Seasonal changes in population structure and gonadal development of three Euphausiid species

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ABSTRACT

Euphausiid specimens, mainly furciliae, postlarvae, and adults of the species Euphausia lucens, Euphausia vallentini and Thysanoessa gregaria were taken in southern Atlantic waters by R/V “Walther Herwig” and “Shinkai Maru” between May 1978 and February 1979. Sampling was performed by means of a bongo net, obliquely hauled from a depth of 100 m to the surface. A total of 26 samples corresponding to different times of the day were analysed.

Measurements of body lengths of both sexes were made, and females were dissected in order to determine lengths and maturity stages of their gonads; percentages of spermatophore attachments were also determined.

The study area is characterized by the influence of subantarctic waters, and climatic seasonal changes operate on the temperature of upper water levels. Monthly evolutions of examined ovaries showed that the species reached their maturity at the end of winter; the highest frequency of spermatophore attachment was observed in spring (October), and a sudden change in the population structure was observed in January and February samples, where developing forms predominated. The finding of mature females of E. lucens and T. gregaria during those months (the latter with attached spermatophores) and the simultaneous presence of their larval forms suggest the existence of a summer population with a high rate of growth.

**INTRODUCTION**

*Euphausia lucens*, *E. vallentini* and *Thysanoessa gregaria* are distributed in temperate waters of the southern hemisphere, southwardly limited by Antarctic waters (Mauchline, Fisher, 1969). Previous results show that the distribution of these species is mainly influenced by the subantarctic current, extending northward up to *circa* 35°S in the upper strata (Ramirez, 1971; 1973). It is hoped that the present study, which covers only a limited sector, can be extended to other latitudes of the region, in order to provide additional information on the reproductive biology of the species.

**METHODS**

The plankton samples were obtained by R/V, “Walther Herwig” (Federal Republic of Germany) and “Shinkai Maru” (Japan), between May 1978 and February 1979. As cruises did not show a complete geographical coincidence, a common area was chosen (Fig. 1), in order to obtain a temporal sequence; in this way, it was possible to cover many months of the year (cf. Fig. 3).

A bongo net, with 60 cm mouth diameter, equipped with a gauze of 330 μ, was obliquely hauled, never below 100 m in deep waters; a total of 26 samples (preserved with 5% formalin) was obtained through different uninterrupted oceanographic cruises, covering day and night hours; this continuous sampling is supposed to palliate the variations of euphausiid populations due to possible vertical movements. Hydrographical information on temperature and salinity from different levels was available for all stations (Fig. 2). A total of 3 699 euphausiids in different stages of development (furciliae, postlarvae and adults) were sorted from 26 samples corresponding to the area investigated by both ships; total length of the specimens (considered as the distance between tip of the rostrum and posterior margin of sixth abdominal segment) was measured; the telson was not included, because of the high frequency of deterioration of the posterior end. Observations on the attachment of the spermatophore sac were also made in these specimens; and females of different sizes were randomly removed in order to measure their ovary length and to determine their maturity stage. Considering the selective role of the net, stages earlier than furcilia were not included. Soulier's table (1965) was used for the classification of developmental stages; the ovaric development was...
classified on the basis of Roger's scale (1973), with modifications introduced by the authors:
Stage I: reduced ovary, formed by cells of equal size and transparency;
Stage II: all cells are still transparent, central ones beginning to increase their size and differing from those of the periphery, which maintain their original diameters;
Stage III: owing to their increasing size, central cells become polyhedric; they are opaque, with large and transparent nuclei; the germinative layer begins its reabsorption. In this stage, the ovaric volume becomes detectable externally as a thoracic dilatation of the animal.

The relative growth of the ovary was expressed through the Ovary Index, corresponding to the percentage of its length in the total body length. A considerable number of specimens were found to be parasitized by Thalassomyces fagei;

RESULTS

Monthly fluctuation of population structure

Monthly changes are expressed as percentage values in Figure 3; specimens are grouped in 1 mm classes, with indication of their corresponding stages. The maximum
adult size corresponds to E. valentini, while minimum adult sizes were found in E. lucens. A marked increase in the mean size of both species is observed from January to November; during these months, profiles are unimodal; the graphs corresponding to Thysanoessa gregaria during October and November are polymodal, with the highest standard deviations of all observed samples. Larval stages are most abundant in January and a change in the population structure occurs during February, when samples show a predominance of juvenile stages. Although these fluctuations are mostly evidenced in the warm season, developing forms were also found during colder months, albeit in some cases very poorly represented. Figure 4 shows the size distribution of 452 specimens of the genus Euphausia obtained in January; 98 of these corresponded to E. lucens and E. valentini. No conclusive features were found for the specific distinction of the 354 remaining specimens; the frequency polygon suggests a possible correlation between its peak and the juvenile stock of E. lucens. Hence, the 354 specimens were incorporated to the histogram of this species (Fig. 3), although their conditional inclusion in the figure should be borne in mind.

