# SIZE COMPOSITIONS OF MALES AND FEMALES IN THE COURSE OF THE LIFE CYCLE OF *EUPHAUSIA SUPERBA*

R.R. Makarov*


## Abstract

Earlier studies did not pay attention to differences in size composition of *Euphausia superba* populations by sex and its seasonal variability. In this paper variations in size and sex composition of samples from commercial catches are analyzed over the reproductive season, using samples from different years. The observed variations were related to stages of krill maturity during the reproductive cycle. Information on size composition by sex is considered to be vital for an understanding of krill population structure. It is suggested that duties of biologist-observers aboard commercial vessels should include not only measurement but also sex determination of adult krill.

## Résumé

Les études antérieures n'ont nullement fait cas des différences de la distribution de fréquences de tailles des populations d'*Euphausia superba* par sexe ou de sa variabilité saisonnière. Dans ce document, les variations de composition par taille et par sexe des échantillons des captures commerciales sont analysées au cours de la saison de reproduction, à l'aide d'échantillons provenant d'années différentes. Les variations observées portaient sur les stades de maturité du krill pendant son cycle reproducteur. Les informations sur la composition en tailles par sexe sont estimées essentielles à la compréhension de la structure démographique du krill. Il est suggéré que les biologistes-observateurs embarqués sur les navires commerciaux aient pour tâche, non seulement de mesurer le krill adulte, mais également d'en déterminer le sexe.

## Резюме

Предыдущие исследования не принимали во внимание различия в размерном составе половых групп популяций *Euphausia superba* и его сезонной изменчивости. В данном труде на примере проб, собранных за разные годы, приводится анализ изменений размерного и полового состава проб на протяжении сезона воспроизводства. Отмеченные изменения были связаны со стадиями половозрелости криля в течение цикла воспроизводства. Информация о размерном составе по половым группам считается необходимой для понимания структуры популяции криля. Наблюдателям-биологам на борту коммерческих промысловых судов предлагается выполнять не только измерение половозрелых особей криля, но и определение их половой принадлежности.


* VNIRO, 17a Verkhnaya Krasnoselskaya Street, Moscow, USSR 107140

Resumen

En estudios anteriores no se ha prestado atención a las diferencias debidas a la variabilidad estacional o al sexo en la composición por tallas de las poblaciones de *Euphausia superba*.. A partir de los muestreos realizados durante varios años en las capturas comerciales, se estudian las variaciones de las composiciones por talla y sexo durante el ciclo reproductor completo. Las variaciones observadas están relacionadas con la fases de madurez del krill en su ciclo reproductor. La información sobre la composición por sexos se considera vital para entender la estructura de las poblaciones de krill. Se sugiere que los observadores-biólogos de los buques comerciales, no sólo se encarguen de medir el krill adulto sino también de determinar su sexo.

## 1. INTRODUCTION

Size composition of *Euphausia superba* (as in all other crustaceans) is the only criterion for examining population age structure in the field. Usually, when analyzing size composition, researchers use modal size for comparison. In general, such analyses are carried out for whole samples without subdividing them into males and females. However, it has been observed that modal size of males and females sometimes differs considerably.

Specialized studies of trends in size composition of males and females in the course of the life history of *E. superba* have not yet been carried out. Earlier isolated observations revealed considerable variations in relative size of males and females at different reproductive stages (Makarov, 1983). Recently collected data have made it possible for us to evaluate these variations in detail. In addition to data on adult krill, available data on juvenile krill were used in analyses of size variations.

## 2. MATERIALS AND METHODS

Samples of *E. superba* taken from commercial catches in different seasons and areas were analyzed for size of males and females at different stages of the active reproduction period - from the beginning of maturation of *E. superba* in spring to the end of spawning and the stage of development in females of "juvenilized" gonads for the next spawning season. Stages of the reproductive cycle are given with reference to developmental stages of females. Specimens were measured to the nearest 1 mm from the tip of rostrum to the end of telson.

An abbreviated scale of maturity stages for females was compiled for the purposes of this study. The following four stages were distinguished (stages of the BIOMASS scale are included in brackets for reference):

A non-mature or at the beginning of maturation (IIB, IIIa-IIIC);

B ready for spawning with developed oocytes (IIID);

C recently spawned (ovaries with residual oocytes), juvenilization of ovaries has not yet started (IIIE);

D post-spawning with juvenilized small ovaries (usually with residual round oocytes surrounded by smaller uniform-sized cells) (IIIC).

The succession of events in the *E. superba* population was considered by observing stages of maturity in males and females as indicators of reproductive cycle stages. Time of sampling was not regarded as of immediate importance for this study. It was considered more important to get results which were not affected by an inter-annual variability caused by differences in dates on which the reproductive cycle stages occurred. For this reason an analysis of the stages of maturity of females has been carried out for all samples combined.

