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The European wing oyster *Pteria hirundo* (Linnaeus, 1758) (Mollusca: Pteriidae): a known species with an unknown life mode

Abstract

The European wing oyster *Pteria hirundo* is studied in terms of autecology: habitat, age and growth, substrate and associated fauna, relationships, and distribution and abundance in the North Aegean Sea of Greece by means of extensive collection, photography, biometry, and application of von Bertalanffy growth equation (VBGE), logistic 3P Prediction Model, and linear regression analysis on morphometric parameters. Results, such as the variety of sessile corals, hydrozoa, bivalves and sea urchins that the species uses as substrate, and its epibiotic polychaetes and bryozoa, are presented and discussed.

Keywords: distribution, autecology, morphometry, age, associated fauna, Aegean Sea, Greece

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Introduction

Pteria hirundo (Linnaeus, 1758), the European wing oyster, is a well-known bivalve of the sublittoral zone from 20-150 m[1] or up to 300 m[2] with numerous references supplying information on the species habitat and distribution. While the species is cultured in Brazil,[3] its exploitation in Greece is very limited.[4] Information on the life history of *P. hirundo* wild populations from the Mediterranean is lacking, presumably due to difficulties in its collection as the species is rather uncommon[5] and lives in habitats of mainly hard substrates of some depth as epizootic on soft and hard corals. This study adds to the knowledge of European wing oyster's autoecology, habitat, age, growth and distribution in the Aegean Sea.

Materials and methods

Individuals of *Pteria hirundo* were sporadically collected (Figure 1) during the period 2006-2021 among by catches of commercial fishing gears of: i) trammel nets and ii) trawls, in the North and Central Aegean Sea.

Figure 1 North Aegean Sea with the stations' locations.

Recorded information referred to depth, substrate type, and surface of collection area depending on the trawl and trammel nets.

The dimensions of undamaged specimens were measured (length, height, width) with an accuracy of 0.05 mm, and the individuals were weighted (total, body, valves) (as dry weight after 48 h, in 80°C oven) (accuracy 0.001 g).

Relationships between dimensions, dimensions and weights were described with linear regressions of the general form $\log Y = a + b * \log X$

For the relationships between dimensions, all specimens of this study were used, while for the relationships between dimensions and weight the specimens of the most numerous collection were used (trammel nets, September 2006).

The age was estimated by counting the winter dense zones[6] both on valves and valve ears as well as by using back calculation when the shells' condition permitted. For the study of the age, specimens were collected from the N. Aegean Sea during April to September when the last winter dense zone on the valves is completed and the new one will be appear later. The theoretical growth curve (von Bertalanffy equation and its parameters L_∞, k and t_o) was calculated according to.[7–9] Organisms as substrate, associated fauna and epibionts of *Pteria hirundo* were identified at the genus level, at least.

Results

Ecological aspects

The specimens of *Pteria hirundo* were collected from depths of 25-443 m with the majority of individuals from 90-324 m of the North and Central Aegean Sea (Figure 1 and Table 1). The species abundance was higher on substrates with *Antipathes* corals and lower on *Eunicella singularis* ones (Table 1). The trammel nets were 4000 m long, while in September 2006 all individuals (36) were collected on a 10 m long part of the net attached with their strong byssus (Figure 2d) on *Antipathes* arms (Figures 2a and e). The mean length of the

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trawling swept/hauling distances was 3858±sd1570 m from where 0-11 *P. hirundo* individuals were collected (Table 1).

Pteria hirundo was found to be strongly attached by the byssus on a variety of sessile invertebrate organisms (Figure 2 and 3) such as the corals *Antipathes dichotoma* Pallas, 1766 (Figure 2a and e) and *Eunicella singularis* (Esper, 1791) (Figure 2b), the Hydrozoa *Aglaophenia* cf. *elongata* (Fig. 3a), *Lafoea* cf. *dumosa* (Fig. 3b) and *Nemertesia* cf. *antennina* (Figure 3c), the bivalve *Neopycnodonte cochlear* (Poli, 1795) (Figure 3d) and on sea urchins (Figure 3e). *P. hirundo* individuals were also found settled on branches of submerged trees (Figure 2c) and on fishing lines. *P. hirundo* itself became substrate for other benthic organisms (epibionts) such as Anomiidae, Polychaeta and six Bryozoa species (Figure 3f-k) three of which, namely *Bugulina flabellata* (Thompson in Gray, 1848), *Fenestrulina orientalis* Liu & Liu, 2001 and *Schizoporella* cf. *japonica* Ortmann, 1890, are referred for the first time from Greece based on Gerovasileiou & Rosso[10]. As associated molluscan fauna with *P. hirundo* were found to be the bivalve *Anadara gibbosa* (Reeve, 1844) (Figure 4a) and the gastropods *Pseudosimnia carnea* (Poiret, 1789) live (Figure 4b), *Ranella olearium* (Linnaeus, 1758) live (Figure 4c), and *Odostomia* aff. *schrami*[11] (Figure 4d). The later *O.* aff. *schrami* was collected also live from the surface of a live deep water sea urchin associated with *P. hirundo* clusters.

