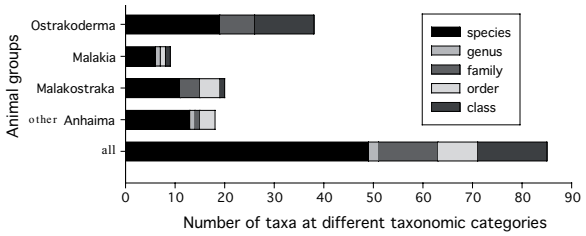

Fig. 2. Numbers and taxonomic level of marine invertebrate taxa recognized in Aristotle's zoological works.

The fact that Aristotle himself did not undertake the task to name all animals he examined has been considered as a difficulty for the construction of a full list of all animals he recorded by later researchers (Louis, 1971). However, although he did not purposely introduce new names or terms where they did not exist, modern marine biology owes to Aristotle a lot of names that appear for the first time in his writings (Table 2). Sixty-six out of the 94 names or descriptive phrases (70%) attributed to marine invertebrates by Aristotle were recorded for the first time in his zoological works (4th century B.C.). The remaining had been recorded in non-biological texts by earlier authors, some of which lived in the 5th century, such as the comedians Philyllius, Epicharmus, Aristophanes (*astakos, balanos, pinna, spatangēs, sōlēn, teuthis*) and the father of medical science Hippocrates (*haimorrhois, pagouros*). A few others have first appeared in the texts of the 6th century, e.g. in Aeschylus tragedies (*konchos, mys*), or even earlier, in the 8th century, in the first written documents of Greek literature, the Homeric epics (*polypous, spongos*). A series of names were used, as mentioned earlier, in the formation of Latin scientific names, successfully or not. Some examples are Malakostraka, *Aplysina, Balanus, Brissus, Eledone,* Cnidaria, *Crangon, Nautilus,* Holothurioidea, Ostrea, *Pinnotheres, Scyllarus,* and Teuthoidea.

Aristotle's scientific knowledge of marine invertebrate diversity

It is clear that, with few pelagic exceptions, Aristotle's marine *anhaima* were benthic invertebrates. This seems quite reasonable since benthic organisms represent 98% versus 2% of the pelagic ones in the marine ecosystem (Gaston and Spicer, 1998).

An estimation of the highly recorded animal names in Aristotle's works showed that they, unsurprisingly, included those of the three major genera (*ostrakoderma, malakia, malakostraka*) and some of the most common

Table 2. Classification of recent invertebrate taxa identified in Aristotle's zoological works. Asterisks indicate that an animal or animal name had not previously appeared in written texts. Numbers in parentheses correspond to the numbered comments given in the text.

Recent taxa		Classical names	Transl ~~Raspaxilla~~ iterated classical names
Porifera	**Demospongiae**		
	Dictyoceratida (89)	σπόγγος	spongos
	Hippospongia communis (91)	σπόγγος μανός*	spongos manos*
	Sarcotragus muscarum (90)	ἁπλυσίας*	aplysias*
	Spongia agaricina (93)	Ἀχίλλειος*	Achilleios*
	Spongia officinalis (92)	σπόγγος πυκνός*	spongos pycnos*
	Spongia zimocca (94)	τράγος*	tragos*
Cnidaria	**Anthozoa**		
	Actinia equina (79)	ἀκαλήφη σκληρή*	acalēphē sklērē*
	Actiniaria (76,77)	ἀκαλήφη *, κνίδη*	acalēphē*, cnidē*
	Alcyonium palmatum (86)	πνεύμων*	pneumōn*
	Anemonia viridis (78)	ἀκαλήφη ἐδώδιμος *	acalēphē edōdimos*
	Veretillum cynomorium (83)	ὁλοθούριον *	holothourion*
Annelida	**Polychaeta**		
	Hermodice carunculata (88)	σκολοπένδρα θαλαττία*	scolopendra thalattia*
Echiura	*Bonnelia viridis* (80)	αἰδοῖον ἀνδρός *	aidoion andros*
Mollusca	**Gastropoda**		
	Bolinus brandaris (58)	πορφύρα	porphyra
	Cerithium vulgatum (59)	σρόμβος*	strombos*
	Charonia tritonis (55)	κῆρυξ *	kēryx*
	Gastropoda (60,61)	στρομβώδη*, στρομβοειδή*, κόχλος	strombōdē*, stromboeidē*, kochlos
	Haliotis tuberculata (51, 52)	λεπὰς ἀγρία *, θαλάττιον οὖς	lepas agria*, thalattion ous
	Hexaplex trunculus (58)	πορφύρα	porphyra
	Monodonta turbinata (57)	νηρείτης*	nēreitēs*
	Patella caerulea (50)	λεπάς	lepas
	Stramonita haemastoma (58)	πορφύρα	porphyra
	Gastropoda un. sp. (54)	αἱμορροΐς*	haimorrhois
	Gastropoda un. spp. (56)	κόχλος	kochlos
	Gastropoda (univalves) (53)	μονόθυρα*	monothyra*
	Bivalvia		
	Arca noae (63)	χήμη	chēmē
	Bivalvia (69,70)	δίθυρα*, κογχύλιον	dithyra*, conchylion
	Cardiidae (67)	κόγχος ῥαβδωτὸς τραχυόστρακος*	conchos rhabdōtos trachyostrakos
	Donacidae (64)	κόγχη	conchē
	Mactridae (64)	κόγχη	conchē
	Mytilus galloprovincialis (73)	μῦς	mys
	Ostrea edulis (72)	λιμνόστρεον*	limnostreon*
	Pectinidae (71)	κτείς	kteis
	Pholas dactylus (62)	βάλανος	balanos
	Pinna nobilis (74)	πίννα	pinna
	Solenidae (75)	σωλήν	sōlēn
	Tellinidae (64)	κόγχη	conchē
	Veneridae (68)	κόγχος ἀρράβδωτος τραχυόστρακος*	conchos arrhabdōtos trachyostrakos*
	Bivalvia un. spp. (66)	κόγχος	conchos
	Bivalvia un. spp. (65)	γάλαξ*	galax*
	Cephalopoda		
	Argonauta argo (7,8,9)	ναυτίλος*, ποντίλος*, ᾠόν πολύποδος*	mautilos*, pontilos*, ōon polypodos*
	Cephalopoda (1)	μαλάκια*	malakia*
	Eledone moschata (4,5,6)	ἐλεδώνη *, βολίταινα*, ὄζολις*	eledōnē *, bolitaina*, ozolis*
	Loligo vulgaris (14)	τευθίς	teuthis
	Nautilus sp. (10)	πολύπους ἐν ὀστράκῳ οἷον κοχλίας*	polypous en ostrakō oion cochlias*
	Octopoda (2)	πολύπους	polypous
	Octopus vulgaris (3)	πολυπόδων μέγιστον γένος*	polypodōn megiston genos*
	Sepia officinalis (11,12)	σηπία, σηπίδιον	sēpia, sēpidion
	Todarodes sagtitatus (13)	τεῦθος*	teuthos*