The bulk of the data used are data on adult specimens. However, some data on *E. superba* larvae and juveniles are also used. Specimens were sexed by observing their internal sexual features (petasmas in males were also taken into account). The same procedure was used in sexing larvae. A comprehensive examination of the anatomy of specimens usually made it possible for the sex of larvae at stages Furcilia V and VI to be determined. Larvae were measured up to the nearest 0.1 mm. Ovaries were clearly visible, but observation of sperm glands presented a difficult and time-consuming task. For this reason, if ovaries were not found, the specimen was counted as male. Comprehensive examinations were undertaken periodically after each 8 to 10 specimens analyzed in order to verify sex determination.

## 3. SIZE COMPOSITION OF MALES AND FEMALES

**Larvae.** Size composition and sex of larvae in stages Furcilia V to VI are shown in Figure 1. Samples were taken from a "patch" concentration of krill in the Scotia Sea in March 1969. As can be seen, the size of males and females differs considerably. The maximum size of males is generally greater than of females. Males are more abundant at stage VI, females are more abundant at stage V. It is clear that males are larger and in a more advanced stage of development than females.

**Juveniles.** In general, the size composition of juveniles (i.e., non-mature females with small even-sized oocytes and males with underdeveloped sperm ducts and external sexual features) follows the pattern found in larvae, though not in such an obvious manner (Figure 2). Differences are often observed in frequency distribution and in some cases in modal size. These differences are not always related to absolute size of males and females in any given sample.

**Adults.** As a rule, only samples with a small range of specimen sizes were selected for the analysis. A small size range was typical for samples taken from the South Orkney Is area. Samples from other areas contained some juveniles and were usually rejected.

In spring, at the beginning of reproduction season, when maturing of gonads takes place (stage of maturity A), the size composition of adult males and females is the same as in juveniles (Figure 3).

The modal size of fully matured females (stage of maturity B) was greater than that of males (Figure 4). Samples collected in 1967 present an exception from this rule. It is noteworthy that other samples taken in 1967 in other areas (South Orkney Is) demonstrate a similar tendency.

If samples consist of specimens at different stages of maturity (A, B, C), females are found to prevail to some extent among larger specimens (excluding 1967 data) (Figure 5).

Towards the end of spawning season (females at stage C are dominant) size composition becomes most diverse (Figure 6).

Soon after spawning (females at stages C and D; later stage D only) the observed size composition returns to that observed prior to spawning (Figure 7). As earlier, males have a greater modal size than females, especially when most of the females are at stage D.

## 4. DISCUSSIONS

As can be seen, in the usual and initial size ratio between males and females of *E. superba*, the number of larger males is greater (this applies to larvae and juveniles as well as adults). This was observed earlier by H. Bargmann (1945). Variability in the relative size of males and females is observed in mature specimens, especially during peak reproductive season, during spawning. During this period some females might be larger than males.

What is the reason for such variability? The problem is rather complicated and require special attention. Of course, we can suggest only some preliminary considerations.

Firstly, it could be suggested that a spatial segregation of males and females leads to such variability.

The different rhythms of diurnal vertical migration of krill of different sizes and sexes can be also considered as a possible cause. It is important to remember that all catches are taken in the upper 100 m layer. Indeed, one reported catch using a Juday net (36 cm diameter) from 200 to 500 m and deeper consisted exclusively of males (over 200 males) (Makarov, 1981). However, at the same time, the sex ratio in catches from nearby areas was 1:1. For this reason this catch can be considered as a local phenomenon (Elephant Is area).

Another explanation relates to the preponderance of males or females in commercial catch samples taken over a vast area. A paper on this phenomenon is being prepared for publication. The reason for this may be related to seasonal changes in vertical distribution of males and females. However, the phenomenon is not frequently observed.

The observed regular and temporal variations in the size composition ratio of males to females can not, however, be reasonably explained by the above suggestions. Because variations in size composition ratio correlate well with stages in the reproductive cycle, it will be also necessary to discuss the question of the post-spawning mortality rate in *E. superba.*

Maturation occurs in males earlier than in females and mating takes place long before spawning (Bargmann, 1945; Makarov, 1983). For this reason, post-spawning mortality of males should also take place earlier. Moreover, larger males and females do mature faster. It may also be possible that an increase in male mortality begins shortly before the spawning season (Figure 4).

If these suggestions are correct, females should have a higher modal size, particularly during early stages of the spawning season in *E. superba* populations.

It is likely that an increase in post-spawning mortality in females begins at later stages of the spawning season. During that time, due to the earlier onset of mortality in larger females, the size compositions of males and females become more similar (Figures 5 and 6). In addition, soon after the spawning season and with the passage of time, new smaller adult females (with juvenilized ovaries) are recruited to the population and the size composition ratio of males to females reverts to its usual, initial value (Figure 7).

The above explanations are not the only ones possible and some other population characteristics need to be analysed in order to clarify the problem further. For example, a similar analysis of males can be carried out. The sex ratio is of particular importance. Indeed, the observed sex ratio in samples was highly variable. Future studies should seek to find causes of this variability in connection with the size composition ratio between males and females.