Table 1 Collection details for *Pteria hirundo* of this study. C =Central

Time	Coordinations (the middle of nets/hauling)	Area (symbols in the map of Fig. 1)	Fishing gear	Mean Depth (m)	No of Individuals
September2006	39° 55' 800 23° 58' 350	NW Aegean Sea (N2)	trammel nets	90-95	36
April-May 2007	40° 27' 320 22° 45' 031	NW Aegean Sea (N3)	trammel nets	25	1
April-May 2007	40° 13' 000 23° 26' 000	NW Aegean Sea (N1)	trammel nets	70	5
July2019	40° 36' 979 25° 07' 825	Thracian Sea (7)		132	2
	39° 46' 564 25° 08' 422	C Aegean Sea (14)		97	7
	39° 05' 100 25° 15' 331	C Aegean Sea (19)		324	11
	38° 28' 331 25° 16' 473	C Aegean Sea (25)		523	0
August 2020	39° 01' 814 23° 45' 752	C Aegean Sea (35)	trawl	360	1
	39° 00' 934 23° 11' 747	C Aegean Sea (37)		45	2
	38° 49' 163 23° 06 466	C Aegean Sea (39)		443	1
	40° 10' 320 23° 16' 089	NW Aegean Sea (42)		66	3
	39° 49' 413 23° 12' 653	NW Aegean Sea (50)		108	3
	39° 50' 670 23° 31' 979	NW Aegean Sea (52)		364	1
June 2021	40° 38' 965 25° 23' 864	Thracian Sea (6)		84	0
	39 ° 42' 965 25° 01' 180	C Aegean Sea (15)		187	3
	40° 31' 273 24° 23' 503	Thracian Sea (64)		311	0

The larval shell shape of *Pteria hirundo* is shown in Figure 4e. The size of the prodissoconch I and II is 150 μm and 420 μm, respectively. On the bases of the late ontogenetic stages the shell is easily recognized as inequivalve. The valves of *P. hirundo* differ in the density and the size of the aragonite prisms. The right (larger) valve consists of significantly more and smaller prisms than the left one (Figure 4f and g).

From the most numerous collection (trammel nets, September 2006), the minimum and maximum length of the specimens was 0.38 cm and 10.62 cm, respectively. The valves were thin and fragile with damages at the margins due to the fishing gears. Therefore, the most accurate shell dimension was that of the width that gives the smaller standard deviation (Table 2). The shell dry weight represents 92.7% of the total dry weight and the body dry weight only the 7.3%. The descriptive statistics of all measurements is presented in Table 2.

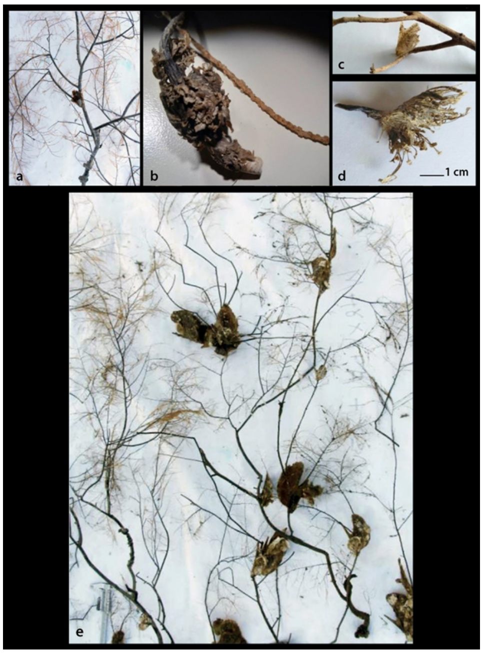

Figure 2 *Pteria hirundo* substrates: a. The coral *Antipathes dichotoma* with an attached *P. hirundo* individual; b. The coral *Eunicella singularis* holdfast ("root") with a part of its dry branch; c. Branch of a land tree; d. Byssus; e. *P. hirundo* individuals attached on *Antipathes dichotoma* branches when removed by the trammel nets in September 2006.