**Monthly evaluation of ovaric maturity**

Figure 5 represents the ovaric maturity of the different species throughout the year. It may be observed that part of the population of Thysanoessa gregaria reaches its third ovaric stage in June, while in Euphausia lucens and E. valentini, this stage is reached at the end of August and in October respectively. In Thysanoessa gregaria, ovaric stages I and II were no longer observed by the end of August, while in E. lucens these stages were still evident in a high percentage of specimens; a transitional change was observed in the ovaric stages of this species at the end of August, which was also observed in T. gregaria specimens caught during August. On the other hand, ripe females of E. Val lentini showed a sudden increase in number during October.

Figure 5

*Monthly frequency histograms showing the percentage representativity of each ovaric stage in the analyzed population.*
Relative ovaric development

The increase in relative size of the female sexual organ is represented in Figure 6, which shows a gradual variation in the slopes of the regression lines, reaching their highest value during October and November. The difference between August and October is more marked in Euphausia species than in T. gregaria. The regression lines of January and February are indicative of the sudden return to ovaric sizes found during winter. Slight differences are observed between the species when comparing their relative gonad sizes during summer. Figure 7 shows the variation curves of ovary lengths, expressed as percentage of the total body lengths; each monthly value corresponds to a mean of measurements from the different samples of each species. The ascending slope of the curve is similar in the three species, as well as the sudden decrease in January, when spawned ovaries are of minimum size. Vertical bars through means indicate the confidence intervals, which show accentuated monthly and specific differences; the higher values for November as well as those for January and February (these two last with exception of E. vallentini), might be partially influenced by the lower number of observed females.

Frequency of spermatophore attachment

Transference of spermatophores has been estimated, in order to determine the mating activity of the different species. Figure 8 represents the percentage of females which carried a spermatophore sac on their thelycum; only positive samples were considered, i.e., other months' populations without the minimal number of implanted females are excluded. T. gregaria exhibits a prolonged period of implantation, from August to February, while in E. lucens this period extends from October to January and in E. vallentini from October.

Figure 6
Regression lines of ovaric evolution. Data are plotted as gonadal growth attained by all individuals during each month against their total length.

Figure 7
Curves of monthly ovaric growth. Points express for each month the mean of the Ovaric Index (percentage of ovary length in total body length); vertical bars represent ±95 confidence limits.
to November. The highest frequency of attachments corresponds to October, with peak values in *E. valentini* (circa 30% of attachment). After these months, values tend to decrease markedly in all species.

**DISCUSSION**

The studied area is under the influence of the subantarctic current, which, though mainly flowing along the external margin of the continental shelf, also determines a thermohaline gradient towards the continent. Data obtained by the Argentine Hydrographic Office indicate the presence of thermoclines during summer at varying depths between 10 and 50 m. During this season, the upper waters usually reach temperatures of 15°C, while underlying layers can be colder than 5°C; during the winter months, due to the mixing processes, temperatures are low in all layers. Figure 2 shows the variations observed at stations: while winter surface temperatures present moderate differences with those of deeper levels, a marked change is observed in the thermocline from October to February. Seasonal changes are also seen to operate in the zooplankton of the sector, a phenomenon which has been observed in previous investigations. Carreto *et al.* (1981), note the ascending values of total biomass during summer; Ramirez (1981) found highest values of copepod numbers in spring; Ramirez and Perez Seijas (1981) mentioned the increase in the adult population of the ostracod *Conchoecia serrulata* during summer; Montú (1971) found a spring increase of total euphausiid larvae. In the present study, the analysis of size distribution also showed the population change produced after November, as a result of the appearance of larvae. Although the factor determining the onset of spawning cannot be exactly determined, its coincidence with the occurrence of peak surface water temperatures should be remarked. Previous authors were unable to determine which factor regulates this process, and remarked that this point “requires much further investigations before any useful conclusions can be drawn” (Mauchline, Fisher, 1969). In this study on population dynamics of *Thysanoessa longicaudata* in the Northern Atlantic, Lindley (1978) suggested that the rate of sexual maturity was controlled mainly by water temperature. In relation to primary production, there is no available information on monthly fluctuation of phytoplankton in this area, though according to studies performed by Mandelli and Orlando (1966), based on photosynthetic assimilation rates of subantarctic waters, the peak values of primary production would be registered during summer; this would represent high food availability for euphausiid larvae which are very abundant in this season.

