

# The local forms of *Zootecus* (Gastropoda: Pulmonata: Subulinidae) of Pakistan: an archaeomalacological case study

Alberto Girod<sup>1\*</sup>, Antonio Balzarini<sup>2</sup>

**Abstract** - In the past, several Asian subspecies and local forms of *Zootecus* have been described and some of them can be linked back to *Zootecus insularis*. Their collecting sites, shell shapes, dimensions and number of whorls have been listed in the past. In recent years, collections, observations and biometrics of dead shells have been carried out in five sites in Pakistan, in both Balochistan and Sindh. The samples have quite different dating; two of them come from archaeological excavations. The biometrics indicate that different shell shapes are locally present among the empty shells accumulated over the years; in the Siranda Lake they have floated from different of areas. A comparison between the *Zootecus* shells cited in the past literature and the shells from the five sites shows, that in these mounds of shells a variety of shapes exists, including those known as *Zootecus agrensis*, *Z. chion*, *Z. gracilor minor*, *Z. polygyratus* and *Z. pullus*. Given the ample polymorphism present in every sample, it is difficult to ascribe the specimens of Siranda Lake to one of the above taxa.

**Key words:** land snail, *Zootecus*, Pakistan, shell shapes, biometrics.

**Riassunto** - Le forme regionali di *Zootecus* (Gastropoda: Pulmonata: Subulinidae) del Pakistan: uno studio archeomalacologico.

In passato sono state descritte per alcune regioni asiatiche molte sottospecie e forme locali di *Zootecus*, alcune riportabili a *Zootecus insularis*. Sono noti le loro località di raccolta, le altezze e diametro della conchiglia ed il numero dei giri della conchiglia. In anni recenti sono state fatte raccolte, osservazioni e biometrie su conchiglie di *Zootecus* da cinque differenti località del Pakistan, in Balochistan e nel Sindh. Due campioni provengono da scavi archeologici. Le conchiglie accumulate nel tempo nei singoli siti hanno forme e dimensioni diverse, inoltre nel caso del Lago Siranda hanno tempi e zone di provenienza molto ampi. Sono state comparate le forme storicamente citate in letteratura con quelle raccolte nei cinque siti la cui antichità è differente e ove compaiono insieme alcune delle forme conchigliari citate per *Zootecus agrensis*, *Z. chion*, *Z. gracilor minor*, *Z. polygyratus* e *Z. pullus*. A causa del polimorfismo presente in ogni campione risulta difficile attribuire con certezza il materiale del Lago Siranda ad uno di detti taxa.

**Parole chiave:** gasteropodi terrestri, *Zootecus*, Pakistan, forme conchigliari, biometrie.

<sup>1</sup> Laboratory of Applied Malacology, Via Ponte Tresa 7, 6924 Sorengo, Switzerland.

<sup>2</sup> Bioecologist, Via M. Buonarroti 18/D, 21010 Besnate, Italia.  
E-mail: antoniobalzarini@virgilio.it

\* Corresponding author: fraberto.girod@gmail.com

© 2017 Alberto Girod, Antonio Balzarini

Received: 3 June 2016

Accepted for publication: 21 December 2016

## INTRODUCTION

During the 2011-2013 annual surveys of the Italian Archaeological Mission to Las Bela, Balochistan (Pakistan), areas south of Uthal, around Lake Siranda, and near Miani Hor (Snead, 1966, 1967; Snead & Frishman, 1968; Dales, 1982) and the promontory of Puhari have been investigated (Biagi *et al.*, 2013a). In addition to the study of many prehistoric shell middens, several empty shells of the land snail *Zootecus* sp. were observed and collected. Much of the countryside is strewn with these small white shells, sometimes heaped up in thousands of specimens in restricted areas as also observed by other malacologists (Auffenberg, 1994; Lindauer *et al.*, 2016). Due to the reduced length and small size of their shells, which were also observed in Arabia and in the Indian subcontinent (Pilsbry, 1906), they were at first ascribed by one of the authors (Biagi *et al.*, 2013b) to *Zootecus chion* (Pfeiffer, 1856) although the question whether the application of the name *Z. chion* for the specimens from Pakistan is not resolved yet. Many taxa are present in the literature concerning Pakistan and the surrounding territory, described as *Zootecus insularis* (Ehrenberg, 1831), *Z. chion* (Pfeiffer, 1856) or *Z. insularis chion* (Haas, 1959; Akhtar, 1978; Solem, 1979). This may have been caused by pronounced variability of shape.

Pilsbry (1906) observed: «*A group of small, pupiform snails, largely eremitic in habits, generally occurring in large numbers, and varying within wide limits in size and degree of taper. Most gatherings from one place show shorter and longer individuals; the diameter remaining more constant for any one colony. The proportion of diameter to length is therefore individually variable.*»

And Gude (1914) wrote: «*...the diameter remaining more constant for any one colony but the proportion of diameter to length is therefore individually variable. There is a good deal of local variation in size and texture, and hence a superabundance of names.*»

The polymorphic species *Zootecus insularis* is widespread and can be found from the Cape Verde Islands to East Africa, Afghanistan, the north, central and southern Indian subcontinent, upper Burma, with several named forms (Pilsbry, 1906; Ramakrishna & Mitra, 2010).

The phylogenetic position of *Z. insularis* is known, as well as features of its metabolism, physiology and ecology; the species is parthenogenetic (Chaudhari & Kulkarni,

1993, 1994; Davison *et al.*, 2005; Wade *et al.*, 2001; Fontanilla, 2010). *Z. insularis* produces an epiphragm during aestivation and comes out from deep in the ground only after periods of rain (Hora, 1928; Raut & Ghose, 1977); *Z. chion*, along with many invertebrates and vertebrates, forms part of the diet of *Varanus bengalensis* (Daudin, 1802) (Auffenberg, 1994).

*Zootecus* sp. is known as a Holocene fossil in the deserts of Libya, Egypt, Sudan (Mienis, 1979, 1992; Marinova *et al.*, 2008; Girod, 2008, 2010) and in the lacustrine deposits of Lake Assal, Djibuti (Van Damme & Gautier, 1994). The local populations of *Zootecus* in the region east of Iran are known by many names (Gude, 1914): *Z. agrensis* (Kurr, 1855), *Z. chion* (Pfeiffer, 1856), *Z. estellus* (Benson, 1857), *Z. gracilior minor* (Pfeiffer, 1856), *Z. pertica* (Benson, 1857), *Z. polygyratus* (Reeve, 1849), *Z. pullus* (Gray, 1834) (Tab. 1).

These taxa were identified and described solely on the basis of morphological characteristics of the shells but their anatomy is still unknown. A revision of the various species and subspecies assigned to *Zootecus* is urgently needed (Neubert, 1998). Louis Germain (1924: 26) suggested that a more detailed study of individuals from distant populations allows to group some forms and to accept that individual variability is very high in every population.

#### Aim of the research

Our research is geographically limited to five sites in Balochistan and Sindh and is restricted to morphometric aspects of the *Zootecus* sp. shells, with the aim to set out the difficulties to give the right taxon name to empty shells. It is important to examine again the assembly of shell-shapes observed on the bottom of Siranda Lake and

to check if their past identification as *Z. chion* is correct (Biagi *et al.*, 2013b). Only dead shells are available and this is a problem for the archaeomalacologists, because in many cases it not possible to collect living individuals so as to compare their anatomy with that known for *Z. insularis* or species like *Z. contiguus* (Reeve, 1849) in the South Arabian countries (Neubert, 2003). A similar problem has recently been observed in the Eastern United Arab Emirates (Lindauer *et al.*, 2016).

