Cah. Biol. Mar. (1997) 38 : 283-289

Morphometric relationships of *Sphoeroides pachygaster* (Pisces - Tetraodontidae) of the Strait of Sicily (Mediterranean Sea)

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Abstract: Basic morphometric relationships of the puffer fish *Sphoeroides pachygaster* of the Strait of Sicily (Mediterranean Sea) are reported. The species is widely distributed in the area, from 80 m to 400 m depth, and is represented by a well established population. The length structure of the sample used showed a main peak for juveniles at 130-140 mm standard length (SL), and a wide size range (83-405 mm, SL), with females reaching a larger size than males. Bivariate relationships of the basic measurements were analysed according to the allometric model after $\log_e$ linear transformation; standard length was considered as the independent variable. Females and males showed coincident (no sex-related differences) relationships for total length, body height and body thickness, while somatic weight, orbital diameter, interorbital distance and snout length relationships were significantly different according to sex. Length-weight relationships were significantly negatively allometric (slope = 2.6) in both males and females, showing significant differences only in the intercepts.

Résumé : *Morphométrie de* Sphoeroides pachygaster *(Téléostéens : Tétraodontidae) du détroit de Sicile (Méditerranée)*
Les relations biométriques du Tétrodon *Sphoeroides pachygaster* du Détroit de Sicile ont été étudiées. Sur les zones prospectées, cette espèce présente une répartition bathymétrique allant de 80 à 400 mètres. La présence d'individus adultes matures laisse supposer l'existence d'une population bien définie sur l'aire prospectée. La distribution des tailles (longueur standard; SL) varie de 83 à 405 mm avec un mode entre 130 et 140 mm correspondant aux juvéniles. Les femelles atteignent une taille supérieure à celle des mâles. Il n'existe pas de différence significative entre les mâles et les femelles pour les valeurs concernant la relation longueur totale - longueur standard, mais une différence significative apparaît entre les sexes pour les valeurs concernant les relations entre la longueur standard et la hauteur et la largeur du corps, le poids éviscéré, le diamètre de l'oeil, l'espace interorbitaire et l'espace préorbitaire. La relation taille-poids montre une allométrie minorante (b = 2.6) aussi bien pour les mâles que pour les femelles et les sexes confondus; cependant l'ordonnée à l'origine (a) présente des différences significatives.

Keywords : *Sphoeroides pachygaster,* Mediterranean Sea, Strait of Sicily, morphometry.

Introduction

Tetraodontidae, named puffers from their capability of inflation by swallowing water or air, are circumtropical, littoral, medium-sized fish inhabiting the oceans world-wide (Shipp, 1974; Smith & Heemstra, 1986; Tortonese, 1986).

The family is traditionally considered to be poorly represented in the Mediterranean Sea, where five species are generally reported, including the "blunthead blasoop" (Smith & Heemstra, 1986) *Sphoeroides pachygaster*

Reçu le 31 janvier 1997; accepté après révision le 26 janvier 1998.
Received 31 January 1997; accepted in revised form 26 January 1998.

(Muller & Troschel, 1884) (Tortonese, 1986; Golani, 1987; Fredj & Maurin, 1987; Shipp, 1990). This puffer, often quoted by the junior synonym *S. cutaneus* (i.e. Tortonese, 1986), is a deep water species, circumglobally distributed in tropical and temperate seas.

In the eastern Atlantic its distribution ranges from the Irish waters to the South African coasts (Shipp, 1974; Wheeler & van Oijen, 1985; Garcia-Castrillo & Cendrero, 1989; Quéro *et al.*, 1991) and its presence in the Mediterranean Sea was reported for the first time in 1979 (Oliver, 1981; western basin). Records of this species were continuous and numerous in the last decades both in the western (Moreno & Roca, 1984; Crespo *et al.*, 1986; Caminas *et al.*, 1990) and in the central Mediterranean (Barletta & Torchio, 1986; Vacchi & Cau, 1986; Bello, 1990; Fiorentino & Zamboni, 1990; Ragonese *et al.*, 1992; Tursi *et al.*, 1992; Bradai *et al.*, 1993; Arculeo *et al.*, 1994). No record however existed for the eastern Mediterranean (Fredj & Maurin, 1987; Papacostantinou, 1990) until 1991, when some specimens of *S. pachygaster* were caught in Israel waters and near the island of Symi in Turkey (Golani D., personal communication).

