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Morphometric relationships in the Chaetognath *Sagitta setosa* Müller 1847: within population versus between population variability*

PILAR ANDRÉU[1] & TECLA RIERA[2]

[1]Instituto de Ciencias del Mar. Paseo Nacional s/n. 08039 Barcelona. Spain.
[2]Dpto. Ecología. Facultad de Ciencias. Universidad de Barcelona. Diagonal 645. 08028 Barcelona. Spain

SUMMARY: *Sagitta setosa* is a neritic Chaetognath exhibiting a discontinuous geographic distribution. To assess the influence of its discontinuous geographic distribution on morphometric variability between isolated populations, we conducted a biometric study of *S. setosa* from three different locations: Goteborg and Plymouth (North Atlantic) and Barcelona (Western Mediterranean). Our results do indicate some disparity between the populations that is reflected not in size differences, largely determined by water temperature, but in shape (body proportions).

Key words: Chaetognath, *Sagitta setosa*, morphometric variability.

RESUMEN: RELACIONES MORFOMETRICAS EN EL QUETOGNATO SAGITTA SETOSA MULLER 1847: VARIABILIDAD INTER- E INTRAPOBLACIONES.— El Quetognato nerítico *S. setosa* presenta una distribución geográfica discontinua. Se ha llevado a cabo un estudio biométrico de las poblaciones de esta especie a fin de comprobar si el aislamiento geográfico, en condiciones ambientales diferentes, ha inducido variabilidad morfométrica en sus poblaciones. Las diferencias encontradas entre las tres poblaciones de *S. setosa* no son importantes en términos de tamaño, pero presentan algunas diferencias en las proporciones del cuerpo, es decir en la forma, que afectan a la longitud del segmento caudal y a la distancia entre las aletas anterior y posterior.

Palabras clave: Quetognatos, *Sagitta setosa*, variabilidad morfométrica.

INTRODUCTION

Sagitta setosa Müller 1847 is a neritic Chaetognath exhibiting a discontinuous geographic distribution (Fig. 1). Although widespread in the Northeastern Atlantic (ALVARIÑO 1965, 1969; RUSSELL 1933; PIERCE 1941; BARNES 1950; MANKOWSKI 1962; BAINBRIDGE 1963; KHAN & WILLIAMSON 1970; O'BRIEN 1976; SANDS 1980; ØRESLAND 1983, 1986; SOUTHWARD 1984; JAKOBSEN 1971), it seems to be absent south of 47° N (BEAUDOUIN 1971, 1976) in the Atlantic Ocean.

Sagitta setosa has been collected in the Western Mediterranean (CHIRARDELLI 1950; HAMON 1952; FURNESTIN 1960, 1970, 1974; DALLOT 1967, 1978; ANDRÉU 1979, 1985; GUGLIELMO 1976 and SOENEN 1970). In the Adriatic Sea it has been cited by HURE (1955), CHIRARDELLI and ROTTINI (1973), GHIRARDELLI (1975), GAMULIN (1977) and GAMULIN & GHIRARDELLI (1983). According to FURNESTIN (1968) *S. setosa* belongs to the portion of the boreal fauna that has remained, in certain areas of the Mediterranean Sea.

Besides the geographic and genetic isolation of the Atlantic and Mediterranean populations, these populations experience very different environmental conditions (e.g., temperature, salinity) that could have produced important morphological divergences

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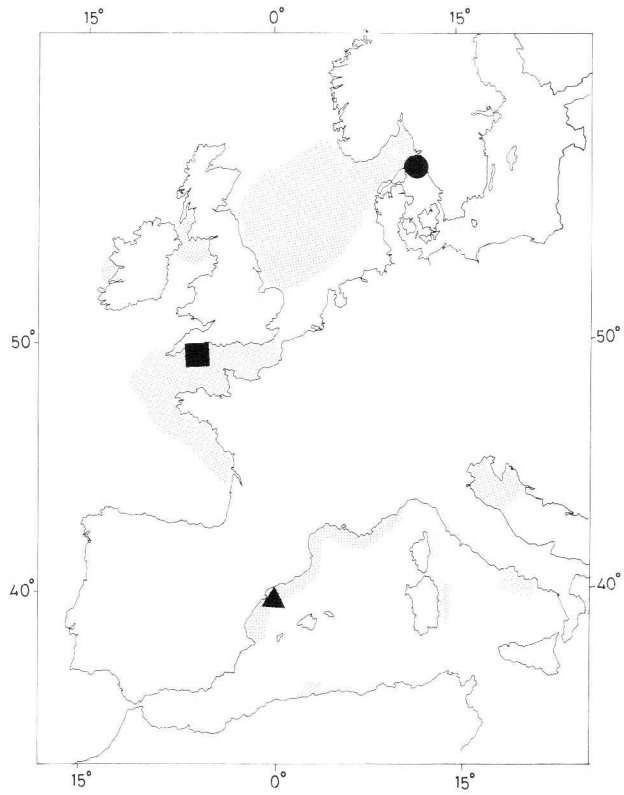