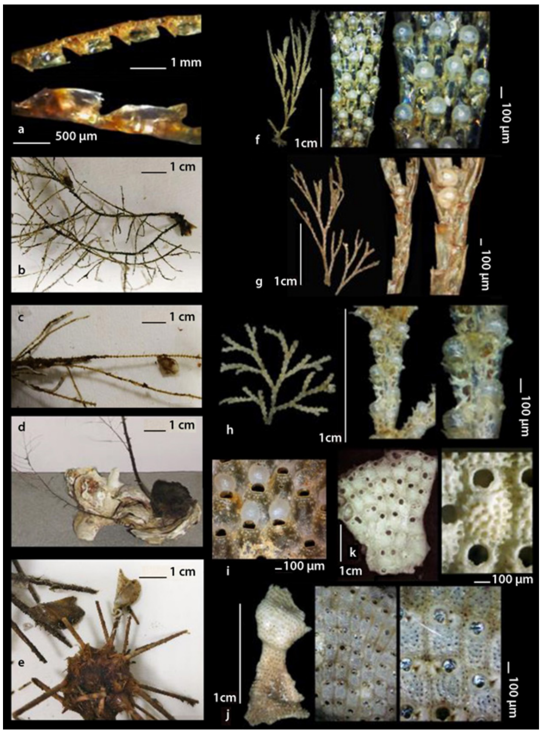

Figure 3: Substrates of *Pteria hirundo*. a-c. Hydrozoa: a. *Aglaophenia* cf. *elongata* Meneghini, 1845; b. *Lafoea* cf. *dumosa* (Fleming, 1820); c. *Nemertesia* cf. *antennina* (Linnaeus, 1758); Bivalvia: d. *Neopycnodonte cochlear* (Poli, 1795) and *Antipathes* sp. coral; Echinodermata: e. *Cidaris* aff. *cidaris* (Linnaeus, 1758); Bryozoa epibionts: f. *Bugulina flabellata* (Thompson in Gray, 1848); g. *Bugula neritina* (Linnaeus, 1758); h. *Cradoscrupocellaria* cf. *bertholletii*; i. *Fenestrulina orientalis* Liu & Liu, 2001; j. *Schizoporella errata* (Waters, 1878) ; k. *Schizoporella* cf. *japonica* Ortmann, 1890.

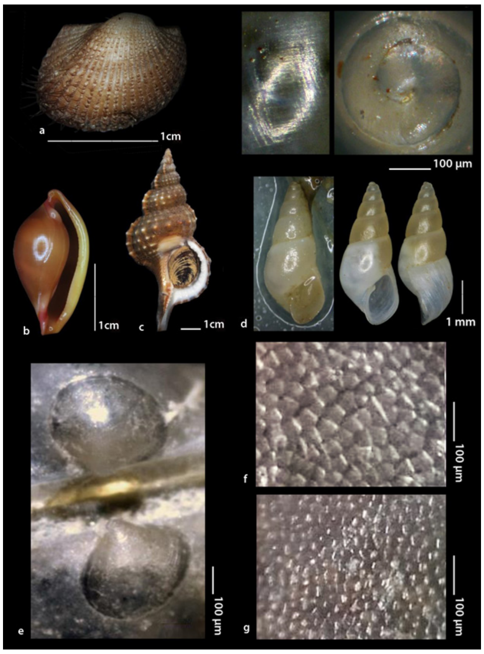

Figure 4 a-d. *Pteria hirundo* associated molluscs in this effort: a. *Anadara gibbosa* (Reeve, 1844) live; b. *Pseudosimnia carnea* (Poiret, 1789) live; c. *Ranella olearium* (Linnaeus, 1758) live; d. *Odostomia* aff. *schrami* van Aartsen, Gittenberger E. &Goud, 1998 live; e. The larval shell of *P. hirundo* (length 420 µm) at the umbo area of an adult individual, the upper valve is the left one; f. Prisms density of *P. hirundo* shell close to ventral margins of the left valve; g. Prisms density of *P. hirundo* shell close to ventral margins of the right (larger) valve.