#### The basin of Lake Siranda

Lake Siranda, some 14 km long and 3 km wide, and only 0.30-0.45 m above the present sea level, is located in the southernmost part of Las Bela Valley (Pakistan, Balochistan) (Fig. 1). Although fed by summer monsoon rains draining into the basin mainly by the Watto River, an easternmost branch of the Porali River, today the lake is often dry, depending on the seasonal precipitation (Akhtar, 2011). According to data from the 1950s, its maximum depth was 1.5 m in the winter and 3 m in the summer.

The bottom of the dry basin of Lake Siranda is covered by muddy and sandy sediments not suitable to the ecology of *Zootecus* because it is a petricolous genus, living on stony ground, under boulders, on hill and mountain slopes (Feulner *et al.*, 2005); sometimes in moist agricultural soils (Al-Khayat, 2010).

Huge quantities of shells are floated into Lake Siranda from the hills and from the Holocene plain deposits by temporary rivers during the summer monsoon (Snead, 1966), producing a mixture of specimens derived from different areas. Such enormous accumulations of shells have been observed in other regions (Fowler, 2005; Lindauer *et al.*, 2016).

Tab. 1 - Historical names, dimensions and whorl numbers of the *Zootecus* described from Afghanistan and Pakistan. AMNH, American Museum of Natural History; NHMUK, National History Museum, London; PZS, Proceedings of the Zoological Society of London.

Local taxa	Collecting areas	H mm	D mm	H/D	Whorls
1) <i>Zootecus pullus</i> Gray, 1834 - P.Z.S., 2 : 66	Balochistan, Quetta; Kutch; Bank of Ganges; Delhi; Uttar Pradesh	10	4	2.5	9-10
2) <i>Zootecus chion</i> (smaller form) <i>gracilior minor</i> (Pfeiffer, 1856)	Not specified	11	4	2.75	
3) <i>Zootecus insularis chion</i> (Solem, 1979, tab. IV: 30)	Afghanistan	11.8±0.15 (9.8-14.3)	5.66±0.071 (4.3-6.4)	2.279 2.234	7 3/4 + (7 1/8-9)
4) <i>Zootecus polygyratus</i> Reeve, 1849	Sindh (Rohri Hills); Baluchistan (Gwadar)	12	4	3	9
5) <i>Zootecus chion</i> , Pfeiffer, 1856	Afghanistan; Punjab; Sindh	12	0.5	2.4	7-8
6) <i>Zootecus chion</i> (#2), Pfeiffer, 1856	Samples from Hyderabad	14	6	2.333	
7) <i>Zootecus agrensis</i> Kur.r 1856 - Malakozoologische Blätter, 2: 107	India: Agra	16	6	2.666	9
8) <i>Zootecus estellus</i> Benson, 1857 - A.M.N.H. ser. 2, 19: 327	Punjab; Sindh; Rajasthan; Andhra Pradesh	18	6	3	8
9) <i>Zootecus pertica</i> Benson, 1857 - A.M.N.H. ser. 2, 19: 328	Sindh	20	5	4	10

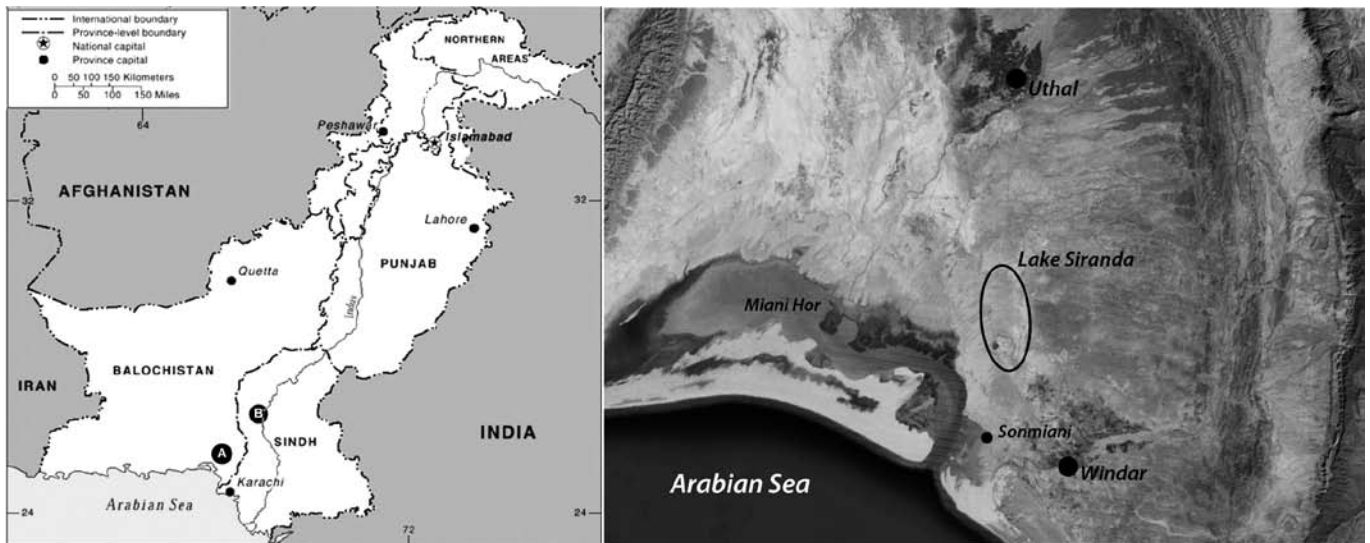


Fig. 1 - Left: map of Pakistan with the areas of the studied sites. A) Balochistan, sites WP16, WP 31, Uthal. B) Upper Sindh, Rohri Hills, site 59, site 480. Right: satellite view of the area of Balochistan, South of Uthal with location of the Lake Siranda and the lagoon of Miani Hor.

Shells of *Zootecus* are present in the Pleistocene dunes visible along the main road N25 to Karachi (Naseem *et al.*, 1996-1997). There are sub-fossil *Zootecus* shells in the old eroded dunes along the beach near Miani Hor lagoon; few shells dated to  $5700 \pm 40$  uncal. BP AMS  $^{14}\text{C}$  (GrA-62258). Sub-fossil shells are also in the ancient exposed sediments along the beds of streams

that flow into Lake Siranda (for example: N25 44.760 E66 37.190) (Fig. 2). Few living specimens of *Z. insularis*, in diapause with epiphragm, have been collected far away from the plain of Siranda on the hills around the River Windar, in the typical stony and dry environment of the species and sent abroad for a future anatomical study (Fig. 3).