Information available strongly support the general opinion which considers *S. pachygaster* a recent immigrant, probably undergoing a fast diffusion eastwards (Ragonese *et al.*, 1992; Arculeo *et al.*, 1994) even though Relini & Orsi Relini (1995) speculated on the possibility of a previous presence of the species within the Mediterranean on the basis of very old ichthyological illustrations.

In the Strait of Sicily, where one of the largest Mediterranean bottom trawl fleet intensively operated since the beginning of the 60's, puffers were never caught nor were they known by Sicilian fishermen till very recently. In the last decade however, captures of puffers became more frequent and data collected after the record by Vacchi and Cau (1986), lead to the hypothesis that *S. pachygaster* is undergoing a very rapid diffusion towards the southern Tyrrhenian and Ionian Sea from a central "core" located off the south-eastern Tunisian coasts (Ragonese *et al.*, 1992).

No detailed information are available on the Mediterranean populations at the moment and only few descriptive measurements are given in the literature. Here an attempt is made to improve the knowledge on the morphometric characters of *S. pachygaster* of the Strait of Sicily.

Materials and Methods

Since 1990 Mazara del Vallo fishermen (South West Sicily, Fig. 1) were interviewed in order to get information on the occurrence and abundance of *S. pachygaster,* which is presently caught exclusively by bottom trawling. Fishermen were asked to provide frozen specimens too, on a voluntary basis, indicating location, date and depth of the captures. Other samples from the seasonal experimental stratified bottom trawl surveys, carried out by the ITPP-CNR of Mazara within the Strait of Sicily from 1990 to 1994, were also collected and examined. Day light hauls of one hour, allocated proportionally to the area, were carried out with a commercial bottom trawl with a 36 mm cod end mesh size.

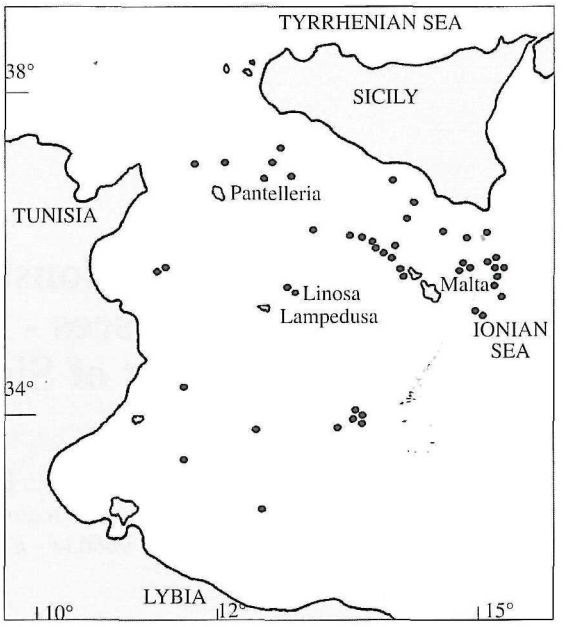

Figure 1. Occurrence sites of *Sphoeroides pachygaster* (solid dots) in the Strait of Sicily (derived from commercial and experimental catch reports).

Figure 1. Lieux de capture (par pêches commerciale et expérimentale) de *Sphoeroides pachygaster* dans le Détroit de Sicile.

On the whole, 403 puffers were obtained and damaged specimens (24 out of 403) were not considered. 379 puffers (212 males and 167 females) were examined. They came from 39 different lots gathered during different months (January, February, March, August, November, December) and years (1990 to 1994) by commercial fishery and are considered here as a unique sample; unfortunately, the total catch from which the samples were derived is not known. The other specimens (n = 24) were caught during nine experimental trawl surveys carried on in May 1990, November 90, January 91, June 91, November 91, January 92, March-April 92, May-June 92 and June 94 by the ITPP-CNR of Mazara.