Table 2 Descriptive statistics of *Pteria hirundo* biometry. TDw: Total Dry weight; BDw: Body Dry weight; ShDw: Shell (both valves) Dry weight for N individuals

Variable	N	Mean	StDev	Minimum	Maximum
Length (cm)	29	6.232	2.794	0.380	**10.620**
Height (cm)	33	4.517	1.736	0.300	6.620
Width (cm)	35	1.323	0.481	0.300	1.880
TDw (g)	36	9.060	6.460	0.000	21.75
BDw (g)	35	0.681	0.449	0.002	1.651
ShDw (g)	35	8.640	5.950	0.090	20.800

Independently of the fishing gear and the recorded period, the size of the individuals in terms of width is presented in figure 5, and shows larger individuals in the NW Aegean Sea.

The dimensions (length, height, width) of the collected specimens by trawls during the period 2019-2021 did not differ statistically (ANOVA one way: $P_{0.05}$ = 0.424 for length, 0.269 for height, 0.629 for width).

The relationship of width with the other two valve dimensions (length and height) shows strong correlation with an R^2>93%, and the relationships (R^2>93%) of width vs. dry weights of *P. hirundo* are presented in Table 3.

The estimated age of 36 *Pteria hirundo* individuals was 12+ years at a length of 7.57 cm. The parameters of theoretical growth curve, von Bertalanffy equation, were calculated as follows:

Table 3 Linear regressions of morphometric parameters (L = length, H = height, W = width) of body (B), shell (Sh) and total dry weight (TDw), R^2: determination coefficient (%), C.I.: confidence intervals of b for 95% probability. Allometry (-/0): negative/isometric€

N	Linear regression logy= loga + blogx	R^2 (%)	$ANOVA_{0.050}$ probability (P)	Standard error of b (95% C.I. of b)	Allometry
56	**logL = 0.7114 + 1.042 logW**	**93.34**	**0.000**	**0.0375 (0.967 – 1.117)**	**0**
29	logL = 0.081 + 1.080 logH	97.87	0.000	0.0193 (0.998 – 1.075)	0
33	logTDw = 0,5285 + 2,7960 logW	97.38	0.000	0.0810 (2.631- 2.961)	-
33	logBDw = -0,6233 + 2,801 logW	93.81	0.000	0.1270 (2.542-3.060)	0
34	logShDw =0,4900 + 2,7482 logW	96.39	0.000	0.0926 (2.559-2.937)	-
33	logShDw = -0,0295 + 0,9960 logTDw	99.98	0.000	0.0025 (0.991-1.001)	0

The Fort-Walfort regression equation was $Wd_{t+1} = 0,257 + 0,856W_t$ (R2 = 94.88%, P0.05 =0.00) and consequently the parameters k, Wd_∞ and to were calculated: k = -lnb=0.156/year, Wd_∞ = a/1-b = 1.79 cm that corresponds to an infinitive length L_∞ = 9.44 cm, to = -a/b constants of regression age vs. –ln(1-Lt/ L_∞)[9] is found to be -0.701. Substituting the values of these parameters, the von Bertalanffy equation is: $L_t = 9.44\left[1-e^{-0.156(t+0.701)}\right]$ (Figure 6).

Discussion

The winged pearl oyster *Pteria hirundo* seems to be widely distributed in the Aegean Sea at a depth range of 25-523 m. The specimens from the open and deeper waters of North (Thracian) and Central Aegean Sea were smaller in comparison with the individuals from the gulfs of NW Aegean Sea. The optimal conditions for successful survival and growth of post larvae to juvenile ages of the species in a farm were found to be a combination of sea water temperature 23 °C and salinity 35 ‰.[3] The period after reproduction of natural populations in the Aegean Sea has to be the summer, based on the occurrence of very small specimens (~5 mm) in August and September.[10,11] The summer temperature and salinity of the North and Central Aegean Sea are 20-24 °C and 32-38‰, respectively; while in the NW Aegean are 24 °C and 35-36 ‰, respectively.[12] The favorable environment for the early age stages of *P. hirundo* is rather that of NW Aegean where the species was found to be more in abundance. The maximum length of the valves, 11 cm, was referred by Pusateri in 2003, from the Mediterranean Sea,[13] which is very close to the largest specimen of this study (10.62 cm) and close to the theoretical L∞ (9.44 cm). The dissimilarity between the size and the number of aragonite prisms between the two valves of the congeneric species *Pteria penguin* (Röding, 1798) was described in detail by Harper & Checa[14] who attribute the difference to the observed higher organic content of the right valve prismatic layer having as a result an increased number of smaller prisms. The calculated life span of *P. hirundo* is more than 15 years, with a low growth rate (k = 0.156/year), quite similar to other congeneric species e.g. *P. penguin* (k = 0.090-0.380/year)[15]. The species total weight rises after a length of 2 cm at an age of about 2 years (Figure 7) and rather indicates the age of fist reproduction at a length of >6 cm, as the inflection point of the prediction model Logistic 3P is 6,42 cm $(P\chi^2 :< 0.0001)$ (Figure 5). The species of *Pteria* seems to be epizootic, as the majority of the specimens of this study (see Figures 2 and 3) were attached to stems of gorgonians. It has been observed that the most abundant species of the Bivalvia group collected from a depth of 50-100 m with a trawl in the Adriatic Sea was *P. hirundo* (2922.19 individuals/km[2] and weighted 35.70 kg/km[2])[16] while the corresponding abundance of *P. hirundo* in the Aegean Sea was only 0-11 individuals per effort, perhaps due to deeper waters and less favorable conditions in general.