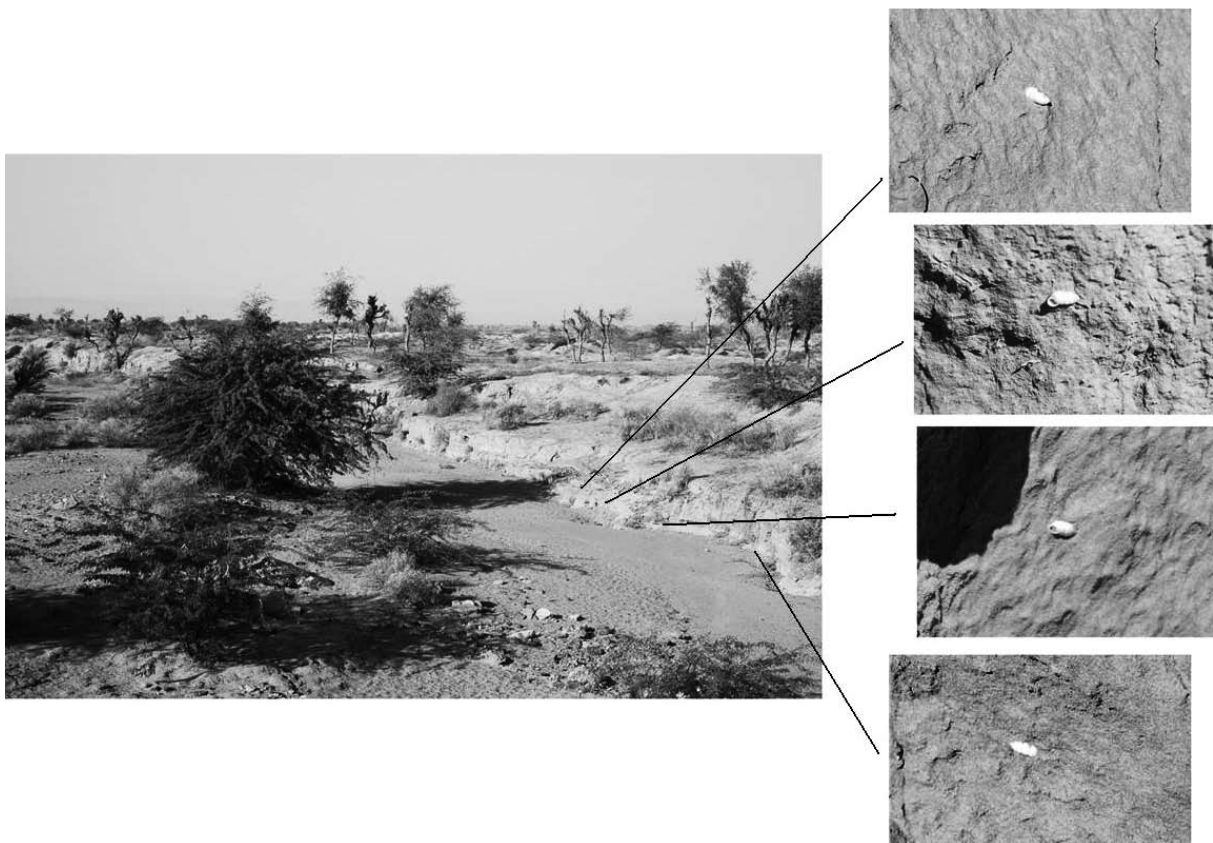


Fig. 2 - WP 199, N 25 44. 760 E 66 37.190 with *Zootecus* shells emerging from sediments (photo by P. Biagi, R. Nisbet, A. Girod).





Fig. 3 - Hills around the River Windar and some living specimens of *Zootecus cfr. insularis* (photo by A. Girod).

The erosion of hills and fossil dunes over centuries/millennia has resulted in the transport of *Zootecus* shells towards Lake Siranda. The floods and changes in the level of the lake release old shells buried in the muddy/sandy bottom and water movements push the empty shells of *Zootecus* and those of freshwater species all around the basin. Among the freshwater species, *Melanoides tuberculata* has been dated to 830±30 uncal. BP, AMS <sup>14</sup>C (GrA-57527), confirming the existence of a freshwater habitat in a historical period. In recent decades, after the rainy season Lake Siranda may become totally dry or change into a saline shallow-water pond.

#### MATERIALS AND METHODS

Five samples coming from different locations and dating were examined (Fig. 1):

i. WP 16, (Balochistan) central zone of Lake Siranda, eastern shore (N25° 32' 108" E66° 37' 274"). *Zootecus* empty shells are accumulated on the beach together with *Pupoides coenopictus* (Hutton, 1834) and the freshwater gastropods *Bellamya bengalensis* (Lamarck, 1822), *Melanoides tuberculata* (Müller, 1774), *Lymnaea acuminata* Lamarck, 1822, *Indoplanorbis exustus* (De-

shayes, 1834), *Gyraulus cf. rotula* (Benson, 1850) and *Gyraulus euphraticus* (Mousson, 1874) (Fig. 4).

- ii. WP 31, (Balochistan). Hundreds of shells are lying on ancient sandy sediments in a depression among two Holocene dunes near the western shore of Lake Siranda (N25° 32' 671" E66° 35' 406") (Fig. 4).
- iii. Uthal, (Balochistan). We received the specimens from NHMGB (BMNH 1903.6.1. 4203, donation H. Godwin-Austen); they were collected at Camp Uthal by Capt. Tigle on 19<sup>th</sup> March 1897 (Biggs, 1962).
- iv. Site RH 59, Rohri Hills (Upper Sindh), 1993 excavation (N 27°25'45.69" E 68°51'27.64"). We received the sample by P. Biagi. The prehistoric site is a mine with adjacent workshop dating to the 3<sup>rd</sup> millennium cal. BC, Mature Indus Civilisation (Fig. 32 in Biagi & Pessina, 1994; Biagi & Starnini, 2012). The subfossil shells (Fig. 5a) were in the pit at a depth of circa 110 cm under layer 2 of aeolian sand and 15 cm above the bedrock of layer 3 (Fig. 5). No other shells were found in the stratigraphy.
- v. Site RH 480, Rohri Hills (Upper Sindh), 1994 excavation (N 27°25'17.9" E 68°51'11.1"). We received the sample by P. Biagi. The prehistoric site is recorded as bladelet workshop dating to the 3<sup>rd</sup> millennium cal. BC,



Fig. 4 - Left: view of shell heaps. WP 16, *Zootecus* sp. with fresh-water malacofauna. Right: WP 31, shells of *Zootecus* sp. only (photo by A. Girod).

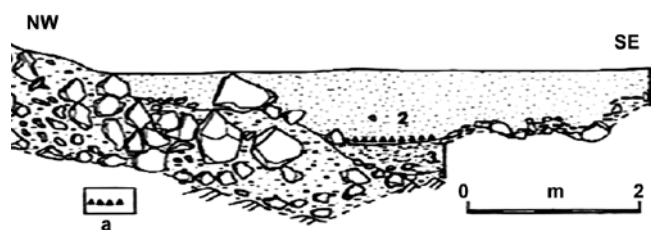


Fig. 5 - Rohri Hills, site 59. Section through the deposits: a) *Zootecus* sp. shells (modified from Biagi & Pessina, 1994).

Mature Indus Civilisation, located about 400 m south-east of Site 59 (Negrino & Starnini, 1995). The shells were only collected at the surface among stones.

Shell height and width (diameter) of the adult specimens were measured using a dial caliper accurate to a tenth of a millimetre (Fig. 6). Morphometric studies were based on classes of 0.1 mm amplitude. The maximum heights and diameters of specimens from the five sites were recorded (Fig. 7) and indices of roundness H/D were calculated (Fig. 8). For each sample the regression lines were elaborated (Fig. 9). These parameters are summarised in Tab. 2.

