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VERTICAL DISTRIBUTION OF ZOOPLANKTON IN THE GROŠNICA RESERVOIR

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ABSTRACT. The vertical distribution of zooplankton is a problem that has long attracted the attention of investigators. It is usually held that the distribution of zooplankton is influenced in greatest measure by temperature and oxygen content among abiotic factors; and by the distribution of phyto- and bacterioplankton (as sources of food) and by the ichthyofauna among biotic ones. The vertical distribution of zooplankton in the Grošnica reservoir varied greatly throughout the year, and significant differences of distribution were also observed in the same month of different years

INTRODUCTION

The vertical distribution of zooplankton is a problem that has long attracted the attention of investigators. It is usually held that the distribution of zooplankton is influenced in greatest measure by temperature and oxygen content among abiotic factors; and by the distribution of phyto- and bacterioplankton (as sources of food) and by the ichthyofauna among biotic ones.

Studies of zooplankton in our country have primarily referred to faunistic composition or production, whereas a relatively small number of investigations have also dealt with the vertical distribution of zooplankton in reservoirs [4,7].

DESCRIPTION OF INVESTIGATED LOCALITY

For water supply of the city of Kragujevac, a dam was constructed on the Grošnica River in 1938. This resulted in accumulation of the Grošnica Reservoir, the oldest lake of its kind on the territory of Yugoslavia. The system supplied the city with an adequate amount of water up until 1950. However, from that period on, the volume of the lake has undergone significant reduction due to increased consumption and filling with sediments. During the period of 1960-1962, the dam was raised by 7.3 m, so that total volume of the lake comprises 3.53 x 10^6 m^3 [10]. During the warm period of the year, thermic stratification is observed from May to the end of September.

MATERIAL AND METHODS

Monthly sampling was carried out during the period from October of 1996 to September of 1998. In order to gain as accurate as possible a picture of the state of affairs in this artificial ecosystem, three permanent sampling points were selected for qualitative and quantitative sampling: I - directly beside the dam as the deepest part of the lake (the *Dam* locality), where its depth varied from 16 to 23 m, depending on the water level; II - the central part of the lake (the *Center* locality - with a depth of 6-15 m); and III - the shallowest part of the lake (the *End of Lake* locality), which is under water even when its level is lowest (with a depth of 1-5 m). Samples of plankton were taken at every 3 m of depth during stagnation and at every 5 m during circulation.

Qualitative samples of zooplankton were taken with a No. 25 plankton net, while quantitative samples were collected with 2-liter hydrobiological bottles and then filtered across a plankton net. Samples were preserved with 4% Formalin at the collection site, while a smaller number were saved there and later processed in the living state in the laboratory of the Institute of Biology and Ecology of the Science Faculty in Kragujevac, where the samples are stored.

RESULTS

Examining the results for total zooplankton, we are unable to discern any regularity in the vertical distribution of zooplankton and temperature. At the *Dam* locality, zooplankton attains maxima at different depths during stratification, so it cannot be said that reduction of temperature with depth either increases or decreases its abundance (Figs. 1-3). The greatest recorded abundance of total investigated zooplankton was in August of 1997 at a depth of 15m (2013 ind/l), while the second greatest value (1907 ind/l) was in the surface layer in July of 1998. The least abundance was in the deepest layers, especially during the period of stratification: minimal abundance (9 ind/l) was in June of 1997 at a depth of 22m. It would appear that decline of abundance with depth is influenced more by decrease in content of dissolved oxygen, although no decline occurred in August of 1997, for example, even though saturation in layers below 5m was under 10%. On the contrary, an increase of abundance with depth was then recorded (Fig. 2). At the *Center* locality (Figs. 4-6), an increase in abundance of total investigated zooplankton with depth occurs almost by rule (except during the period of May-June of 1997), although the greatest abundance (5900 ind/l) was in August of 1998 at a depth of 5m, the indicated value being the greatest abundance of total investigated zooplankton recorded throughout the entire investigation at any locality (the second greatest abundance in general, 5808 ind/l,was at the *End of Lake* locality in the layer of water-bottom contact, also in August). Evidently, at this locality also, decrease in content of dissolved oxygen, especially pronounced in the summer months of 1997 did not affect the distribution of total investigated zooplankton. Minimal abundance (47 ind/l) was recorded in June of 1996 at a depth of 8m.