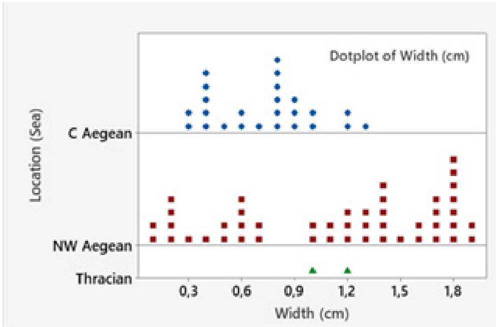

Figure 5 Dot plot diagram of *Pteria hirundo* specimens' size in terms of width in the study area.

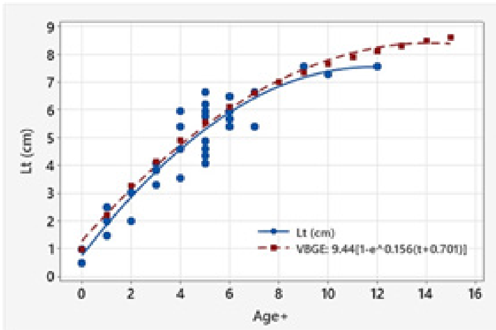

Figure 6 Estimated (round dots, solid line) and calculated growth of *Pteria hirundo* [von Bertalanffy growth equation (VBGE), dotted line].

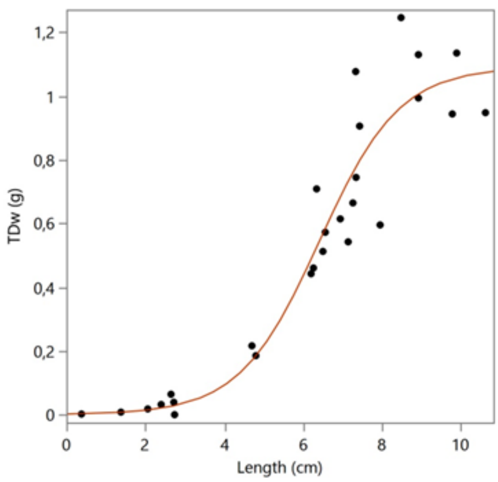

Figure 7 Logistic 3P Prediction model for the total dry weight (TDw) changes with the size (Length).

Odostomia schrami is an E Atlantic inhabitant initially reported as a worn out shell (spec, nov., holotype NNM 57490) from off Mauritania[11]. Since then, a live specimen was collected from NE Thermaikos Gulf, N Aegean Sea[17] and now a much larger specimen from a different location (station 7) of the N Aegean Sea. As the later finding represents a rather adult individual and these is no relevant image documented report available in the literature we added the "aff." to our specimen. If it is indeed *O. schrami*, these two findings from two distant locations are indicative of an established population, and gave us the opportunity to examine in detail its characters, among them, the size of the protoconch (embryonic shell 245 μm, larval shell 315 μm, maximum diameter), the finely spirally striated surface of the shell, the flared lower part of the outer lip, the animal colour and its habitat in the E Mediterranean Sea. Concerning the collected sea urchins, we avoid identifying them as one of the two deep sea Mediterranean species *Cidaris cidaris* (Linnaeus, 1758) or *Stylocidaris affinis* (Philippi, 1845) because their spines were broken due to trawling. The relative length of those spines to the diameter of the dermal skeleton comprises a useful tool in the discrimination and specific identification of those two similar species[18]. The use of cf. for some species of this work (e.g. hydrozoa and bryozoa) is due to the worn samples due to trawling.

Further investigations are needed to complete the life cycle of the species and its survival under the present climate and anthropogenic pressures.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

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