Fish were defrosted in the laboratory. On well preserved animals the following measurements were taken, to the lowest mm: total length (TL), standard length (SL), height (BH) and thickness (BT) of the body, longitudinal orbital diameter (OD), interorbital distance (ID) and snout length (SNL) (Fig. 2). All measurements were taken according to

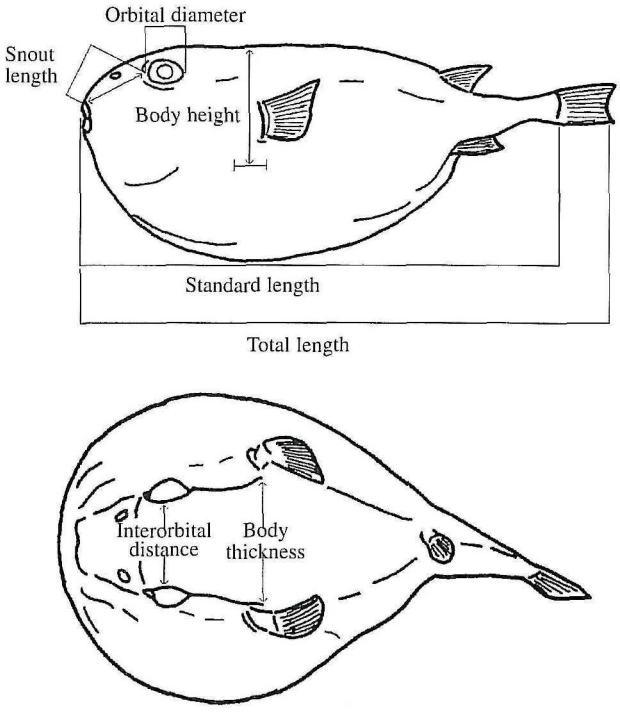

Figure 2. Schematic representation (lateral and dorsal view) of a defrosted specimen of *Sphoeroides pachygaster* showing the morphometric measures taken: total length (TL), standard length (SL), height (H) and thickness (T) of the body, longitudinal orbital diameter (OD), interorbital distance (ID) and snout length (SNL).

Figure 2. Mensurations effectuées sur *Sphoeroides pachygaster* indiquées sur deux schémas (vue latérale et vue dorsale) : longueur totale (TL) ; longueur standard (SL) ; hauteur du corps (H); largeur du corps (T) ; diamètre de l'œil (OD) ; espace interorbitaire (ID) et espace préorbitaire (SNL).

Holden and Raitt (1974) except for height: this was recorded after the location of an arbitrary reference point, due to the highly variable degree of dilatation of fish abdomen (Vacchi & Cau, 1986).

The following measurements of mass, to the lowest centigram, were made: somatic weight (SW; body without viscera and gonads) and gonad weight (GW). Total body weight was not considered in the analysis due to the water (Laroche & Davis, 1973) and debris present in the abdomen.

Bivariate plots with standard length as the independent variable were screened for errors and smoothed ("Lowess" procedure in Systat for Windows, 1992) in order to detect any substantial departure from linearity or abrupt change in the relationship of the transformed data. Suspicious values were not considered in the final computation.

The classic $\log_e$ allometric model :

$$\log_e Y = \log_e a + b^* \log_e X$$

was used to analyse length and weight data where the $\log_e a$ represents the intercept of the line on the Y axis and the b coefficient denotes the kind of allometric relationship: isometric (b = 1 or b = 3 for length and weight respectively) or allometric (negative: b < 1 and b < 3; positive: b > 1 and b > 3). The derived slope (b) of each regression line for the log transformed data was tested for allometric status against the isometric slope (b' = 1 or b' = 3) using a *t*-test (i.e., the ratio between the differences b-b' and the standard error of the slope).