To evaluate the statistical difference between the five regression lines, the Analysis of Variance (ANOVA) with Fisher test was applied (Tab. 3).

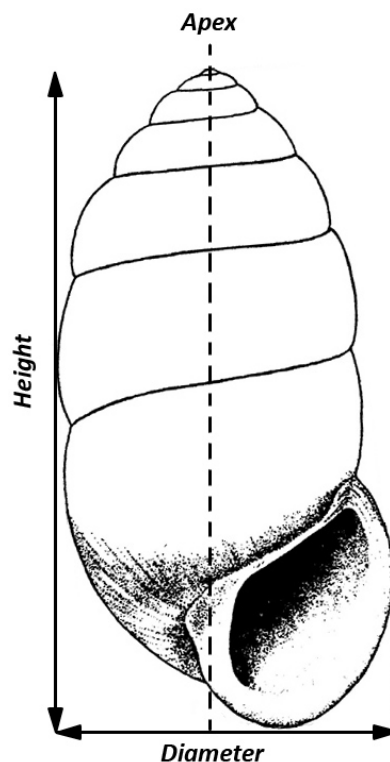


Fig. 6 - Shell measurements (drawn by Dael Sassoon).

Tab. 2 - Number of individuals, heights (H), diameters (D), means, roundness indices (H/D), whorl numbers and linear regression coefficient for *Zootecus* sp. of the five sites.

	WP 16	WP 31	UTHAL	RH 59	RH 480
Numbers of individuals	240	162	217	197	167
Mean H mm	10.75	11.40	11.57	11.97	10.70
Max H mm	13.50	13.30	14.85	17.00	12.90
Min H mm	8.00	9.50	8.30	10.00	8.50
Delta H mm	5.50	3.800	6.55	7.00	4.40
Mean D mm	4.69	4.85	4.80	4.19	4.87
Max D mm	6.00	5.60	5.50	4.85	5.60
Min D mm	3.80	3.90	4.10	3.70	3.50
Delta D mm	2.20	0.95	1.40	1.15	2.10
Mean roundness H/D	2.30	2.30	2.41	2.85	2.19
Whorl numbers	8	8	8 and 9	8 and 10	7 and 8
Linear regression equation	$y = 0.2493x + 1.9771$	$y = 0.1606x + 3.0419$	$y = 0.302x + 1.1788$	$y = 0.10278x + 2.9634$	$y = 0.2122x + 2.5862$

Tab. 3 - Results of ANOVA test. DF, degree of freedom; S<sup>2</sup>, variance; F, variance ratio; P, significance level.

Source of variation	Deviance	DF	S <sup>2</sup>	F	P
Within groups variance	107.8805	986			
Common regression slope	0.226133	1	0.226133	2.075882	<0.01
Between regression slopes	0.8000667	4	0.200017	1.836137	<0.05
Error for coefficient	106.8637	981	0.108933		

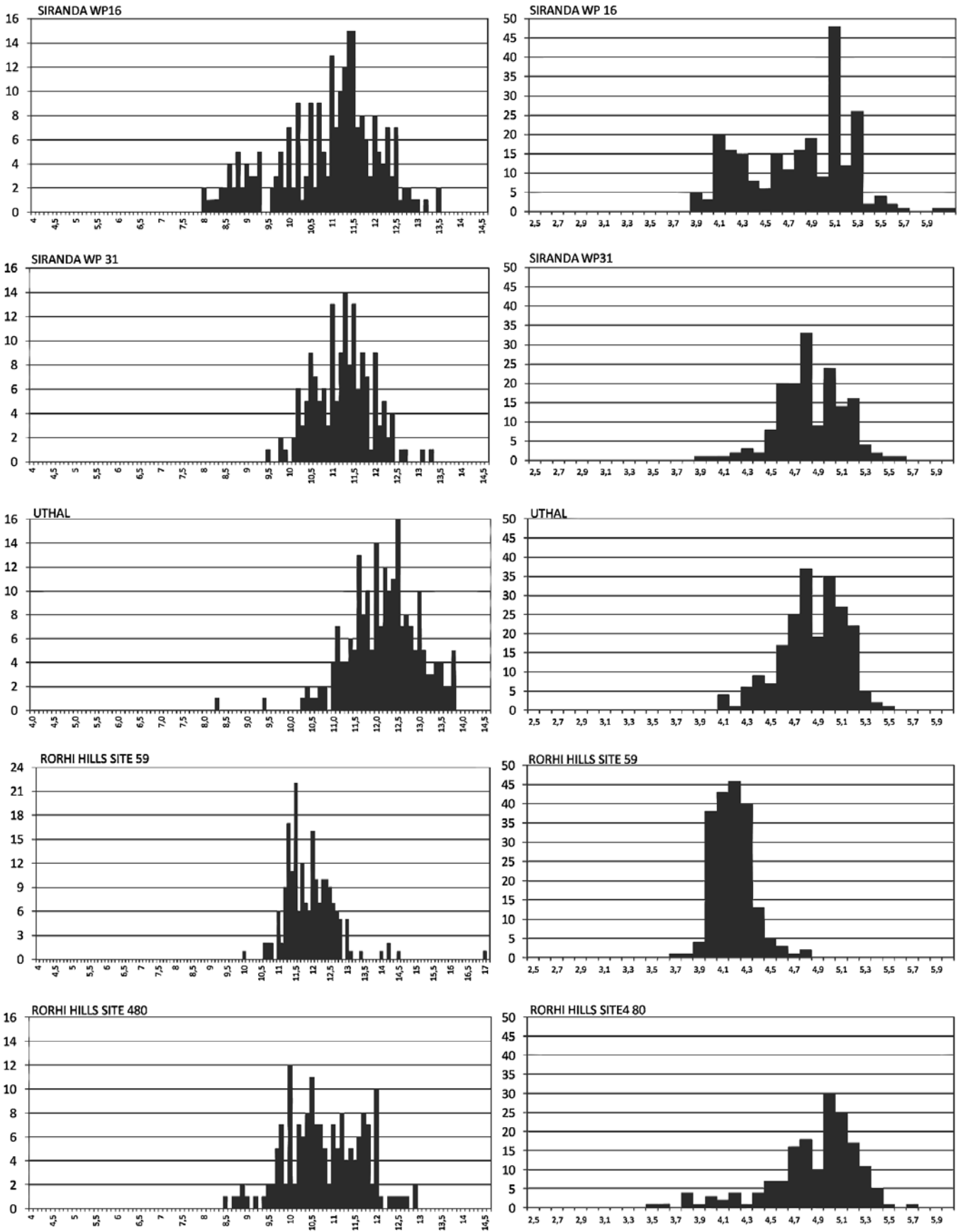


Fig. 7 - Distribution of 0.1 mm dimension classes of individuals from the five sites. On the left the shell height; on the right the shell diameter: x-axis = number of individuals, y-axis = dimension classes.