Additional information over all seasons of any particular year is required for these purposes. Such information may be gathered aboard a commercial fishing vessel, because numerous repetitive observations are most important in this case. Commercial vessels more or less maintain their position on fishing grounds and with a transfer of observers from vessel to vessel there is a good chance of covering the whole spawning season of *E. superba*.

Sex determination of krill is not a difficult task because these observations deal only with adult krill. Repetitive observations can be also made very easily.

The type of information described above is valuable for assessing size composition of *E. superba*. Variations in size frequency distribution and, in particular, new additional size peaks may be the result not only of a real shift in occurrence of some size (age) groups, but also of the sequence of reproductive cycle stages. The latter relates to considerable variations in the size ratio of specimens from the same size (age) groups of the population. As was observed, spawning aggregations of krill, even within a limited area, may differ considerably in compositions of females in terms of stages of maturity.

Therefore, the duties of biologists-observers aboard commercial vessels (as suggested at CCAMLR-VII) should include not only daily measurements of krill size but also sex determination of adult krill. The latter is important not only for the acquisition of the information discussed here, but will enhance our knowledge of the biological processes involved. Continuing monitoring of krill size and sex composition in trawl catches (the so-called differentiated approach to measurement) will help researchers to develop an optimal sampling strategy for the subsequent thorough analysis of samples ashore.

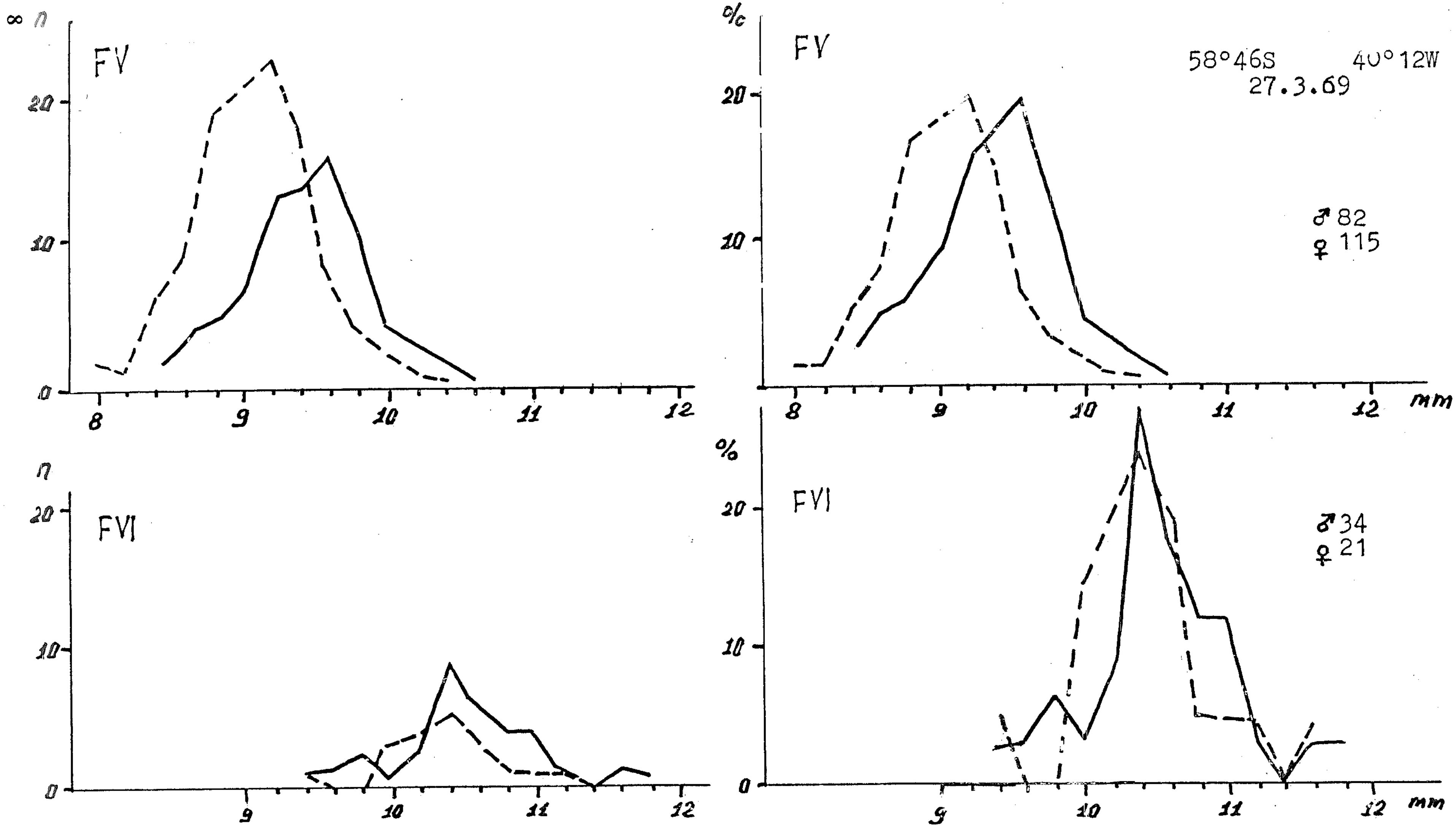



Figure 1: Size composition of *E. superba* males and females, larvae stages Furcilia V and VI. (Males - dotted lines, females - unbroken line).