In the group Protozoa, it is difficult to discern any regularity in vertical distribution. At both localities, abundance increases with depth during certain periods, but declines with depth at other times. Thus, for example, at the *Dam* locality, abundance increased with depth in August of 1997, whereas the opposite process (Fig. 2) occurred during the following month (September), even though temperature conditions and content of dissolved oxygen did not change significantly (Fig. 14). Maximal abundance at this locality (519 ind/l) was in July of 1997 at a depth of 8m, minimal abundance (2 ind/l) being recorded in June of 1997 at a depth of 22m. The greatest abundance of Protozoa in general (1044 ind/l) was in August of 1998 at a depth of 5m at the *Center* locality (Fig. 57). That minimal values of abundance do not depend upon temperature and oxygen is indicated by the fact that the least number of Protozoa (14 ind/l) was recorded once in the deepest layers (at 12m in May of 1997), but a second time already during the next month (in June) close to the very surface at a depth of only 3m (Fig. 4).

In the group Rotatoria, great variations are expressed in the vertical distribution. The most common situation is that at least two maxima appear throughout the vertical column of water, usually in the surface layer and the layer of water-bottom contact, while abundance varies greatly between these two layers, a third maximum being sometimes recorded, usually in the layer of the metalimnion. At the *Dam* locality, maximal abundance (1437 ind/l) was in August of 1998 at a depth of 15m (Fig. 3), minimal (6 ind/l) in June of 1997 at a depth of 22m (this was at the same time the lowest value in general) (Fig. 1). At the *Center* locality, the highest value (4166 ind/l) was in August of 1998 at a depth of 5m (Fig. 6), the lowest (16 ind/l) in June of 1997 at a depth of 15m (Fig. 4). The greatest abundance of Rotatoria in general comprised 4207 ind/l and was recorded in the shallowest part of the reservoir in August of 1998 just above the bottom (Fig. 6).

The abundance of Cladocera during the cold period and in spring is very low, with the result that the vertical distribution is fairly uniform. In the summer months, Cladocera abundance increases with increase of depth, so that the greatest values are generally recorded in the deepest layers at the different localities. At the *Dam* locality, however, a conspicuously opposite trend was observed, i.e., abundance declined with depth, during the summer months of 1998. At this locality, the greatest abundance comprised 324 ind/l and was recorded in August of 1997 in the deepest layer (Fig. 2), while the minimal value (1 ind/l) was recorded several times, mainly in the deepest layers, but in the surface layer as well in March of 1998 (Figs. 2 and 3). During the colder period and even the summer months in 1998, there were cases where not one representative of Cladocera was recorded in samples from greater depths. At the *Center* locality, abundance almost always increases with depth, the highest value (531 ind/l) being recorded in August of 1998 in the deepest layer (Fig. 6), the lowest (1 ind/l) in June of 1997 (Fig. 4) and February of 1998 (Fig. 5) in the surface layers. At this locality, Cladocera were recorded in all samples. The greatest abundance of Cladocera in general (689 ind/l) was recorded in the shallowest part of the reservoir in the layer of water-bottom contact in June of 1998 (Fig. 6).

Like the group Cladocera, Copepoda are represented by a small number of specimens during the colder period, with the result that the vertical distribution is relatively uniform. As in the group Rotatoria, great variation in vertical distribution occurs during the summer months, and two abundance maxima are often recorded at different depths. At the *Dam* locality, the abundance of Copepoda increased with depth at the beginning of summer in 1997, declined in autumn of that year, and declined without fail in 1998. At this locality, the greatest number of Copepoda (135 ind/l) occurred in August of 1997 at a depth of 12m (Fig. 2), while the smallest number (only 1 ind/l) was recorded several times, for the most part in the deepest layers. In May, June, and September of 1997 and in August of 1998, not a single representative of Copepoda was recorded in samples from the greatest depths (Figs. 2-4). At the *Center* locality, abundance almost invariably increases with depth (there are exceptions from time to time). The greatest abundance at this locality, which at the same time was the greatest abundance in general, comprised 831 ind/l and was registered in August of 1998 at a depth of 8m (Fig. 6), while the minimum (only 2 ind/l) occurred in June of 1997 in the surface layer (Fig. 4). Representatives of Copepoda were recorded in all samples at the *Center* locality.

DISCUSSION

The vertical distribution of zooplankton in the Grošnica reservoir varied greatly throughout the year, and significant differences of distribution were also observed in the same month of different years (Figs. 1-6). Drastic differences are sometimes observed between localities in the same month. During the summer months, thermic stratification and stratification of oxygen are sometimes accompanied by stratification of zooplankton, with decrease of density toward the deeper layers. This was partly the case at the beginning and end of summer in 1997 at the *Dam* locality (Figs. 1 and 3). A similar zonation was also noticed in earlier investigations [4]. At the *Center* locality, an increase of zooplankton abundance in the deeper layers sometimes occurred during the summer. Increase of abundance from time to time in the deepest layers was also recorded by Janković [4], especially in the group Rotatoria. This was observed in the present investigations as well.