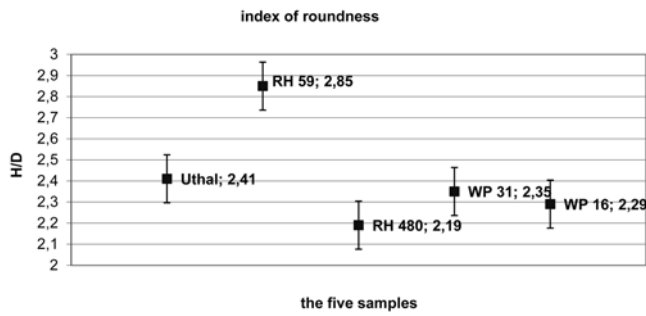


Fig. 8 - Shells index of roundness H/D of the five samples.

The analysis of variance to test the significance of differences between the regression coefficient regression is a F test with F k-1 and N-2k:

$$F_{k-1, N-2k} = \frac{S_b^2}{S_e^2}$$

It is obtained by the ratio between:

- the variance of the differences between the linear regression coefficients  $S_b^2$  also called variance of deviation from regression;

- the variance of the residual around separate lines  $S_e^2$  or error variance (Soliani, 2005).

The published critical values for F (Fowler & Cohen, 2010) are the following:

	$F_{1, \infty}$	$F_{1, \infty}$
P=0,05	254,31	5,6281
P=0,01	6365,9	13,463

For P=0.05 the critical value is much greater than the tabulated value therefore we can reject the null hypothesis and there is no common trend in the relationship between diameter and height. For P=0.01 the critical value is much greater than the tabulated value therefore we reject the null hypothesis and we can say that there is a difference between the angular coefficients. To verify the source of variation the Tukey test was applied to the ten possible data pair of angular coefficients (Tab. 4).

Four pairs of the angular coefficients have a value above the tabulated one and the differences are statistically significant: RH59-WP31, RH59-WP16, RH59-Uthal, WP31-Uthal. The pair RH59-RH 480 is not statistically different.

The average roundness indices H/D of the shells has been also compared (Fig. 8).

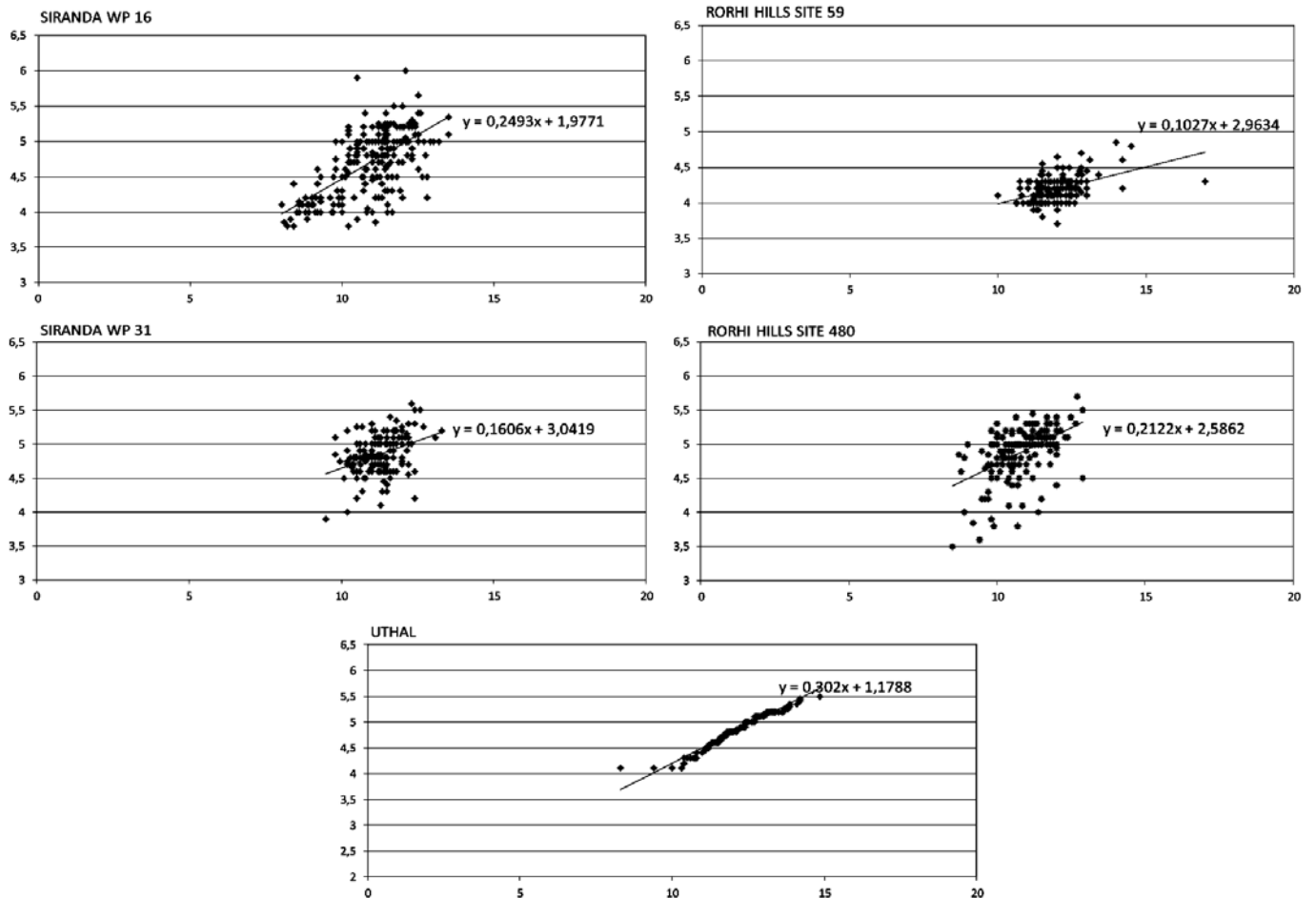


Fig. 9 - Linear regression analyses of the height - diameter relationships in the samples; x-axis = diameter in mm; y-axis = height in mm.

Tab. 4 - Values of  $q$  based on Tukey test. The pairs pointed out with asterisks (\*) are significantly different.

Comparison of samples	$q$
RH59 - RH480	0.5853
RH59 - WP31 *	4.8001
RH59 - WP16 *	5.9384
RH59 - UTHAL *	6.402
RH480 - WP31	1.3343
RH480 - WP16	1.5047
RH480 - UTHAL	2.8947
WP31 - WP16	3.4168
WP31 - UTHAL *	5.4741
WP16 - UTHAL	2.2843

### Siranda WP 16

On one hand, the graphical presentation of the height classes reveals some variability of the shell shape (Fig. 10A) confirmed by a fairly constant difference between maximum and minimum values, probably caused by the different origins of lake sediments and it illustrates a bimodal distribution centred on heights of 8.6 mm and 11 mm (Fig. 7). A similar distribution is shown by the diameter classes, with maxima at 4.1 mm and 5.1 mm (Fig. 7). Diameter and height thus seem correlated; this is confirmed by the  $b$  coefficient of the linear regression line, equal to 0.25, the highest value obtained in these analyses. The  $a$  coefficient 1.97 (Tab. 2; Fig. 9).

### Siranda WP 31

Analysis of height classes shows a unimodal distribution in the heights and diameters, with respective peaks at 11.3 mm and 4.8 mm (Fig. 7). The lower differences between maximum and minimum values in comparison to WP 16 indicates that the WP 31 population shows less morphological variation (as would be expected for samples taken from a hollow between dunes) and this is confirmed by the scatter plot (Fig. 9) in which values are more closely grouped; although the average diameter is greater than at WP 16, the maximum value is inferior and the minimum value almost identical.