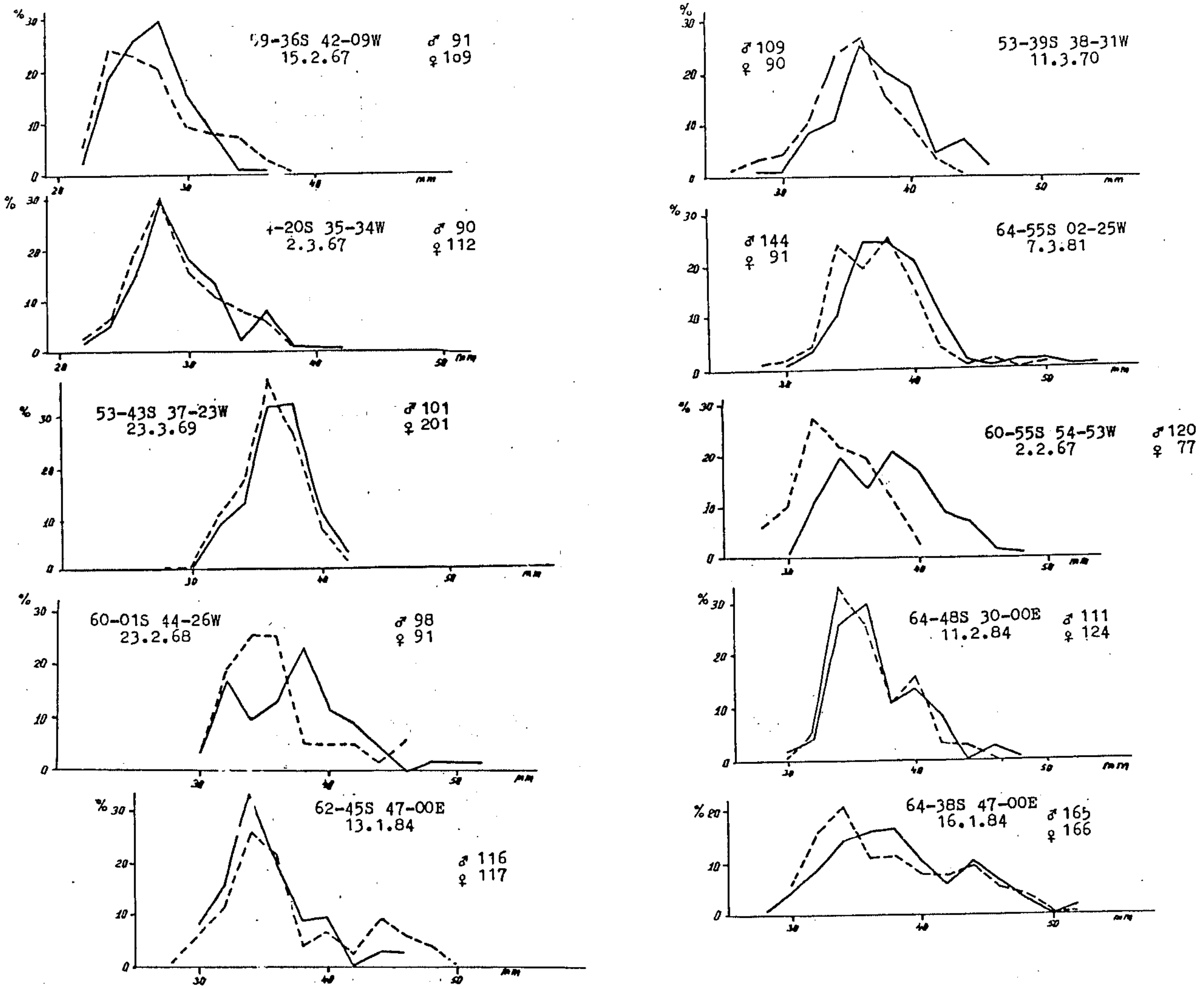



Figure 2: Size composition of juvenile *E. superba*, males and females. (For legend, see Figure 1).