Pronounced vertical stratification of zooplankton in the deepest parts of the reservoir during the summer might be attributable to the very unfavorable oxygen and appearance of H_2S in the deepest layers, since this gas is known to exert unfavorable influence on the vertical dsitribution of zooplankton [4]. However, decrease in content of dissolved oxygen in the deepest layers at the *Center* locality did not negatively affect the abundance of zooplankton.

That the vertical distribution of zooplankton is affected by factors other than temperature and oxygen is clearly indicated by the very unequal vertical distribution of zooplankton during the colder period, when values of temperature and oxygen content are the same throughout a vertical column of water.

The vertical distribution of individual groups in the composition of zooplankton is in keeping with that of total zooplankton, although deviations sometimes occur. Thus, a decrease in abundance of most groups in the composition of zooplankton occurred in December of 1996 at the *Dam* locality. However, the abundance of total zooplankton did not decline because an increase occurred in that of Protozoa (above all the species *Tintinnidium fluviatile*) in the deepest layer. Moreover, intensive development of Rotatoria (primarily the species *Synchaeta kitina* and *Keratella quadrata*) at the same locality in June of 1997 was in contrast with decrease in the number of specimens in other groups (Fig. 1). The results on vertical distribution of zooplankton represent a "sector" of the migrations performed by zooplankton. Even though all samplings were done at approximately the same time (10:00-14:00 h), it must always be kept in mind that vertical distribution is hard to attribute solely to positive or negative phototaxias, since many other factors are involved whose importance is not always adequately explained.

Zooplankton is not confined to the illuminated zone, and its vertical distribution is more varied than that of phytoplankton. The vertical distribution is not constant because many species of zooplankton can swim. Specimens of most species usually rise from the deeper layers to the surface, although certain species perform inverse migrations [3]. Light is believed to be one of the factors causing vertical migrations of zooplankton [5]. Studying vertical migrations of zooplankton in Lake Prespa, Serafimova-Hadžišče [9] singled out three ecological groups of zooplankton: the first group consists of species that during the day populate the surface layers (although they are also present in the deeper layers as well), and whose abundance in those layers increases at night because individual organisms then migrate from greater depths; the second group includes species that primarily inhabit the deepest layers; and the third group is composed of organisms that avoid strongly illuminated layers by day, but populate them in great numbers at night.

Ringelberg *et al.* [8] hold that it is difficult to speak exclusively of light as a factor dictating vertical migrations, since they are also governed by the action of internal factors (such as endogenous rhythms of activity) and external factors (such as the amount of food).

There are different interpretations attempting to explain the adaptive value of vertical migrations in aquatic organisms [5]. Because the greatest amounts of food are found in the surface layers, it is logical to ask why zooplankton abandons the food-rich surface layers and enters the food-poor deeper ones. A good reason for doing so is to avoid predators and increase individual chances for survival and reproduction [5,6]. This reduces coincidence of the habitats of planktophagic fish and zooplankton [2]. Avoidance of visually oriented predators is usually considered to be the main adaptive value of vertical migrations [5], although movement into deeper layers can expose organisms to new predators not present in the surface layers [5].

The importance of understanding vertical migrations lies in the fact that they show how the community functions where the photosynthetic activity of phytoplankton is concerned and indicate the level of competition or predation in the case of zooplankton [5]. In studying the vertical distribution of chlorophyll in the oligomesotrophic Lake Samish (USA), Barbiero & McNair [1] recorded the greatest amount of chlorophyll in the metalimnion as a consequence of dominance of diatoms and chrysophytes in that layer. The authors cite the Si gradient as the most important factor determining the vertical distribution of those forms. It has even been demonstrated experimentally that vertical migrations of the species *Diaptomus kenai* (Calanoida, Copepoda) are lacking in the absence of predators, whereas vertical migrations in the opposite direction occur when a predator (*Chaoborus*) is introduced [5].

One of the problems in understanding regularities governing vertical migrations is that there are no methods suitable for monitoring individual plankters in open water, available methods making it possible to monitor only vertical distribution of the population instead [5]. Field investigations must not solely confine themselves to data on the vertical distribution of zooplankton by day and at night, but should also include data on temperature, food distribution, and (where possible) predators [6].

Evidently, the problem of vertical migrations will further occupy the attention of many investigators, since "after more than 150 years of field studies and 100 years of laboratory experiments, vertical migrations remain an enigma" [8].