The  $b$  coefficient of the linear regression line is quite low (0.16), which indicates a lower correlation between height (the values of which are in this case generally elevated) and diameter. The  $a$  coefficient is equal to 3.0419 (Tab. 2; Fig. 9). The moderate roundness index (2.3) indicates that the greater number of specimens in the sample is not elongate (Fig. 10B).

### Uthal

Analysis of the height classes reveals – with the exception of a few outliers – a unimodal height distribution with quite elevated values (centred on 12.5 mm), in accord with diameter measurements (Fig. 7). The scatter

chart illustrates a distribution in which height increases linearly with increase in diameter (Fig. 9). The linear regression  $b$  coefficient of 0.3 is one of the highest found, confirming the strong correlation between height and diameter. The  $a$  coefficient, on the other hand, is the lowest of the samples studied (1.18) and the index of roundness (2.41) is fairly high (Tab. 2); these values correspond to shells distinguished by an averagely elongate shape in which, as height increases, the diameter increases in linear proportion. The presence of continuous variation among the specimens, without discontinuities, would be expected from a sample collected in a fairly restricted zone with a certain degree of internal variability (Fig. 10C).

### Rorhi Hills site 59

Analysis of the height classes shows a modest spread in height measurements, with a modal value of 11.5 mm and the majority of the sample in the interval between 10.6 mm and 13.0 mm (Fig. 7). The distribution of diameter values, with a mode of 4.2 mm, likewise exhibits a modest dispersion (Fig. 7). The scatter chart (Fig. 9) reveals shells with little morphological variation, but with a consistent correlation between height and diameter confirmed by a linear regression line  $b$  coefficient of 0.1027, the lowest among the populations examined. The quite high  $a$  coefficient (2.96) and the highest roundness index found (2857), indicate generally elongated shells. However, this population contains a few individuals of different shape, as may be seen from the distribution of diameters (Fig. 7), which show more or less continuous variation between the extreme values (3.7-4.85 mm), but change little as height increases. Thus in a few individuals the height – and the H/D ratio is lower. The presence of a certain morphological variability is evident, given the considerable height range, one of the largest found in this study. On the contrary, the difference between maximum and minimum diameter values is not great (Tab. 2). The biostatistics evidence a certain uniformity of shape, as might be expected from subfossil shells lying in a limited archaeological surface at a depth of 110 cm (Fig. 10D).

### Rorhi Hills site 480

Analysis of height classes reveals a distribution ranging between 8.5 mm and 12.9 mm, quite a small interval in which no modal class stands out clearly (the most frequent are 10 mm, 11 mm and 12 mm) (Fig. 7). The difference between maximum and minimum values is not large at 4.4 mm (Tab. 2). The distribution of diameter measurements is centred on 5 mm (Fig. 7). The  $b$  coefficient of the linear regression line (0.21) is high, demonstrating a strong correlation between height and diameter although the population is not widely spread (Fig. 9). The  $a$  coefficient is 2.6. The low roundness index (2.19) denote a sample distinguished by a rather squat shell shape (Tab. 2). The comparison with WP16, WP 31 and Uthal shows that this archaeological sample seems to come from a more uniform empty shells accumulation (Fig. 10E).



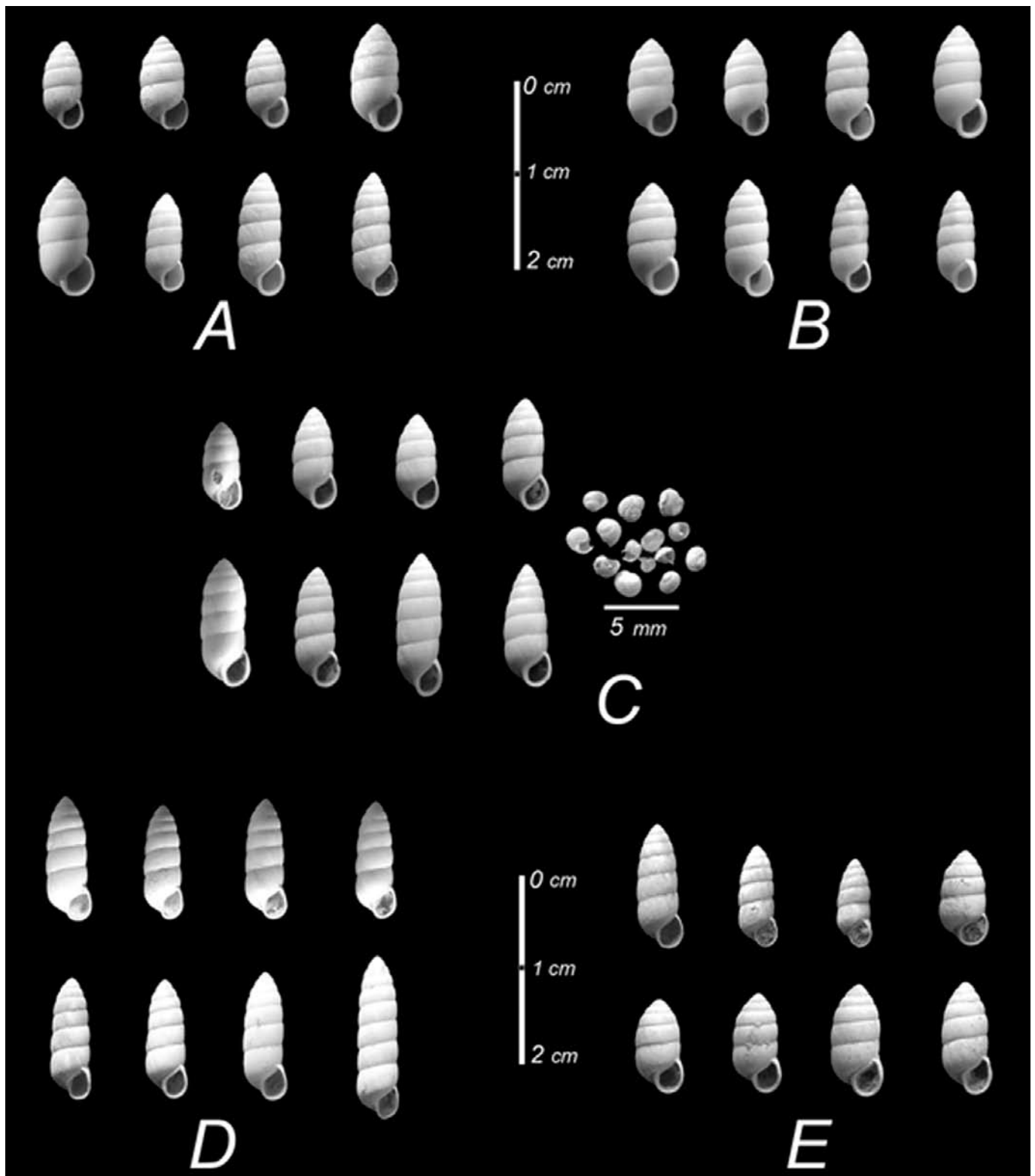


Fig. 10 - *Zootecus* sp.: Examples of different shell shapes. A) Siranda WP 16. B) Siranda WP 31. C) old collection from Uthal with some juvenile individuals. D) Rohri Hills site 59. E) Rohri Hills site 480 (photo A. Girod).