Differences between males and females were tested with an analysis of covariance (Kleinbaum & Kupper, 1978) with the following model:

$$Y = ß_0 + ß_1 X + ß_2 Z + ß_0 X^* Z$$

where Y and X denotes the dependent (sequentially: $\log_e$ TL, $\log_e$ BH, ..., $\log_e$ SW) and the independent ($\log_e$ SL, in the present case) variables respectively, *Z* represents the effect to be tested (sex differences), *X*Z* is the interaction term and $ß_i$ (with i from 0 to 3) the corresponding regression coefficients.

The procedure was as follows: the whole model is fitted and the hypothesis $H_0 : ß_3 = 0$ tested; rejection of this H_0 indicates a difference in the slope (and consequently the intercept) for males and females relationships. Otherwise the two lines are at least parallel (at the probability level of confidence chosen). Then the model is refitted after having excluded $ß_3$ and the testing procedure is repeated for $ß_2$. If the null hypothesis $H_0 : ß_2 = 0$ is rejected that means that males and females have the same slope but different intercepts, otherwise the two lines are statistically coincident and the model 2 is reduced to 1. The level of rejection was placed at p = 0.01.

Individual standard lengths were pooled in classes of 10 mm width (1 cm) for length frequency distributions. Sex ratio was expressed as the percentage of females on sexes combined (F/(M+F)) and was computed for the whole sample and for arbitrary size (SL) categories: "small" (< 155 mm), "medium" (155 - 204 mm), "large" (205 - 250 mm) and "extra-large" (> 250 mm) animals; a χ^2 test was performed on the categorised sex - ratio values. Statistical analysis and computations were performed using the package Systat for Windows (1992).

Results

Main descriptive features and basic measurements taken on the different samples from the Strait of Sicily, considered as a unique sample, are reported in Table 1. The length structure of the sample is showed in Figure 3. Females reached a considerable larger size than males. Sex - ratio was 44.9% on the whole sample and 37.4%, 34.4%, 37.0% and 98.0% respectively for the four size categories considered (small, medium, large and extra-large). In all cases the departure from the theoretical 50% sex - ratio resulted to be significant (whole sample: χ^2 value = 67.7; p < 0.01).

Table 1. Morphometrics descriptive statistics for males and females of *Sphoeroides pachygaster* sampled from the Strait of Sicily.
Tableau 1. Données biométriques obtenues sur *Sphoeroides pachygaster* mâles et femelles du Détroit de Sicile.

Variable	Sex	N	Minimum	Maximum	Mean	Standard error
Total length (mm)	Males	202	95	292	176.4	2.95
	Females	166	125	455	226.1	5.83
Standard length (mm)	Males	205	83	262	153.3	2.59
	Females	167	105	405	198.2	5.83
Body height (mm)	Males	205	17	53	30.9	0.55
	Females	166	18	85	40.8	1.25
Body thickness (mm)	Males	206	14	56	30.5	0.59
	Females	165	18	89	40.4	1.35
Orbital diameter (mm)	Males	106	7	22	12.6	0.24
	Females	165	7	30	14.7	0.41
Interorbital distance (mm)	Males	204	16	41	24.7	0.36
	Females	162	17	65	31.6	0.91
Snout length (mm)	Males	204	15	44	23.5	0.38
	Females	162	15	63	29.9	0.91
Somatic weight (g)	Males	196	26.4	450.0	142.5	6.88
	Females	160	40.0	1974.0	355.0	27.93

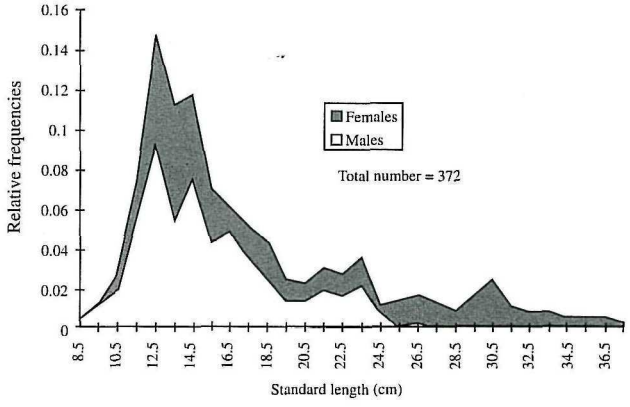

Figure 3. Length frequency distribution by sex of *Sphoeroides pachygaster* of the Strait of Sicily.
Figure 3. Distribution, par sexe, des fréquences de tailles de *Sphoeroides pachygaster* du Détroit de Sicile.