FIG 1. — Distribution of neritic Chaetognath *S. setosa* after different authors (dotted area). The individuals studied were from to three different areas: Goteborg, Plymouth and Barcelona.

between them, and may develop, provided enough time in isolation, genetic differences (MARCUS 1986; BUCKLIN 1986).

Here we examine the morphometric characteristics of Atlantic and Mediterranean populations to quantify whether there is any evidence for morphological divergence between them.

MATERIAL AND METHODS

The individuals measured were collected in Goteborg and Plymouth (North Atlantic) and Barcelona (Western Mediterranean), in springs, summer and autumn (Table 1).

Temperature and salinity data as well as the characteristics of the sampling methods can be found in ØRESLAND (1983, 1986), ANDRÉU (1985) and ARIAS *et al.* (1987).

The specimens were counted and measured under a stereo microscope. Body length (LT) was measured from the top of the head to the end for the tail, excluding the tail fin. To describe form, we measured

TABLE 1.— Date, number of individuals measured, size range in mm, temperature and salinity from the three locations studied.

Location	*Date*	*N.° ind.*	*Size range*	*Mean*	*Salinity*
			LT (mm)	*Temp. °C*	*Range ‰*
GOTEBORG	May	11	6.8-12.1	9	16-31
GOTEBORG	June	5	6.9-13.8	12	16-31
GOTEBORG	September	27	6.7-12.3	15	16-31
PLYMOUTH	February	4	12.0-13.8	9	35
PLYMOUTH	June	19	9.1-12.8	13	35
PLYMOUTH	September	21	9.0-11.1	16	35
BARCELONA	March	7	9.8-12.0	12	37.8
BARCELONA	June	21	7.9- 9.8	18	37.8
BARCELONA	September	21	7.8-10.0	21	37.8

the following dimensions: length of the tail segment (SC), position of the ventral ganglion in relation to the anterior fin (AA-GV), distance between the posterior end of the anterior fin to the posterior fin (AA-AP), posterior fin length (AP), length of the segment of the posterior fin over the trunk (APT), length of the posterior fin over the tail (APC), ovaries length (LO) and diameter of mature eggs (DH) (Fig. 2).

The maturity stages were determined according to the Russell classification as modified by ZO (1973). Only mature individuals were considered for this study.

Principal component analysis was used to study the variation among populations (THORPE, 1976). The analysis was based on the correlation matrix between the different dimensions considered, after logarithmic transformation.

To quantify the form of *S. setosa* for each population and sampling period, we calculated allometric coefficients relating linear body dimensions (D) to total length (LT) according to the equation,

$$D = aLT^b$$

where the exponent (b) reflects the fractional change in the particular body dimension measured with changes in body length, using the total length as reference. Allometric equations were calculated for each site and date, using least squares regression analysis, for error in estimating body length is much less than that in estimating the other dimensions considered. This equation provides a convenient framework to relate animal characteristics to body size (PETERS, 1986).