**OBSERVATIONS AND CONCLUSIONS**

On the basis of the biostatistical analysis of specimens from the five sites, it is clear that a large number of shapes in each sample is present. The heights, diameters and roundness indices are far from uniform and in each site the range of values is broad (Figs. 8, 10, 11). The subfossil shells of RH 59, extracted from a restricted archaeological area, have a more uniform elongate shape and diverge from the other samples (Fig. 8). The subfossil specimens of RH 480 have a low variability of shape too; they are small in size, with less whorls and a globular shape (Figs. 8 and 10E). The samples WP 16, WP 31 and Uthal, composed by shells dispersed on the soil surface, differ from RH 59 and RH 480. Their inhomogeneity is caused by the huge quantities of empty shells coming from unknown geographical area(s), periods of accumulation and chronology.

It was only possible to compare the linear regression of the five samples with the mean of the few diameter and height dimension of taxa described in the literature (Tab. 1). *Z. chion* from Hyderabad, *Z. agrensis* and *Z. estellus* differ from the shell shapes of the five samples which fall within the range of variability recorded for the taxa *pullus*, *chion gracilor minor*, *insularis chion*, *polygyratus*, *pertica* (Fig. 11). The description as *Z. chion* of the dead shells from the Lake Siranda is not wrong, giving the archaeomalacologist a partial answer because *Z. pullus* and *Z. polygyratus* have been also listed for Balochistan. The attribution of the right taxon name to the shells enclosed in the other samples is also uncertain.

**Acknowledgments**

Research at Uthal and Siranda was supported by the Italian Ministry of Foreign Affairs (MAE, Rome) and the Cà Foscari University, Venice, Archaeology Research Funds. The authors are grateful to the Uthal Maritime University for conducting the joint project and giving logistic support; to the General Consulate of the Islamic Republic of Pakistan in Italy (Milan) for sponsoring the research project; to Prof. Fred Naggs and Dr. Jonathan Ablett, Natural History Museum London, Dr. Eike Neubert, Naturhistorisches Museum der Burgergemeinde Bern for their kind collaboration and friendly exchange of opinions. A special thanks to Dr. Guido Pacchetti (former Dpt. of Ecology, University of Milan) for his suggestions on the statistical analysis and to Prof. Paolo Biagi (Cà Foscari University, Venice) for having given up the samples RH 59 and RH 480.

**REFERENCES**

Akhtar S., 1978 – On a collection of freshwater molluscs from Lahore. *Biologia*, 24: 437-447.  
 Akhtar S., 2011 – The South Asiatic monsoon and flood hazards in the Indus River, Pakistan. *Journal of Basic and Applied Sciences*, 7: 101-115.  
 Al-Khayat J.A., 2010 – First record of five terrestrial snails in the State of Qatar. *Turkish Journal of Zoology*, 34: 539-545.  
 Auffenberg W., 1994 – The Bengal monitor. *University Press of Florida*, Gainesville.

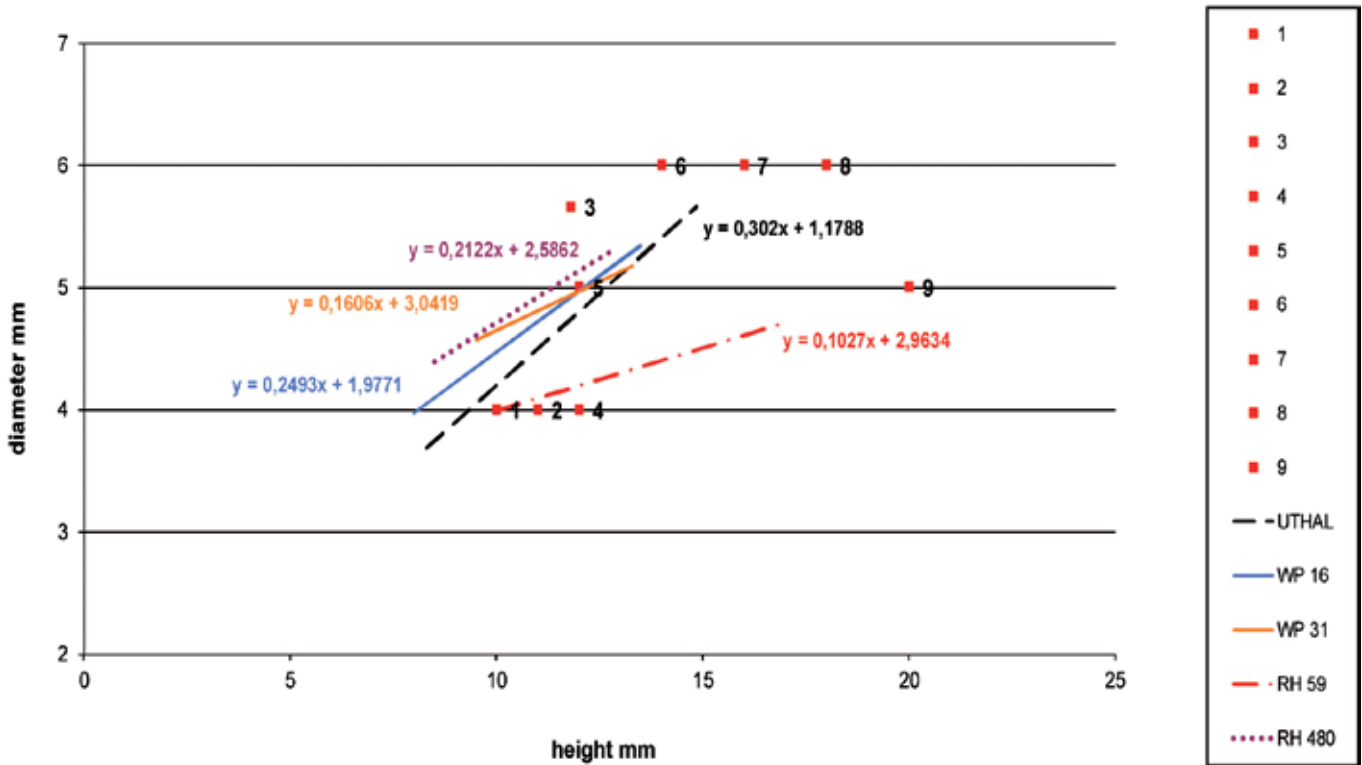


Fig. 11 - Comparison between the linear regression of the five samples and the shapes described in the past literature. 1) *Z. pullus*. 2) *Z. chion gracilor minor*. 3) *Z. insularis chion*. 4) *Z. polygyratus*. 5) *Z. chion*. 6) *Z. chion* from Hyderabad. 7) *Z. agrensis*. 8) *Z. estellus*. 9) *Z. pertica*.