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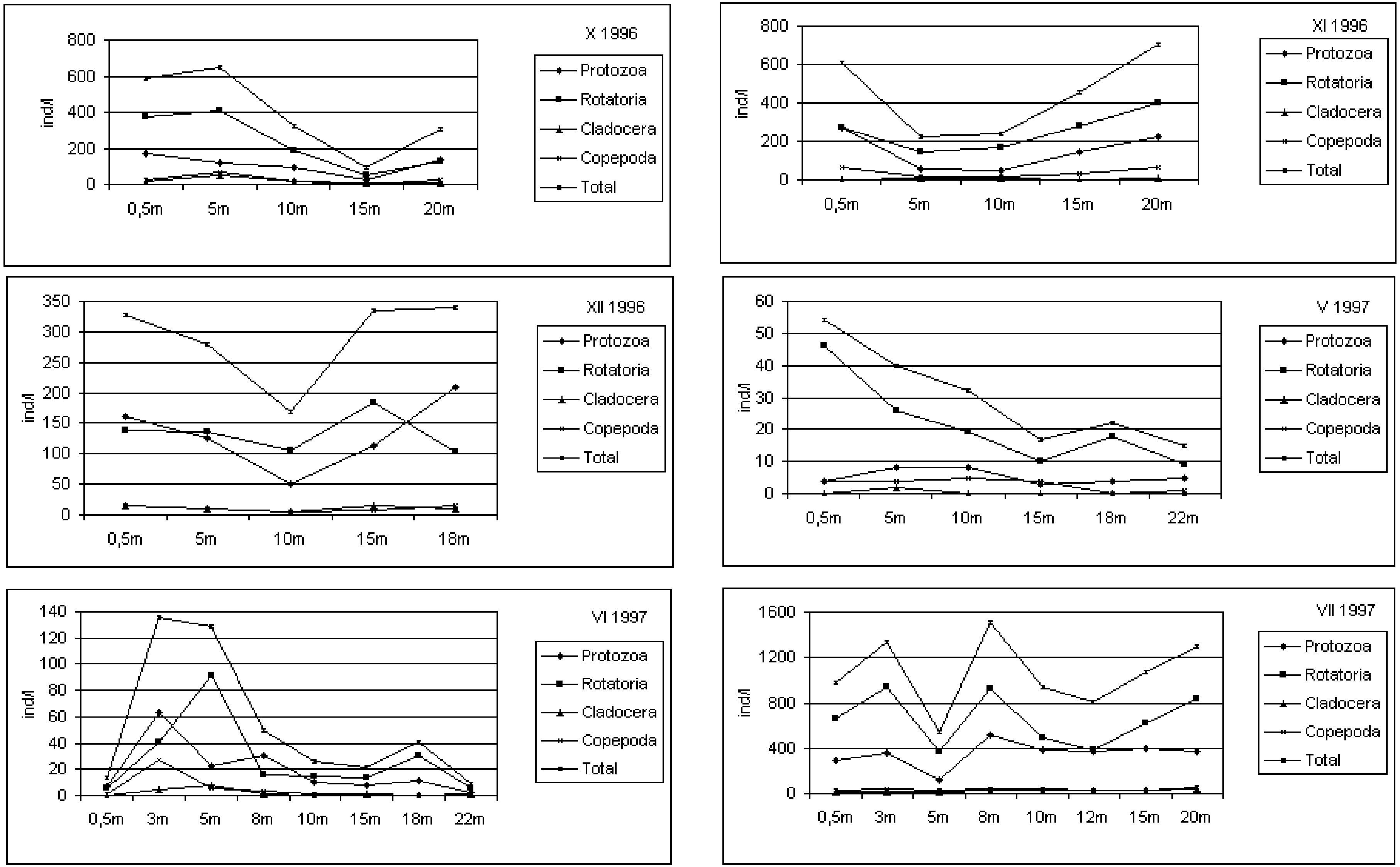

Fig. 1. Vertical distribution of zooplankton on locality *Dam* in the Grošnica Reservoir