Since no samples were obtained in December, we were unable to determine the spawning period of the different species; modal values of juveniles of *E. lucens* reached 7 mm (total length) in January, while post larvae and juveniles of *T. gregaria* reached 6 and 8 mm respectively during this month; according to the growth curves of euphausiids in the northern and southern hemispheres computed by Mauchline (1969, fig. 115, 116) from statistical analysis of samples studied by different authors, in order to reach the mentioned sizes the growth period of these species should start in November-December.

The persistence of mature females of *E. lucens* and *T. gregaria* during January and February respectively (in *T. gregaria* with attached spermatophore), is coincident with the presence of larval forms of 3 and 5 mm. As pointed out by Lindley (*op. cit.*), should a second generation occur within the year, the adults derived from the spring spawning would mature very quickly and reproduce as soon as they attain the appropriate stage of development. On this basis, the presence of a summer, fast-growing population can be inferred, though observations were limited to a few specimens of mature females.

Further evidence will be necessary to determine whether this is also the case for southern populations. In relation to this point, the characteristics of *E. valentini* differ from the other two species: its growing population, with a mean of over 13 mm (total length) during February, includes very few larval specimens under 10 mm; this fact is coincident with: 1) the absence of mature females from November onwards, as shown in Figure 5; 2) the
low gonadal values during January and February; and 3) the adjustment of the confidence intervals of its lowest ovaric sizes (Fig. 7).

Although hatching appears to take place in summer, growing specimens of *T. gregaria* were also found during cold months; this evidence, which lacks statistical significance, is also mentioned by other authors (Nepgen, 1957; Einarsson, 1954) for various species.

Considering the monthly profile of total length for each species (Fig. 3), a clear decrease in the rate of body growth was observed during the winter months. The general hypothesis that the decrease in growth rate results from the increasing metabolic demands of the gonads is coincident with our results. Indeed, an ovaric increase is observed during the colder months: its growth was observed during the winter months. The decreasing body length during winter could also be attributed to the low water temperatures, evidenced in the thermic profiles of Figure 2, though this decrease should be also observed in ovaries, which begin to increase their positive allometry from August onwards. Nevertheless, female maturity and relative ovaric growth probably constituted two independent processes: the first had its culmination in late winter (*T. gregaria* and *E. lucens*) or spring (*E. valentini*), when most specimens reached the maturity (stage III); the second process continued until November, being evident through the positive allometry of this parameter in relation to total body length.

In accordance with the results obtained, several facts may be pointed out:

1) Considering their monthly length distribution, the species reached the maximum of their mean sizes in November.

2) The decreasing number of females with attached spermatophores and the attainment of maturity (stage III) were indications of the beginning of massive spawning during the same month.

3) Post larvae of *T. gregaria* were also found, though in low numbers, during the autumn and winter months; *E. lucens* and *E. valentini* larvae were not found after August.

4) The occurrence of post larvae during January is concluded to result from November spawning; the development from nauplii to postlarvae would have taken place during this period.

5) After attaining maturity, ovaries of the three species increase in size markedly during October and November, which is evident from the slopes of their repress lines.

6) Average ovary lengths in summer (January) were much lower, approaching autumn and winter values, presumably because they were spent.

7) In *T. gregaria*, a considerable proportion of mature specimens was observed during February; some of these specimens also had attached spermatophores.

8) The mean size of these specimens was found to be lower than the corresponding value in October, which suggests the presence of a fast-growing summer population.

9) The graph of relative ovaric sizes of the three species denotes an increment of the confidence index during November; the dispersion causing this effect is interpreted as the beginning of the spawning period.

10) A similar dispersion was observed in the summer values of *E. lucens* and *T. gregaria*; this fact could be attributed to the coexistence of developing forms with a few adult specimens.

REFERENCES