Form variability was then assessed from variability in the allometric coefficients. To evaluate the im-

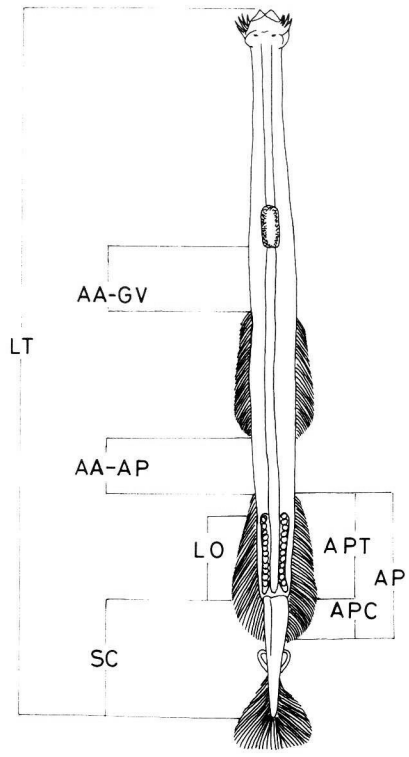

FIG 2. — Description of the characters measured: LT, body lengh. SC, length of tail segment. AA-GV, Anterior fin-Ventral ganglion distance. AA-AP, Anterior fin-Posterior fin distance. AP, Posterior fin length. APT, Length of posterior fin over trunk. APC, Length of the posterior fin over tail. LO, Ovarion lenght. AP-VS, Posterior fin-Seminal vesicles distance.

TABLE 2.— Allometric coefficients for the dimensions considered in the different locations. Above, pooled data; in parentheses, for the different seasons.

	Goteborg	*Plymouth*	*Barcelona*
SC	0.8 (0.8-0.8-0.7)	1.1 (1.1-1.3-1.1)	0.8 (0.8-0.8-0.7)
AA-AP	0.9 (1.2-0.7-0.9)	1.8 (4.3-2.3-2.5)	2.3 (1.9-2.7-3.2)
AA-CV	1.1 (1.3-0.6-1.1)	2.3 (6.5-2.2-3.1)	2.6 (2.2-3.1-2.8)
LO	1.9 (2.4-1.3-1.9)	2.0 (2.1-2.2-3.1)	2.6 (1.9-3.4-4.1)
AP	1.1 (1.2-1.1-1.0)	1.1 (3.4-1.3-1.4)	1.2 (0.8-1.4-1.7)
APT	1.2 (1.2-1.2-1.3)	1.2 (1.7-1.4-1.4)	1.4 (1.1-1.9-1.7)
APC	1.0 (1.1-0.9-0.9)	1.2 (2.1-1.4-1.5)	1.3 (0.9-1.9-1.5)
DH	1.0 (1.1-0.5-0.9)	1.9 (7.9-2.6-2.5)	1.1 (2.0-1.4-1.4)

portance of variability *within* populations compared to variability between populations, we partitioned the variability in the allometric coefficient (b, Eq. 1) among a population (i.e., site) and a within population (i.e., date) component using variance component analysis (SOKAL & ROHLF 1969).

The importance of water temperature on body size has been demonstrated for many marine organisms (KINNE 1970). Therefore, we tested whether water temperature could account for some of the variability of *S. setosa* form by calculating correlation coefficients between mean water temperature for each season and site and the allometric coefficients.

RESULTS AND DISCUSSION

Principal component analysis (PCA) explained 65.9 % of the total variance (PC1 47.7 %, PC2 18.2 %). The first component was related to the total body length as observed in previous morphometric studies (RIERA, 1983) and, consequently, it does not discriminate among populations. The second axis appears to be related with two of the dimensions considered: anterior fin-posterior fin distance (AA-AP) and anterior fin ventral ganglion distance (AA-GV). Thus, the information provided by PCA did not contribute much to show morphometric variations among populations.

The allometric coefficients from the different populations are shown in Table 2. The individuals from Goteborg show nearly isometric growth with respect to total length, while the trend for the Barcelona population is a positive allometry, which means that different dimensions increase faster than the total length. These overall difference between the Atlantic and Mediterranean populations indicate some genetic influences of their isolation.

However, the variation in the allometric coefficients according to site and date shows that the *within* population variability is greater (i.e., high variance contribution from sampling dates) than the variability *among* populations (i.e., among locations; Fig. 3). The exact contributions of these two sources of variation differ depending on the linear dimensions considered. The between population variability in the allometric exponents for the caudal segment and anterior fin-posterior fin distance is greater than the *within* population variability. This suggests the existence of an important genetic contribution to morphometric variability in these populations, beyond the influence of differences in water temperature.