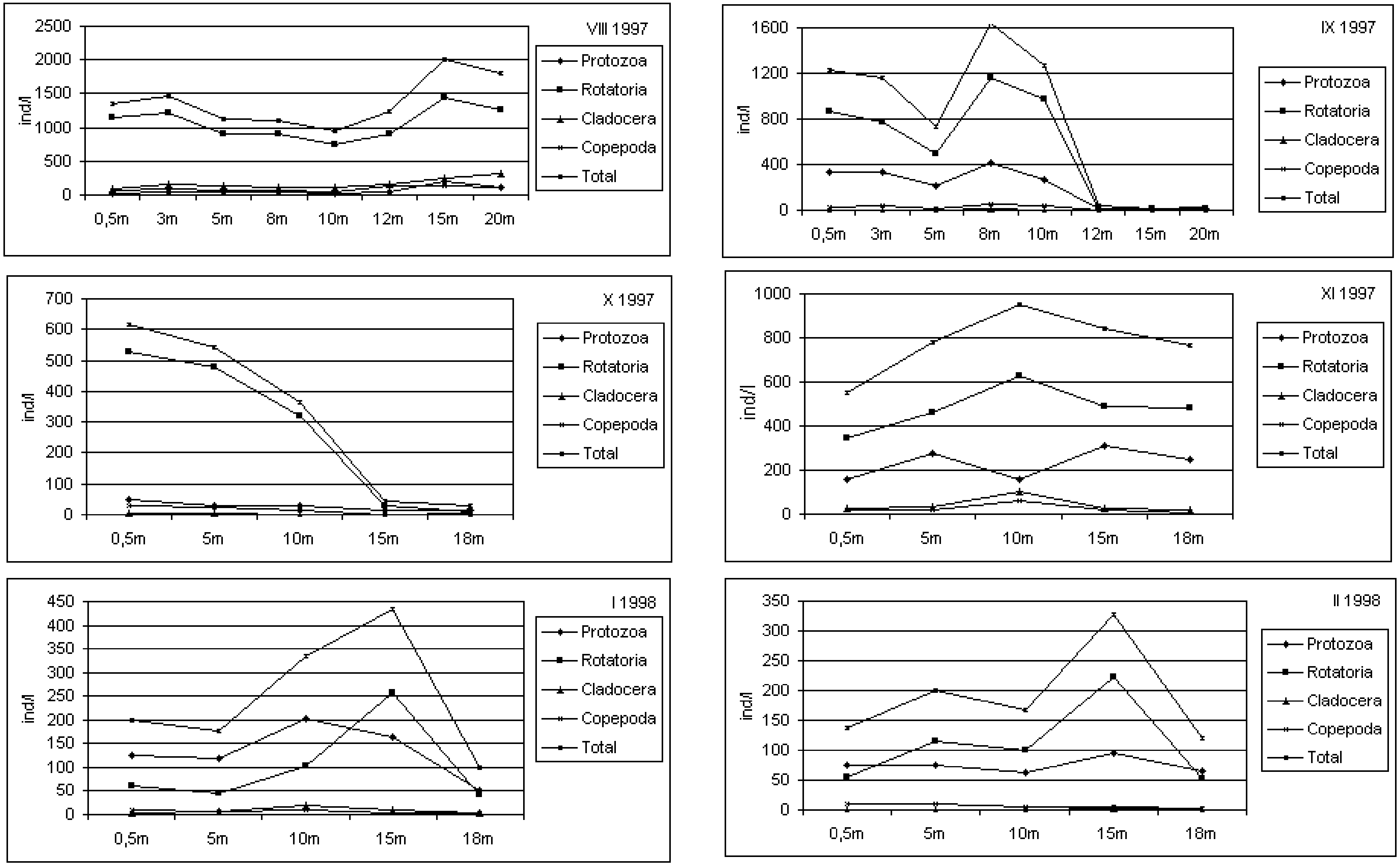

Fig. 2. Vertical distribution of zooplankton on locality *Dam* in the Grošnica Reservoir