Arthropoda	**Crustacea**		
	Alpheidae (25)	πιννοφύλαξ σπόγγων*	pinnopfylax spongōn*
	Amphipoda (87)	ψύλλος θαλάττιος*	psyllos thalattios*
	Anomura (34)	καρκίνιον*	karkinion*
	Brachyura (26)	καρκίνος	karkinos
	Calappa granulata (31)	καρκίνος Ηρακλεωτικός*	karkinos Herakleotikos*
	Caligus sp. (84)	οἶστρος, ὁ τῶν θύννων*	oistros o tōn thynnōn*
	Cancer pagurus (30)	πάγουρος	pagouros
	Cymothoidae, Isopoda (85)	φθείρ θαλαττία*	phtheir thalattia*
	Galatheidae (36)	ὅμοιον ἀστακοίς μικρὸν ὥσπερ καρκίνοι*	omoion astakois, micron ōsper karkinoi*
	Homarus gammarus (16)	ἀστακός	astakos
	Maja squinado (29)	μαῖα*	maia*
	Malacostraca (15)	μαλακόστρακα*	malakostraka*
	Natantia (20)	καρίς (in part)	karis (in part)
	Natantia un. sp. (22)	καρίδων μικρὸν γένος*	karidōn micron genos*
	Ocypode cursor (28)	ἵππος*	hippos*
	Paguridae (35)	κύλλαρος*	kyllaros*
	Palinurus elephas (18,19)	κάραβος, καραβώδη	karabos, karabōdē
	Penaeidae un.sp. (21)	καρίδες κυφαί*	karides kyfai*
	Pinnotheres pisum (32,33)	πιννοτήρης*, πιννοφύλαξ*	ponnotērēs*, pinnophylax*
	Polybius depurator (27)	καρκίνος μικρός*	karkinos mikros*
	Pontonia pinnophylax (24)	καρίδιον*	karidion*
	Scyllarus arctus (17)	ἄρκτος*	arktos*
	Squilla mantis (23)	κραγγών*	krangōn*
Echinodermata	**Crinoidea**		
	Antendon mediterranea (81)	ἀσπίς*	aspis*
	Asteroidea		
	Asteroidea (46)	ἀστήρ*	astēr*
	Echinoidea		
	Brissus unicolor (44)	ἐχῖνος λευκός*	echinos leucos*
	Cidaris cidaris (43)	ἐχίνων γένος μικρόν*	echinōn genos mikron*
	Echinoidea (39)	ἐχῖνος	echinos
	Echinoidea un.sp. (42)	βρύσσος*	bryssos*
	Echinoidea un.sp. (41)	σπατάγγης*	spatangēs*
	Paracentrotus lividus (40)	ἐχίνων τὸ ἐσθιόμενον γένος*	echinōn to esthiomenon genos*
	Shaerechinus granularis (45)	ἐχινομήτρα*	echinomētra*
	Holothurioidea		
	Holothuria forskali (82)	δοκίας*	dokias*
Chordata	**Ascidiacea**		
	Ascidiacea (47)	τήθυον	tēthyon
	Halocynthia papillosa (49)	τήθυον ἐρυθρόν*	tēthyon erythron*
	Phallusia mammilata (48)	τήθυον ὠχρόν*	tēthyon ōchron*
Names not corresponding to current taxa			
	Bivalvia, Gastropoda, Echinoidea, Asteroidea, Ascidiacea (37,38)	ὀστρακόδερμα, ὄστρεα	ostrakoderma, ostrea