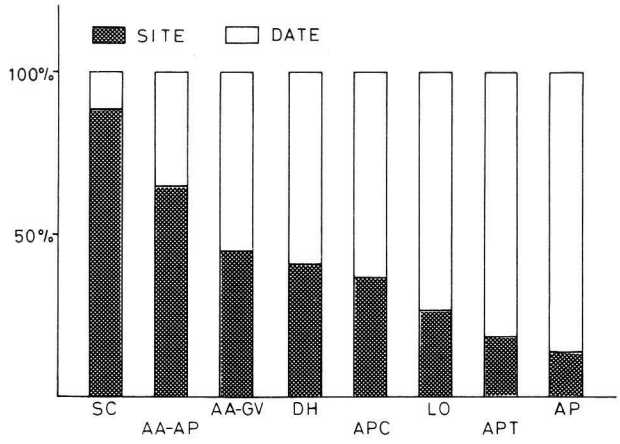

FIG 3. — Percentage of variation in the allometric coefficients according to site and date for the dimensions considered.

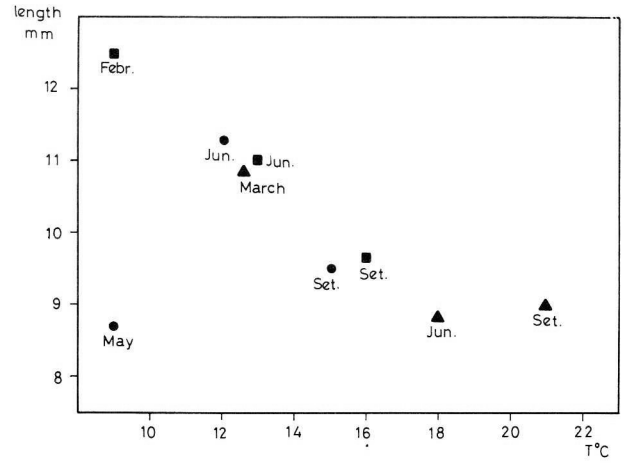

FIG 4. — Relationship between temperature and mean total length in different months. Goteborg. Plymouth. Barcelona.

The correlation matrix among temperature, total length expresed in mm, and the allometric coefficients is shown in Table 3. Total length was negatively correlated with water temperature (—0.55) in agreement with findings elsewhere for *S. elegans* (MCLAREN 1966). Consequently, the individuals from Goteborg and Plymouth, living at lower temperatures, should be larger than thoes from Barcelona. This trend was observed for all individuals except for the Goteborg specimens collected in May, that were smaller than expected (Fig. 4). This discrepancy could be explained by food limitation during development or transport of individuals from other areas (ØRESLAND, 1986).

Water temperature is also highly correlated (r = 0.77) with the allometric coefficients describing the change in ovarian length with change in total length. This would indicate that the Barcelona population should have larger ovaries for their size, although this difference appears to be under phenotypic control.

Although the morphological differences between Atlantic and Mediterranean populations were modest, our results do indicate some disparity between the populations that is reflected not in size differences (largely determined by water temperature), but in body proportions. These differences however, could be accounted for by adaptations to environmental peculiarities of the two populations and by genetic drift determined by geographic isolation of the populations.

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TABLE 3.— Correlation coefficients matrix between temperature, total length (mm) and the allometric coefficients. Significance levels * = 5 %.

	T	*LT*	*SC*	*AA-AP*	*AA-GV*	*LO*	*AP*	*APT*	*APC*	*DH*
T	1									
LT	−0.55	1								
SC	−0.38	0.56	1							
AA-AP	0.16	0.30	0.42	1						
AA-CV	−0.10	0.45	0.47	0.94*	1					
LO	0.77*	−0.61	−0.16	0.52	0.27	1				
AP	−0.22	0.50	0.43	0.83*	0.91*	0.14	1			
APT	0.47	−0.08	0.12	0.78*	0.65	0.70*	0.61	1		
APC	0.16	0.12	0.44	0.88*	0.84*	0.55	0.79*	0.90*	1	
DH	−0.40	0.67*	0.61	0.80*	0.93*	−0.05	0.91*	0.40	0.67*	1

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