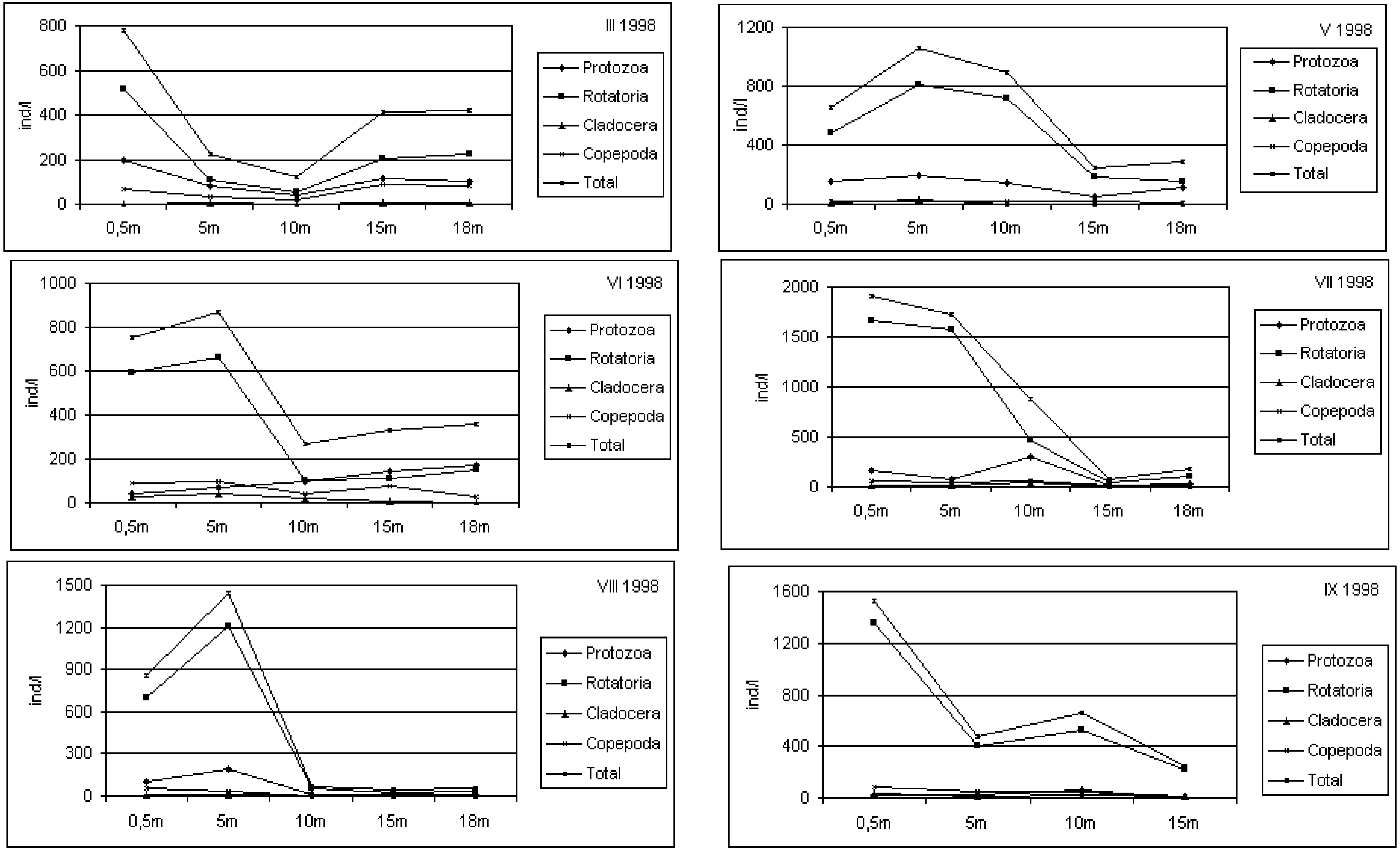

Fig. 3. Vertical distribution of zooplankton on locality *Dam* in the Grošnica Reservoir