or economically interesting marine animals, e.g., octopus, sepia, lobster, crab, sea urchin. The names with more than 20 occurrences (Fig. 3) constitute over 50% of total animal name records. Additionally, the number of records per animal group (times a group is mentioned) in the studied texts was compared with the number of current Aegean commercial species of the same benthic groups (as given by Chintiroglou *et al*., 2005b) (Fig. 4). Obviously, the pattern for all benthic groups was similar in both cases, indicating that the great philosopher focused his scientific interest on organisms exploited by humans in various ways (see also Fig. 4).

As previous studies have shown, the zoological information derived from the study of classical texts may help historical biogeographers in the reconstruction of the faunas of older epochs (Voultsiadou and Tatolas, 2005). Historical data on biodiversity are much appreciated by modern scientists, although they sometimes require that we sacrifice some of the precision and analytical elegance

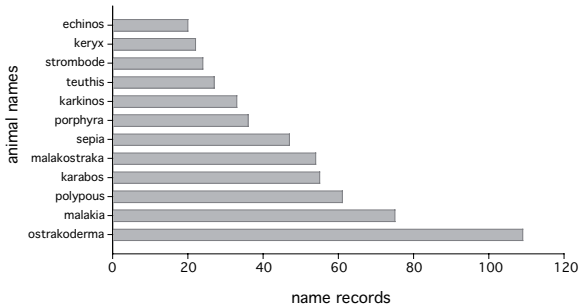

Fig. 3. Highly recorded (more than 20 occurrences) animal names in Aristotle's zoological works.

(Jackson *et al*., 2001). In an attempt to examine the general biodiversity pattern in the Aegean as illustrated in Aristotle's works, the only source of information for the status of marine fauna 25 centuries ago, and to evaluate his scientific knowledge of benthic diversity, a comparison of benthic taxa diversity given in his works with the relative current data for the Aegean Sea (as given by Chintiroglou *et al*., 2005a) was made (Fig. 4). The comparison showed that Aristotle had a remarkable, well-balanced scientific knowledge of the diversity of the various invertebrate groups, very similar to the one acquired by modern marine biologists in the same area of study. Lennox (2001b) questioned the taxonomic purpose of the Aristotle's grouping of animals since "as one can see they differ widely in extension". However, on the basis of the above comparison, the difference in the extension of Aristotle's groups should be attributed to the uneven distribution of species inside higher groups. The differences existing between the number of taxa recorded by Aristotle and the number of current taxa inside groups (Fig. 4) only means that Aristotle had given to molluscs or cnidarians more attention than justified by the number of species of these groups. On the contrary, he did not pay much attention to polychaetes possibly due to their not so obvious variety of form.

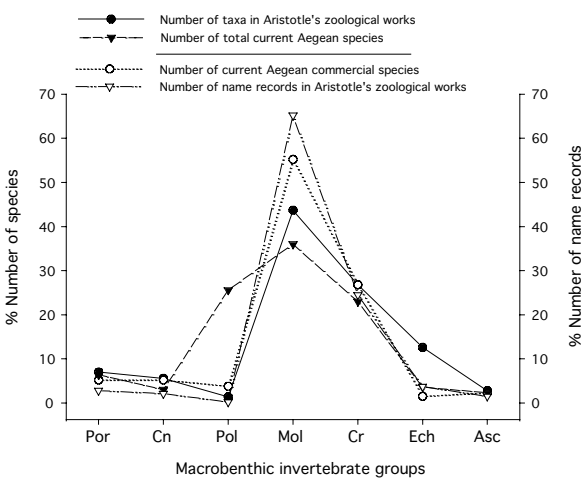

Fig. 4. Aristotle's knowledge of macrobenthic invertebrate diversity as compared to the current knowledge. Animal groups: Por, Porifera; Cn, Cnidaria; Pol, Polychaeta; Mol, Mollusca; Cr, Crustacea; Ech, Echinodermata; Asc, Ascidiacea.

In conclusion, we can say that Aristotle's contribution to the knowledge of the diversity of benthic marine invertebrates is very high, taking into account the absence of any zoological background and the primitive facilities of his age. He had a balanced scientific knowledge of all the major benthic invertebrate groups. There have been difficulties with the recognition of various marine animals recorded in his writings by previous researchers, as shown by several wrong identifications. This study, conducted by Greek speaking marine zoologists living and diving in the same area with the great philosopher, thus being very familiar with the objects of his inquiry, contributed to the clarification of some confusing points. We think that it should be considered as a necessary starting point for any further analysis of the great philosopher's knowledge on the marine environment and its organisms.

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