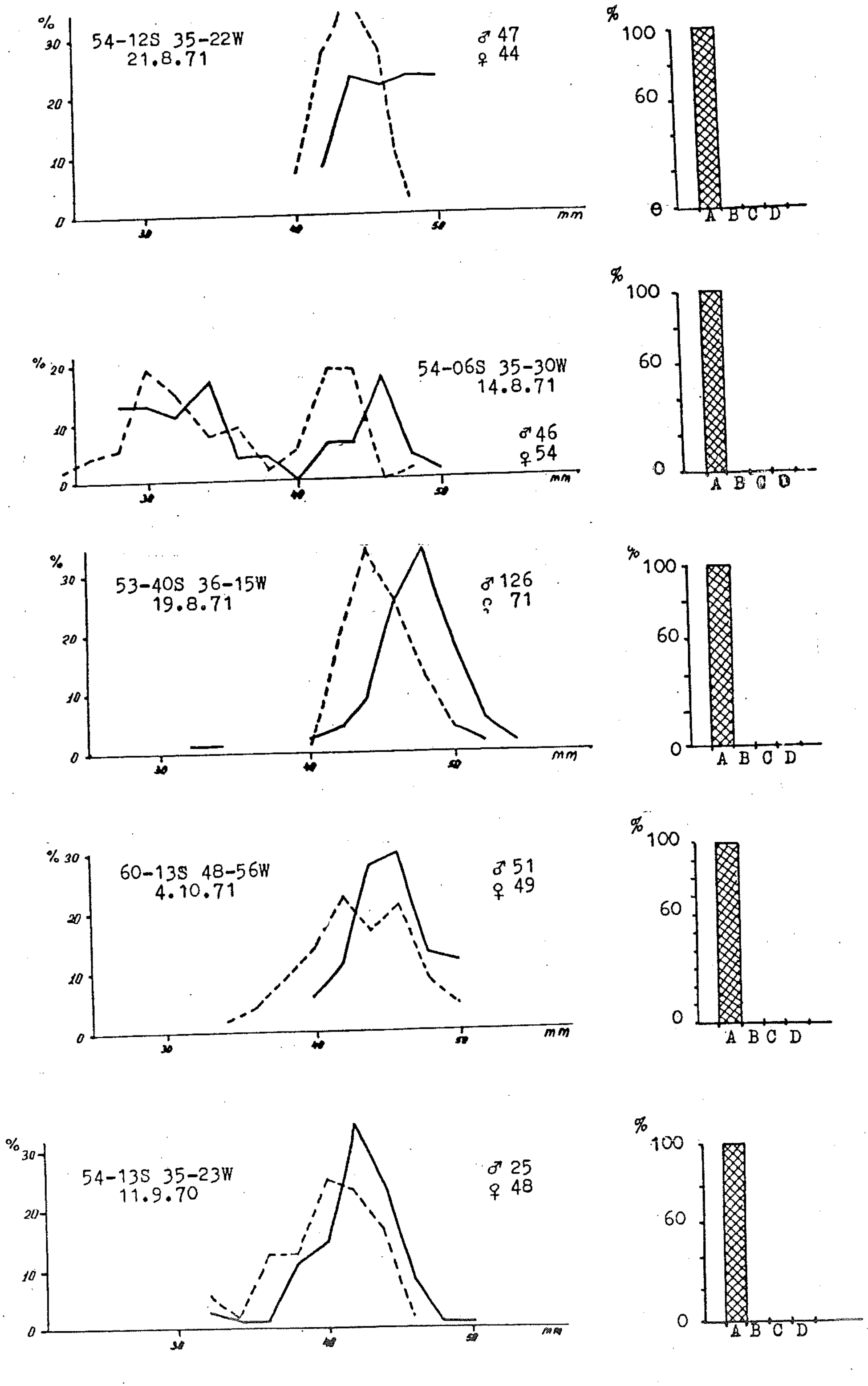



Figure 3: Size composition of *E. superba* males and females in pre-spawning season. (For legend, see Figure 1).

