J. Mar. Biol. Ass. U.K. (1999), **79**, 1137–1138
Printed in the United Kingdom

A single maturity classification key for five common Mediterranean chaetognath species

G. Kehayias, C. Koutsikopoulos*, N. Fragopoulu and J. Lykakis

Section of Animal Biology, Department of Biology, University of Patras, 26 500 Patra, Greece
*E-mail: ckoutsi@upatras.gr

A single maturity classification key applied to five common chaetognath species of the eastern Mediterranean is presented. The efficiency of the key was tested using biometrical data: body length (BL), ovary length (OL) and seminal vesicle width (SVW). For each species the key proved easy to use and efficient in the distinction of the maturity stages providing a satisfactory size separation between them.

Chaetognaths are protandric hermaphrodite animals; the female and male gonads appear in different locations in the body and they become mature at different phases of the life cycle. All chaetognath species do not follow the same sequence in their development and the degree of protandry is species specific. For this reason it is difficult to obtain a classification base valid for all species (Alvariño, 1992). Several schemes for the classification of the maturity stages of chaetognaths have been proposed, and the number of stages adopted ranges from three to six (reviewed by Alvariño, 1965). Many authors have developed their own identification system based on the developmental characteristics of a particular species largely dominating the chaetognath community (King, 1979; Williams & Collins, 1985). In the eastern Mediterranean, where the number of coexisting chaetognath species is usually greater than five (Furnestin, 1979; Kehayias et al., 1994), the use of several classification keys decreases the possibilities of interspecific comparisons. A single maturity classification system has been applied to five common chaetognath species of this area (Table 1). This system is based on the ovary and seminal vesicle development and can be considered as a modification of Ghirardelli's (1961) key established for *Sagitta enflata*. In comparison to other identification systems, it is based on fewer developmental stages (4) and it does not take into account, as a classification characteristic, the testes development, because their observation is difficult without using staining techniques (Sands, 1980). Furthermore, the efficiency was investigated (the facility and mainly the clarity in the distinction of the maturity stages) by using biometrical data: body length, ovary length and seminal vesicle width.

All classification criteria separate the development of chaetognaths into a number of stages based on phyletic characteristics of the animals that change during maturation. The development is always associated with growth, and each stage of maturity represents a particular size range in the population. Thus, the stages of a classification key reflect the ontogenic development of the organisms. As sexual maturation is a continuous process, not synchronous for all the individuals, its separation into a number of stages leads to an overlapping of the range of morphometrical parameters. This can be evaluated by the comparison of biometrical parameters such as body length, ovary length and seminal vesicle width between the different stages. The success of the classification increases as the overlapping of the biometrical characters corresponding to the different stages decreases.

Zooplankton samples for this study were collected from two neritic areas (Kisamos and Patraikos Gulf) in Greek waters (eastern Mediterranean) with a WP-2 net (200-μm mesh size). In Kisamos Gulf (23°40′E 34°35′N) zooplankton sampling was conducted on six sampling occasions from September 1988 to July 1989, while in Patraikos Gulf (21°43′E 38°14′N) on six sampling occasions from February to August 1992. The chaetognaths were identified to species level and classified to maturity stages according to the present key. From each sample a number of random selected chaetognath specimens were examined and measured. Body length (BL) was measured from the top of the head to the end of the tail, excluding the tail fin. Measurements were also taken on ovary length (OL) and seminal vesicle width (SVW).

Among the 1526 specimens of the five chaetognath species measured from both areas, 42.7% were *S. enflata*, 18.6% were *S. bipunctata*, 16.6% were *S. serratodentata atlantica*, 14.6% were *S. minima* and 7.5% were *S. setosa*. Stage II specimens represented the higher percentage in the population of *S. enflata* while stage III specimens dominated the populations of the other four species.

The use of the present key resulted in a good size separation of the selected morphometrical characters (BL, OL, SVW) between the four developmental stages of the five studied species (Figure 1). There were statistically significant differences in BL among the four stages of development for all species

Table 1. *Definition of the main features of the classification of chaetognaths maturity stages.*

Developmental Stage	Characteristics
Stage I	Young without visible ovaries
Stage II	Visible ovaries but not visible seminal vesicles
Stage III	Both ovaries and seminal vesicles visible
Stage IV	Seminal vesicles filled with sperm, large ova in the ovaries