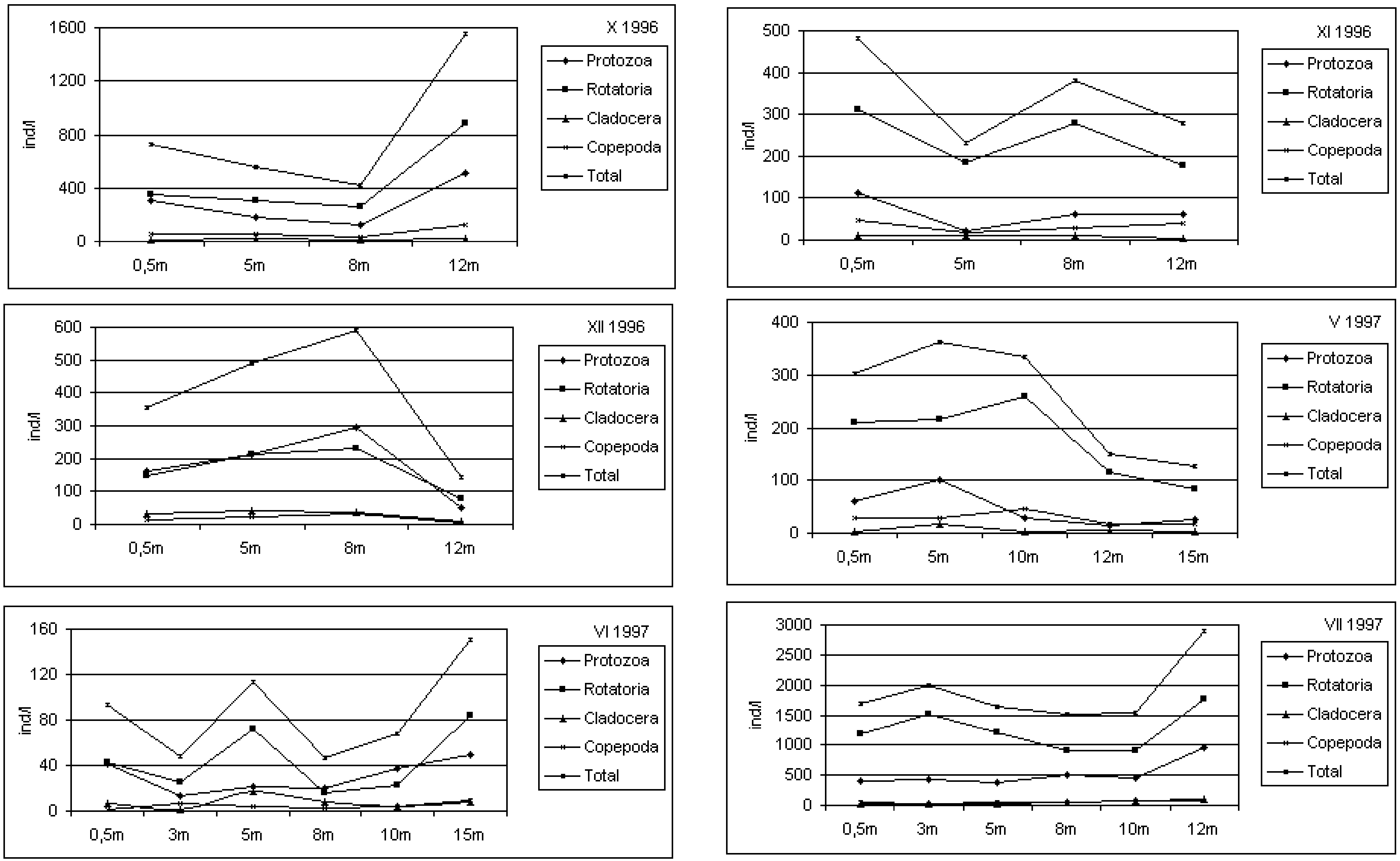

Fig. 4. Vertical distribution of zooplankton on locality *Centre* in the Grošnica Reservoir