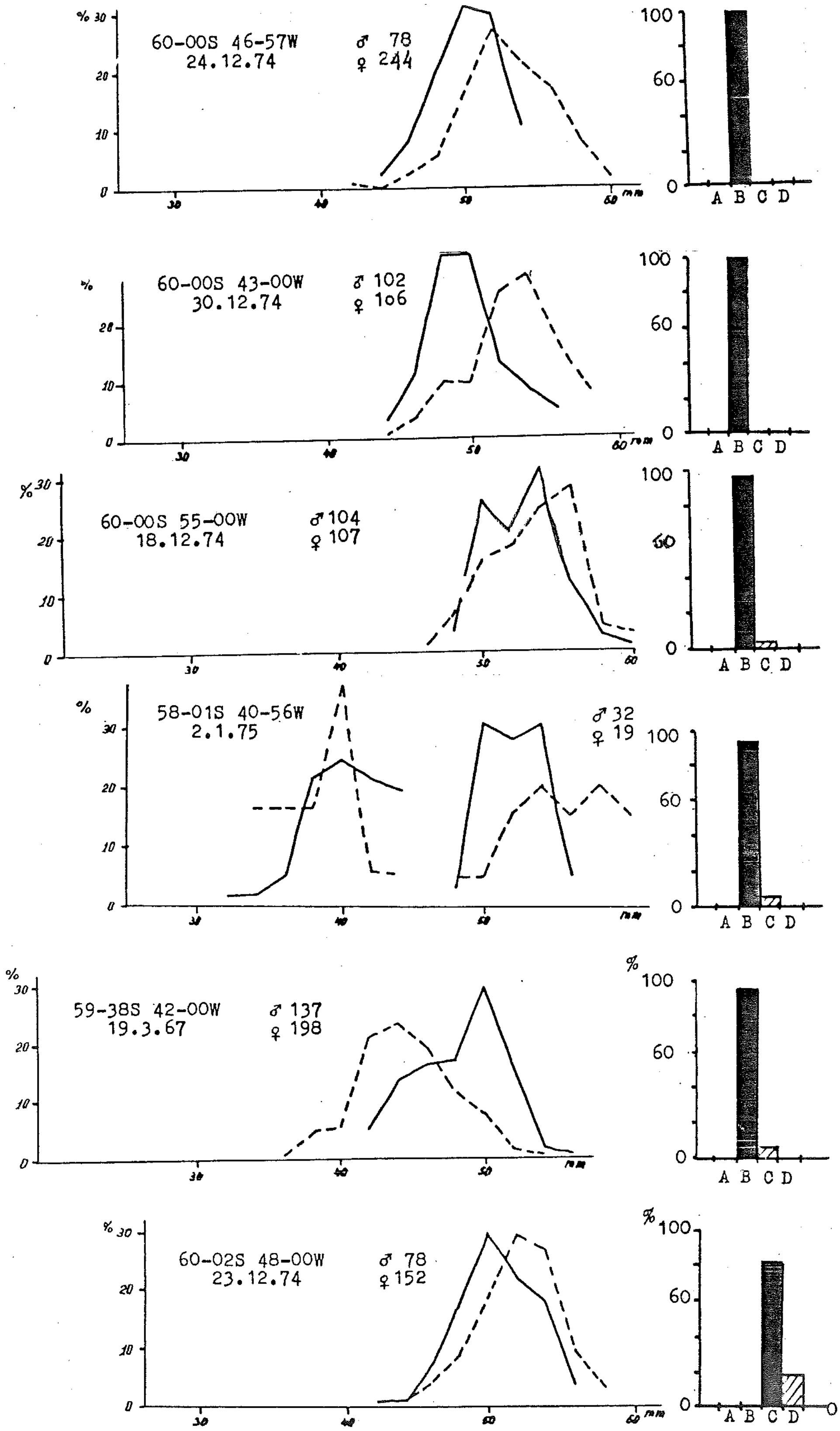



Figure 4: Size composition of *E. superba* males and females at stages of full maturity. (For legend, see Figure 1).