Some slight discontinuity was evidenced by the smoothing techniques, but with no regular pattern, more likely to be a consequence of the sampling method. Females and males showed coincident relationships for total length (TL), body height (BH) and body thickness (BT) and parallel lines for somatic weight (SW), whereas for orbital diameter (OD), interorbital diameter (ID) and snout length (SNL) relationships resulted significantly different, both in slope and intercept values (Table 2). As for the coincident relationships, allometry was positive (slope > 1) for BH and BT and negative (slope < 1) for TL, but differences from the isometric value resulted to be significant only for total length and body thickness.

These results indicate that puffers become "thicker" as they grow in standard length whereas their caudal peduncules become shorter; on the contrary, the relationship between the body height and standard length remains invariant. However, the comparison of the coefficient of determination and standard error of the estimates (Table 2) clearly evidences the higher variability of the SL-BH relationship as a consequence of the difficulty to cope with this measure.

As for the orbital diameter (OD) and the interorbital distance (ID), results indicate a larger variability in males than in females (standard errors are higher and coefficient of determination lower in the former); however, large males tend to have much larger eyes and consequently a shorter interorbital distance than females of the same size, these two parameters being inversely correlated (see the higher intercept and slope coefficients for OD in males, and the higher intercept and slope coefficients for ID in females; Table 2). A significant negative allometry resulted for both variables and sex with the exception of the OD in males for which the hypothesis of isometry cannot be rejected.

A significant negative allometry also resulted for snout length in males whereas the hypothesis of isometry could not be rejected for females.

Standard length-somatic weight relationships were significantly negatively allometric (slope<3) in both males and females, showing significant differences only in the intercepts (Table 2).

Discussion and conclusions

Regression analyses and statistical tests are useful tools to investigate specific and intraspecific differences in allometric growth, but information on the biology of the

Table 2. Morphometric $\log_e$-linear relationships for males and females of *Sphoeroides pachygaster* sampled from the Strait of Sicily.
Tableau 2. Relations biométriques ($\log_e$-linéaires) des mâles et des femelles de *Sphoeroides pachygaster* du Détroit de Sicile.

	Sex	N	Int.	s.e. Int.	b	s.e. b	t_{com}	*0.01 -* *0.001	r^2
Total length	M + F	367	0.242	(0.016)	0.979	(0.003)	7.00	**	0.996
Body height	M + F	370	-1.709	(0.104)	1.021	(0.020)	1.05	NS	0.873
B. thickness	M + F	370	-2.061	(0.065	1.087	(0.013)	6.69	**	0.952
Orbital diameter	M	205	-2.613	(0.168)	1.022	(0.033)	0.67	NS	0.820
Orbital diameter	F	165	-2.134	(0.115)	0.913	(0.022	3.95	**	0.913
Interorbital distance	M	203	-0.930	(0.120)	0.823	(0.024)	7.38	**	0.853
Interorbital distance	F	162	-1.498	(0.085)	0.937	(0.016)	3.94	**	0.954
Snout length	M	203	-1.245	(0.130)	0.875	(0.026)	4.80	**	0.849
Snout length	F	162	-1.768	(0.092)	0.977	(0.018)	1.28	NS	0.950
Somatic weight	M	196	-8.378	(0.162)	2.620	(0.032)	11.87	**	0.971
Somatic weight	F	160	-8.633	(0.117)	2.677	(0.022)	14.68	**	0.989

N = sample size; Int. = intercept; b = slope; s.e. = standard error, $t_{com.}$ and $t_{0.01}$ = computed and critical value of the t statistic to test the allometry status; *= allometric relationship; r^2 = coefficient of determination.