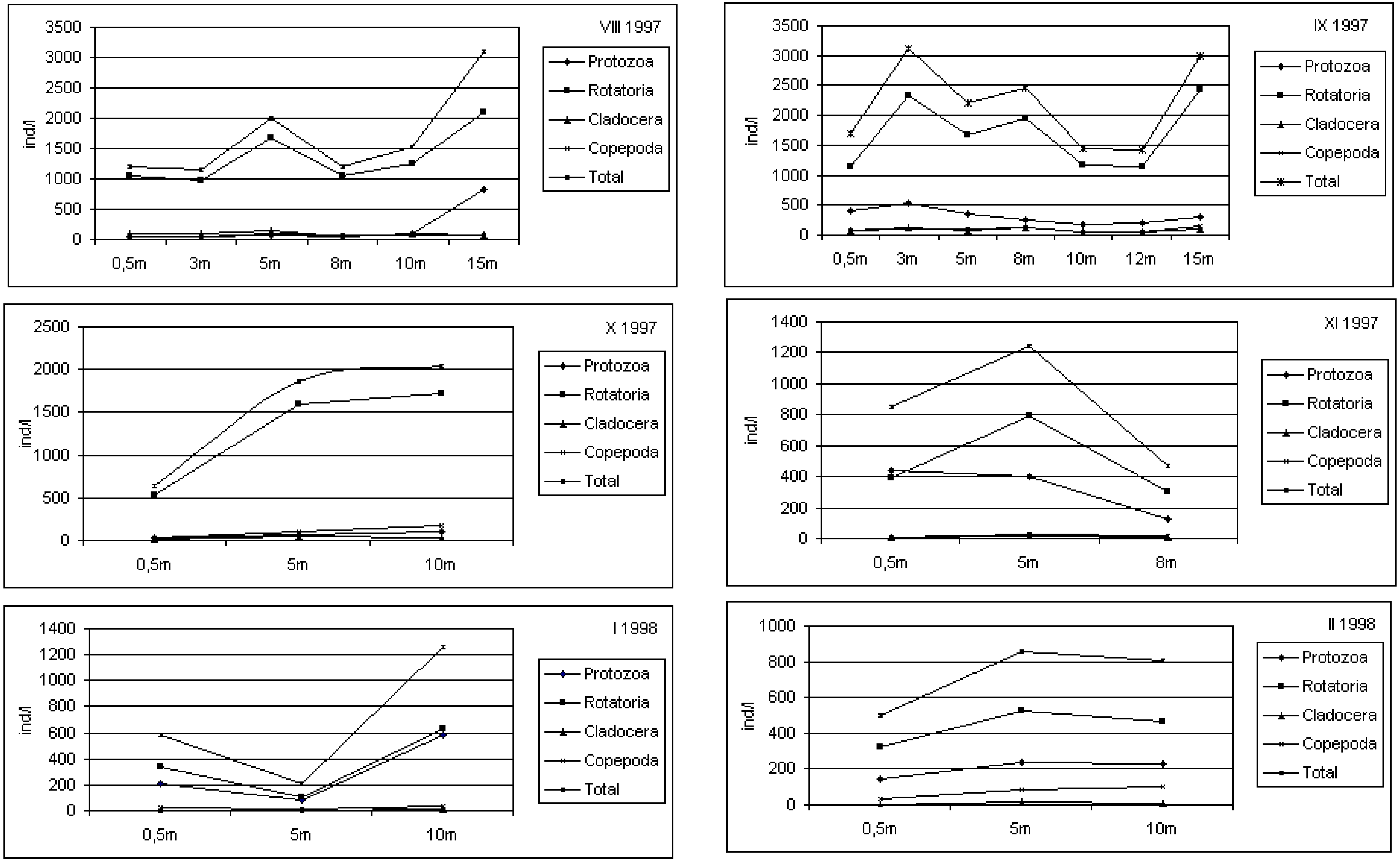

Fig. 5. Vertical distribution of zooplankton on locality *Centre* in the Grošnica Reservoir

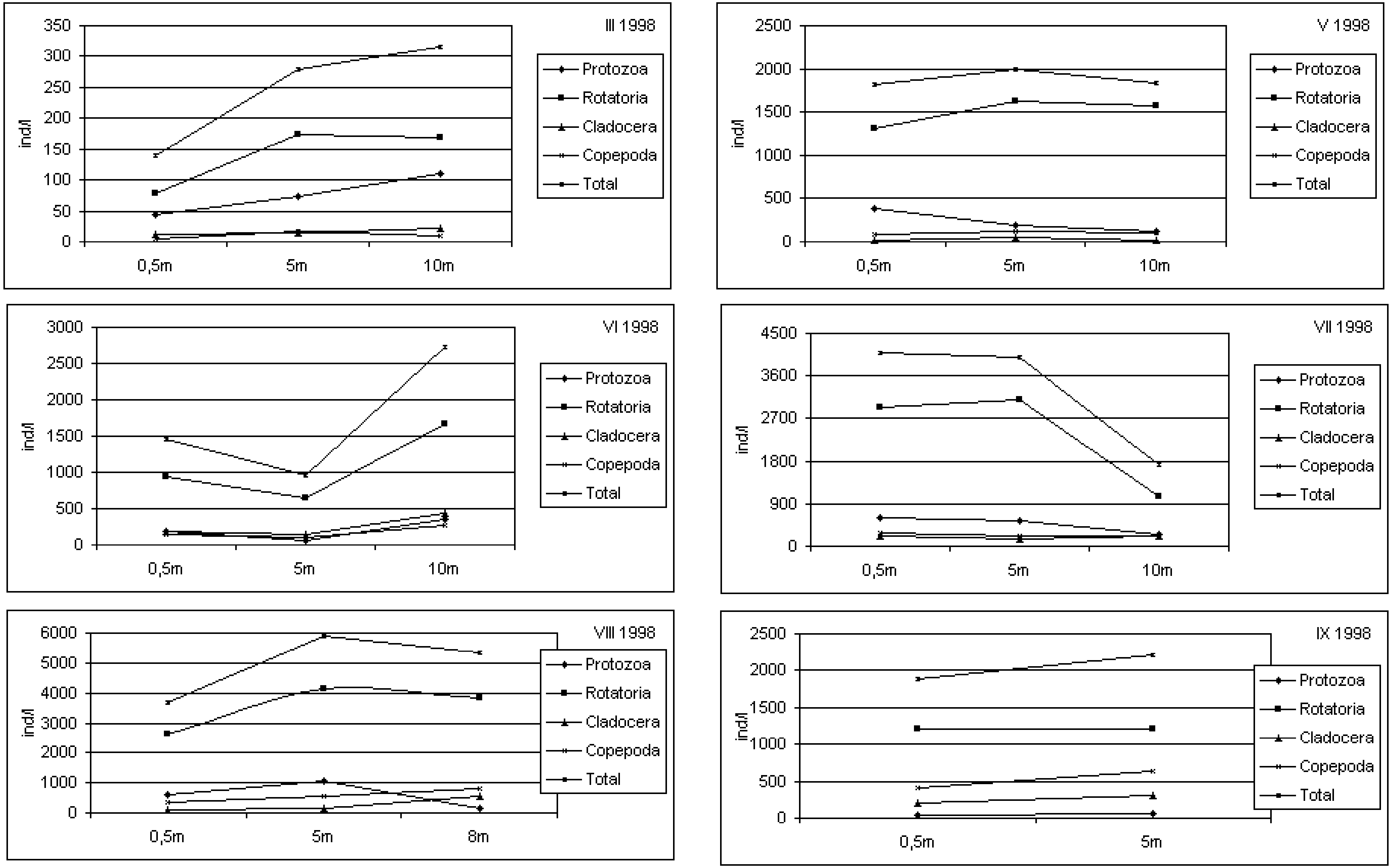

Fig. 6. Vertical distribution of zooplankton on locality *Centre* in the Grošnica Reservoir