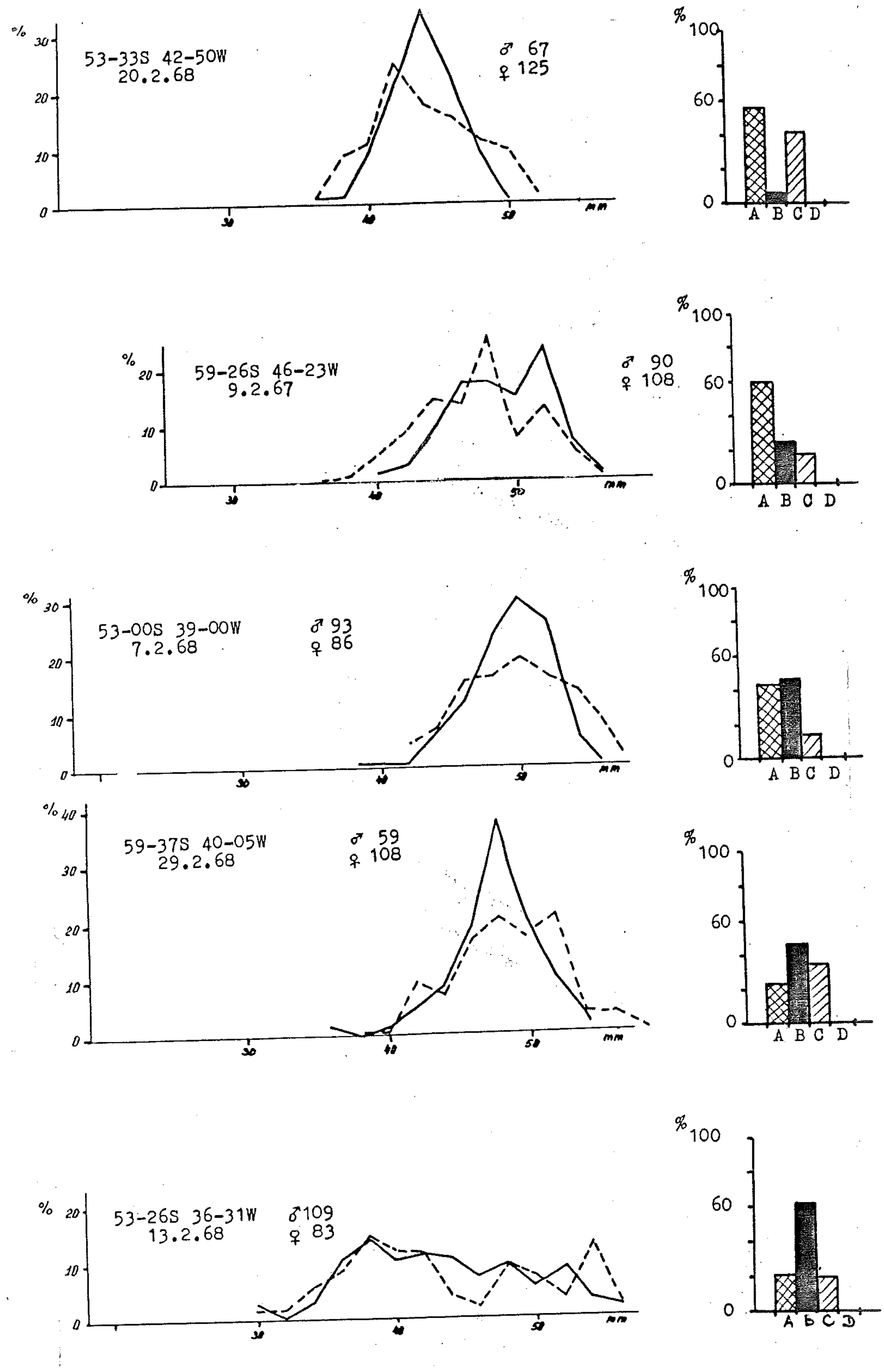



Figure 5: Size composition of *E. superba* males and females in spawning season. (For legend, see Figure 1).