- Biagi P. & Pessina A., 1994 – Surveys and excavations in the Rohri Hills (Sindh-Pakistan): a preliminary report on the 1993 campaign. *Ancient Sindh*, 1: 13-75.
- Biagi P. & Starnini E., 2012 – Technological choices and lithic production in the Indus period: Case studies from Sindh (Pakistan). *Iranian Archaeology*, 2: 21-33.
- Biagi P., Fantuzzi T. & Franco C., 2013a – The shell middens of the Bay of Daun: environmental changes and human impact along the coast of Las Bela (Balochistan, Pakistan) between the 8<sup>th</sup> and the 5<sup>th</sup> millennium BP. *Eurasian Prehistory*, 9 (1-2): 29-49.
- Biagi, P., Girod A. & Nisbet R., 2013b – Prehistoric shell middens, seascapes and landscapes at Lake Siranda (Las Bela, Balochistan, Pakistan): preliminary results of the 2011 fieldwork season. *Journal of Asian Civilization*, 36 (1): 1-25.
- Biggs H.E.J., 1962 – Mollusca of the Iranian Plateau-II. *Journal of Conchology*, 25: 64-72.
- Chaudhari R.D. & Kulkarni A.B., 1993 – Effect of monocrotophos on the protein metabolism of a terrestrial snail, *Zootecus insularis*. *Journal of Ecotoxicology and Environmental Monitoring*, 3 (2): 157-159.
- Chaudhari, R.D. & Kulkarni A.B., 1994 – Aspects of lipid metabolism in the terrestrial snail, *Zootecus insularis* due to monocrotophos intoxication. *Journal of Ecotoxicology and Environmental Monitoring*, 4 (2): 121-126.
- Dales G.F., 1982 – Adaptation and Exploration at Harappan Coastal Settlements. In: Anthropology in Pakistan: Recent Socio-Cultural and Archaeological Perspectives. Pastner S. & Flam L. (eds.). *Indus Publications*, Karachi: 154-165.
- Davison A., Wade C.M., Mordan P.B. & Chiba S., 2005 – Sex and darts in slugs and snails (Mollusca: Gastropoda: Stylomatophora). *Journal of Zoology*, 267: 329-338.
- Feulner G., Neubert E. & Green S.A., 2005 – Land Snails. In: The Emirates, a natural history. Hellyer P. & Aspinall S. (eds.). *Tridend Press Ltd.*, Cape Town: 223-227.
- Fontanilla I.K.C., 2010 – *Achatina (Lissachatina) fulica* Bowdich: its molecular phylogeny, genetic variation in global populations, and its possible role in the spread of the rat lungworm *Angiostrongylus cantonensis* (Chen). Thesis, University of Nottingham, July 2010.
- Fowler J. & Cohen L., 2010 – Statistica per ornitologi e naturalisti. *Franco Muzzio Editore*, Roma.
- Fowler S., 2005 – A rough sheller's guide to the Northern Emirates. *Dubai Natural History Group*.
- Germain L., 1924 – Mission Guy Babault dans les provinces centrales de l'Inde et dans la région occidentale de l'Himalaya, 1914. Résultats scientifiques. Mollusques terrestres et fluviatiles. *Ed. Blondel la Rougery*, Paris.
- Girod A., 2008 – Paleo-environmental considerations about the molluscs of Wadi Abu-Ashem, SW Omdurman (Sudan). *Triton*, 17: 9-14.
- Girod A., 2010 – Terrestrial Molluscs from Takarkori (Libyan Sahara). *Triton*, 22: 27-30.
- Gude F.Z.S., 1914 – The fauna of British India including Ceylon and Burma. Mollusca II. *Ed. Taylor & Francis*, London.
- Haas F., 1959 – Shells collected by the expedition. Annex F. In: An anthropological reconnaissance in West Pakistan, 1955 with appendixes on the archaeology and natural history of Baluchistan and Bahawalpur. Field H. (ed.). *Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University*, 52: 228.
- Hora S.L., 1928 – Hibernation and aestivation in Gastropods molluscs. On the habits of a slug from Dalhousie (Western Himalayas), with remarks on certain other species of Gastropods mollusks. *Records of the Indian Museum*, 30: 357-373.
- Lindauer S., Hinderer M., Steinhof A. & Uerpmann H.P., 2016 – Reservoir effects due to different geological settings in the Eastern United Arab Emirates. *ResearchGate*. DOI: 10.13140/RG.2.1.5144.2164.
- Marinova E., Linseele V. & Vermeersch P., 2008 – Holocene environment and subsistence patterns near the Tree Shelter, Red Sea Mountains, Egypt. *Quaternary Research*, 70: 392-397.
- Mienis H. K., 1979 – *Zootecus insularis* (Ehrenberg) from Currelly's site, Sinai. *Levantina*, 18: 207.
- Mienis H.K., 1992 – A second record of *Zootecus insularis* (Ehrenberg, 1831) from an archaeological site in Sinai, Egypt. *Malacológiai Tájékoztató*, 11: 51-52.
- Naseem S., Sheikh S.A. & Qadeeruddin M., 1996-1997 – Geochemistry and tectonic setting of Gadani-Puhari segment of Bela Ophiolites, Balochistan, Pakistan. *JKAU: Earth Sciences*, 9: 127-144.
- Negrino F. & Starnini E., 1995 – A preliminary report of the 1994 excavations on the Rohri Hills (Sindh - Pakistan). *Ancient Sindh*, 2: 55-80.
- Neubert E., 1998 – Annotated checklist of the terrestrial and freshwater molluscs of the Arabian Peninsula with descriptions of new species. *Fauna of Arabia*, 17: 333-461.
- Neubert E., 2003 – The continental malacofauna of Arabia and adjacent areas II. The genus *Zootecus* Westermund 1887 (Gastropoda: Pulmonata: Subulinidae). *Archiv für Molluskenkunden*, 132: 153-160.
- Pilsbry H.A., 1906 – Achatinidae: Stenogyrinae and Coeliaxinae. In: Manual of conchology 18. Tryon G.W. (ed.).
- Ramakrishna A.D. & Mitra S.C., 2010 – Annotated checklist of Indian land molluscs. *Records of the Zoological Survey of India*, 306.
- Raut S.K. & Ghose K.C., 1977 – Effect of upwardly directed shell aperture on the aestivating land snails *Achatina fulica*. *The Nautilus*, 91: 31-33.
- Snead R.E., 1966 – Physical geography reconnaissance: Las Bela coastal plain, West Pakistan. *Louisiana State University Studies. Coastal Studies Series*, 13: 1-117.
- Snead R.E., 1967 – Recent Morphological Changes along the Coast of West Pakistan. *Annals of the Association of American Geographers*, 57: 550-565.
- Snead R.E. & Frishman S.A., 1968 – Origin of sands on the East side of the Las Bela Valley, West Pakistan. *Geological Society of America Bulletin*, 79: 1671-1676.
- Solem A., 1979 – Some mollusks from Afghanistan. *Feldiana Zoology*, New Series, 1.



- Soliani L., 2005 – Manuale di statistica per la ricerca e la professione. Statistica univariata e bivariata parametrica e non-parametrica per le discipline ambientali e biologiche. Università di Parma. <<http://www.dsa.unipr.it/soliani/soliani.html>> (retrieved on April 2016).
- Wade C.M., Mordan P.B. & Clarke B., 2001 – A phylogeny of the land snails (Gastropoda: Pulmonata). *Proceedings of the Royal Society of London, Series B, Biological Sciences*, 268: 413-422.
- Van Damme D. & Gautier A., 1994 – A malacological mini-mystery almost solved: the genus *Soleilletia* Bourguignat 1885 (Bivalvia). *The Journal of Molluscan Studies*, 60: 425-429.