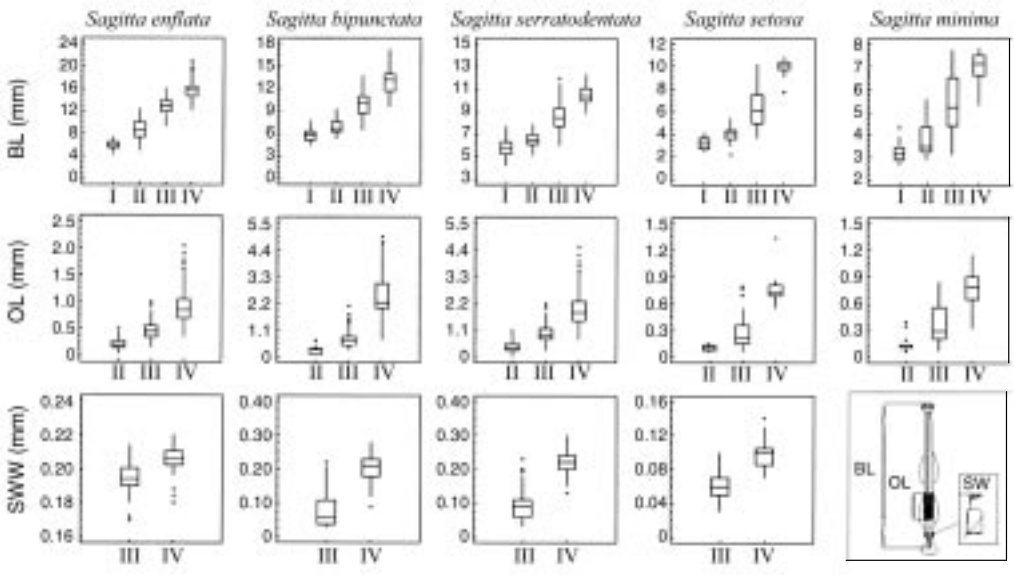

Figure 1. Changes in the body length (BL), ovary length (OL) and seminal vesicle width (SVW) during the ontogenic development (stages I–IV) following the present classification key. For each stage the plots represent the median value (horizontal segment), the range containing 50% of the individuals (box), vertical segments represent 1.5 times the interquartile range and dots represent scarce individual values.

(one-way ANOVA, $P<0.001$). The increase in the mean BL among stages I and II varied between 12.0% (*S. serratodentata atlantica*) and 45.9% (*S. enflata*), among stages II and III varied between 30.8% (*S. serratodentata atlantica*) and 53.5% (*S. setosa*), while among stages III and IV between 21.7% (*S. enflata*) and 57.5% (*S. setosa*). These results showed a rather regular increase on the BL during the species ontogenic development. A non-significant overlapping between BL ranges of the four stages in all five species was observed with *S. enflata* having the smaller overlap. Moreover, there were statistically significant differences in the OL among the stages II, III and IV for all species (one-way ANOVA, $P<0.001$). The increase of OL between stages was remarkable in species in which the mature ovaries could reach a considerable length like *S. serratodentata atlantica* and *S. bipunctata*. In these species, the increase in the mean OL among stages II–III and III–IV exceeded 200%, while in the other three species it was lower than 100%. There were also statistically significant differences between SVW of stage III and IV for all species (*t*-test, $P<0.001$). No measurements of SVW for *S. minima* specimens were taken because of their small size. The increase in SVW between the stages III and IV for the other four species was from 35.2% (*S. enflata*) to 162.5% (*S. bipunctata*).

The width of the seminal vesicle as an indicator of ontogenic development is proposed for the first time in this study. The width of the seminal vesicle as morphometric character, instead of its length, was selected because this formation has the tendency to swell during maturation, while the length remains unchanged. During maturation from stage III to stage IV (according to the present study) the sperm fills the seminal vesicles provoking considerable increase in the SVW in all five species. Therefore, the SVW can be considered as a characteristic feature of the development in all the studied species. Its progressive increase during maturation contributes to a better body distinction between the maturity stages.

Seasonal variation in BL of all five species was observed. The older developmental stages III and IV, and in some cases even stage II, showed statistically significant differences in BL between the sampling periods in both areas (one-way ANOVA, $P<0.01$). The maximum mean BL in all five species was recorded during the colder seasons while the minimum was observed in summer period. This seasonal variation in BL could be responsible for the wide size range seen mainly in the older developmental stages. Alvariño (1992) stated that differences in size of chaetognath specimens at various stages of maturity may be related to temperature or to variations in the quality and quantity of the food supply.

In conclusion, the proposed single key for the developmental stages of chaetognaths proved easy to use, efficient and could contribute to the development of comparative studies.

REFERENCES

Alvariño, A., 1965. Chaetognaths. *Oceanography and Marine Biology. Annual Review*, **3**, 115–194.

Alvariño, A., 1992. Chaetognatha. Sexual differentiation and behaviour. In *Reproductive biology of invertebrates*, vol. 5 (ed. K.G. and R.G. Adiyodi), pp. 425–470. New Delhi: Oxford University Press and IBH.

Furnestin, M.-L. 1979. Aspects of the zoogeography of the Mediterranean plankton. In *Zoogeography and diversity in plankton* (ed. S. van der Spoel and A.C. Pierrot-Bults), pp. 191–253. Utrecht: Bunge Scientific Publishers.

Ghirardelli, E., 1961. Istologia e citologia degli stadi di maturità nei Chetognati. *Bolletino di Pesca, Piscicoltura e Idrobiologia*, **36**, 5–19.

Kehayias, G., Fragopoulu, N. & Lykakis, J., 1994. Vertical community structure and ontogenetic distribution of chaetognaths in upper pelagic waters of the eastern Mediterranean. *Marine Biology*, **119**, 647–653.

King, K.R., 1979. The life history and vertical distribution of the chaetognath, *Sagitta elegans*, in Dabob Bay, Washington. *Journal of Plankton Research*, **1**, 153–167.

Sands, N.J., 1980. Ecological studies on the deepwater community of Korsfjiorden, Western Norway. *Sarsia*, **65**, 1–12.

Williams, R. & Collins, N.R., 1985. Chaetognaths and ctenophores in the holoplankton of the Bristol Channel, U.K. *Marine Biology*, **85**, 97–108.

Submitted 30 November 1998. Accepted 3 June 1999.