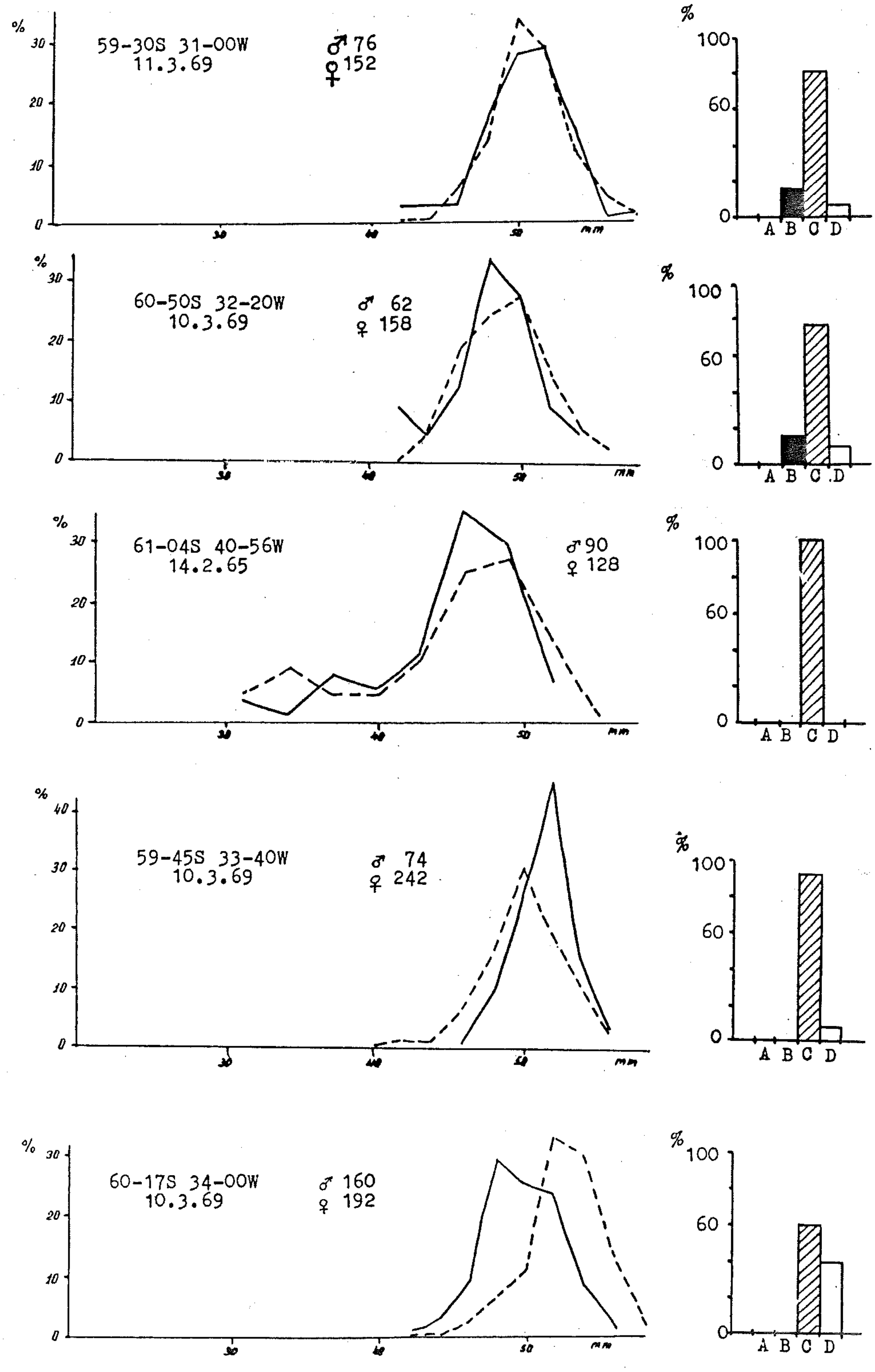
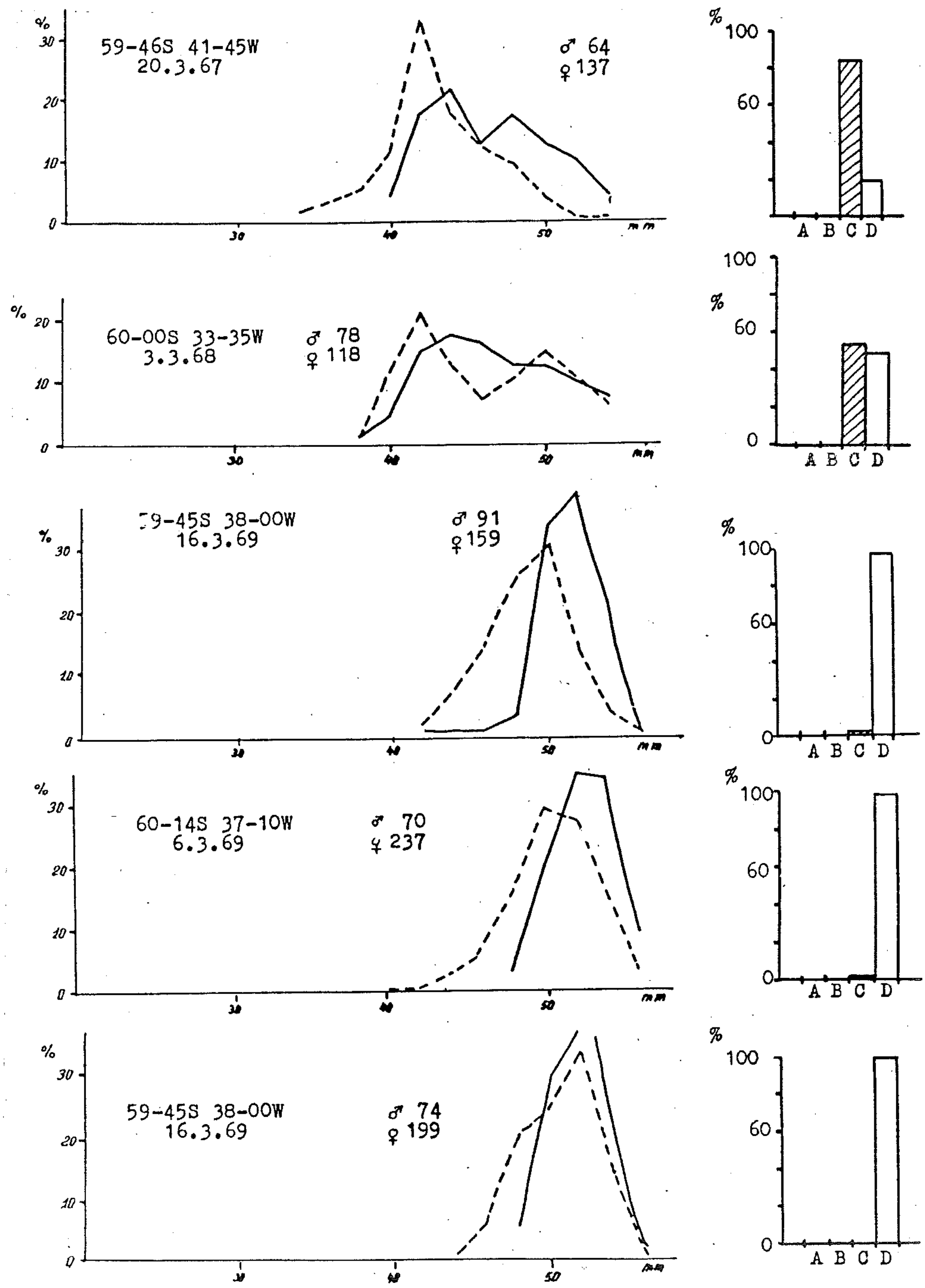



Figure 6: Size composition of *E. superba* males and females towards the end of spawning season. (For legend, see Figure 1).

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