N = effectif ; Int. = ordonnée du point où la droite coupe l'axe des y ; b = coefficient d'allométrie ; s.e. = erreur standard, $t_{com.}$ et $t_{0.01}$= l'écart de la distribution de Student (test de la différence entre estimation et valeur hypothétique) ; * = relation d'allométrie ; r^2 = coefficient de détermination.

species are required to provide an insight into the functional significance of allometric growth itself. Sexual dimorphism in fish is the results of the contrasting balance between costs and benefits driven by the selection pressure on the two sexes (Parker, 1992). Large size in females might be favoured by the need to increase fecundity, even though the longer maturity is delayed the lesser are the chances of surviving to reproduce. Small size in males might indicate no intense sperm production competition at the time of spawning (or contest to mate females) (Parker, 1992). Unfortunately, published information on puffers morphometry are generally few (Laroche & Davis, 1973; Targett, 1979; Pauly, 1991) and sexes are often not separately considered. As for *S. pachygaster* in particular, information are even fewer, especially for the Mediterranean specimens, for which only reports on scattered findings, with few basic biological data, are available and measurements usually reported as single values (Calvario *et al.*, 1980; Bello, 1990; Fiorentino & Zamboni 1990; Arculeo *et al.*, 1994). Therefore, both specific biological information and data to compare populations from different areas are lacking. As a consequence, any attempt to explain and discuss the morphometric relationships obtained for *Sphoeroides pachygaster* of the Strait of Sicily is difficult. The comparison of the observed (not $\log_e$-transformed) individual values did not evidenced any discrepancy between the Atlantic and the Mediterranean populations (Vacchi & Cau, 1986; Rivas *et al.*, 1993), but a statistical test aimed to detect existing differences would require the comparison of the coefficients of the allometric curves.

Despite the above mentioned constraints, due to the wide size range of the sample examined and to the sample size itself, the present results provide a new description of the general morphometry of *S. pachygaster* within the Mediterranean waters, and allow the following considerations.

Basic results are consistent with the known frame for these fish: females reach a larger size than males at all ages in the genus *Sphoeroides* (Welsh & Breder, 1922; Laroche & Davis, 1973) and a negative allometry in the length-weight relationships is of general occurrence in puffers. The slight differences between females and males (not significant in the present case) suggest that females grow relatively better than males considering their strong gonad investment (Welsh & Breder, 1922; Laroche & Davis, 1973; Targett, 1979; Pauly, 1989; 1991).

Results also clearly indicate the need to separately analyse males and females for growth analysis purposes and to focus morphometric measures on well definable parameters, as independent as possible from the deformation of the body.

The effectiveness of using a single relationship for all length ranges examined was also evidenced, even though

further data are required to better clarify this point, since a slight growth discontinuity in subadults and adults was noticed for the Atlantic population (Shipp, 1974).

The wide size range observed in the Strait of Sicily sample (the largest specimen captured, 455 mm TL, is the largest so far reported for the species), its numerical consistence and the presence of several mature females (unpublished data) indicating a sexual complete cycle (Bradai *et al.*, 1993), confirm the existence of a well established, autonomous population.

Up to date it is not known if *Sphoeroides pachygaster* of the Mediterranean can be poisonous but it is well known that tetrodotoxin is found only in fishes of the order Tetraodontiformes (Mosher *et al.*, 1964) and among these, the most toxic species belong to the genus *Sphoeroides*. Uncareful consumption could therefore be lethal. However, many puffers are successfully exploited around the world, and represent a popular food in spite of concern about their potential toxicity (as for the Japanese marketed "fugu", at the moment largely supplied by aquaculture and import). Therefore, adequate toxicological studies on the Mediterranean population would be appropriate and investigations for a possible active exploitation of the Sicilian or other Mediterranean populations is worth a thought.

Acknowledgements

Our deepest thanks to all local fishermen, who made this work possible with their actual contribution. In particular we wish to thank Captains Dell'Arno, Giacalone, Ginnastica, Giunta and Ingargiola.

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