Трудове на Института по океанология
*Том 4. Варна, 2003*
*Българска академия на науките*

# Daily Dynamics of Zooplankton in the Varna Bay (May, 2001)

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**Introduction**

Considerable daily changes in the vertical zooplankton distribution occur in the surface of seas and oceans. These changes are determined by a large range of vertical migrations of the species like *Calanus euxinus, Pseudocalanus elongatus* and *Sagitta setosa*. Many other organisms, mainly inhabitants of the surface migrate within a range of 10-15 m (K o v a l e v et al., 1996).

Daily zooplankton vertical migration is a dynamical phenomenon which is related with the biological and ecological adaptation of the aquatic organisms (H a r r i s at al., 2000). These zooplankton migrations are made due to the active search for the most favorable living conditions in water.

Zooplankton vertical distribution as a consequence of its daily vertical migration reflects a transitory qualitative and quantitative state of the zooplankton in water environment (K o n s u l o v, 1991).

Insignificant water spring stratification of the surface does not exclude the possibility for zooplankton daily vertical migration. However, the degree of its occurrence is not large because in vertical direction the possible migration track is short (15-20 m) and does not leave the photic layer to the bottom (K o n s u l o v, 1991).

**Materials and methods**

The study is based on data collected at a standard sampling network during the scientific cruises in Varna Bay in spring (May) of 2001, on the board of Navy vessel "Admiral Br. Ormanov". The zooplankton samples were collected by a vertical plankton "Jedy" net – 36 cm diameter and 150 μm mesh size. At station 2, located in front of cape Galata, samples were collected at 19.20, 23.30, 3.30, 7.30, 11.30 and 15.30 o'clock from two depths: 10 - 0 and 20-10. Samples were fixed to 4% formalin solution. Species abundance per cubic meter was performed according to Dimov's method (D i m o v, 1959). Biomass ($mg/m^3$) was estimated by using individual standard weights (P e t i p a, 1959).

**Results and discussion**

In spring the surface water in the Varna Bay revealed insignificant stratification. The average water temperature was 18.59°C, decreased in depth to 10.75°C. Thermocline was limited within the layer between 5 - 9 m. Salinity, also changed in the zero and bottom layers - 15.88 ‰ and 18.38 ‰ respectively. Dissolved oxygen concentration diminished from surface (9.75 ml/l) to bottom (7.87 ml/l).

On the basis of the obtained results in the investigated area, zooplankton species were identified belonging to the phylum Protozoa, Coelenterata, Ctenophora, Nemathelminthes, Annelida, Mollusca, Arthropoda, Chaetognatha. In the spring zooplankton is presented mainly by *Acarita clausi, Oithona similis, Pleopis polyphemoides, Noctiluca scintillans, Cirripedia nauplii, Lamellibranchia veliger,* etc.

The vertical zooplankton distribution can be traced more thoroughly during the light and dark part of the day. In the upper 10 meters during the afternoon hours (19.30 o'clock) the zooplankton abundance was 7891 $ind/m^3$. Zooplankton abundance structure was mostly presented by *N. scintillans* over 51%, which was followed by meroplankton (17 %), copepods and cladoceras both with equal percentage parts (15.7 %). Concerning the benthic larval, the highest value was registered

for *Cirr. nauplii*, significantly much lower were *Polychaeta larvae* (225 ind/m$^3$) and *Lamellibranchia veliger* (113 ind/m$^3$). The greatest part of the copepod abundance due to opportunistic species *A. clausi* (564 ind/m$^3$), followed by the young (338 ind/m$^3$) and the nauplii stages (113 ind/m$^3$).

In the bottom layer the recorded zooplankton density was 4919 ind/m$^3$ or 1,6 folds lower than in 10-0 m. The contribution of all groups in the zooplankton abundance structure was as follow Meroplankton 44 % (2164 ind/m$^3$), Copepoda (20 %), *N. scintillans* – 20 % and *P. polyphemoides* (16 %). Meroplankton abundance structure was mostly presented by *Cirr. nauplii,* in the other benthic larval had equal contribution.

At 23.30, the numerical abundance in surface was at about 7994 ind/m$^3$. The Protozoa (*N. scintillans*) had the biggest share (62 %) in the total abundance. The copepods contributed – 11 % and *P. polyphemoides* – 7 %. The density of *Cirr. nauplii* dominated among the benthic larval, approximately 7 times lower was the registered value of *Polychaeta larvae*. Adult forms of *A. clausi* were most abundant of the Copepods. Its nauplii and young stages were 7 folds lower.

In 20 -10 meters, the registered total abundance was 4139 ind/m$^3$. Equally present were *N. scintillans* and meroplankton (1129 ind/m$^3$). Each of them forms 27 % of the abundance in the layer. The same significant have got Cladocera (941 ind/m$^3$) and Copepoda (940 ind/m$^3$), each owning 23 % of the quantitative parameter.

When compare the investigated layers from both samplings they showed that the tendency of concentration of organisms on the surface was kept. *N. scintillans* which abundance prevailed in both layers exhibited over 4 folds higher value in the upper layer than the bottom one. On the contrary of the first sample, the meroplankton registered smooth abundance decrease towards the bottom. Copepoda and Cladocera representatives demonstrated an increase of this parameter in the layer 20 - 10, more strongly expressed for the Cladocera. Besides, in the surface layer, domination of groups and species of zooplanktoners was more strongly exhibited while the bottom layer was characterized with even more distribution of the abundance between the main zooplankton groups and inside them.

In the early morning hours (3.30), in the upper layer the total abundance was 9455 ind/m$^3$. *N. scintillans* contributed the biggest part of abundance structure over 56 %. Then followed meroplankton with 27 %, copepods – 9 % and Cladocera (*P. polyphemoides*) – 8 %. Benthic larval was represented mainly by *Cirr. nauplii* and *P. larvae*. *A. clausi* if compare with the other copepods showed about 3 folds density higher.

In total, for the bottom layer the numerical abundance was at about 4262 ind/m$^3$. A significant part of it belonged to the meroplankton and copepods, which together formed over 71 %. Cladocera had significantly lower density taking part with 19 %. Heterotrophic dinoflagellate *N. scintillans* was also presented with 2 times lower abundance.

Retracing the changes in the zooplankton abundance along the vertical range showed significantly higher concentration of zooplankton in the surface layer mainly due to the concentration of *N. scintillans* in the surface layer (over 13 folds higher than in the bottom layer). Meroplankton abundance diminished towards the depth. The other two main groups of zooplankton exhibited reverse tendency of slightly manifested increase of 1.5 times of both Copepoda and Cladocera. The adults of *A. clausi* keep higher density toward the surface, but the larvae forms – lower. Unlike, they (adults and larval of *A. clausi*) had similar participation in the bottom layer.

Further, the total abundance early in the morning (7.30) in surface was 7298 ind/m$^3$. The numerical abundance of *N. scintillans* was again higher – 53 %. Copepoda was characterized with prevalence of *A. clausi* adult individuals while its larvae stages were less represented. Referring benthic larval, the prevalence of *Cirripedia nauplii* over *Polychaeta larvae* was preserved (about 2.5 folds).

In the layer below 10 meters, the greatest part of the total abundance (4871 ind/m$^3$) was *N. scintillans* contributed 50% followed by Copepoda 20 %, meroplankton (15 %) and Cladocera (9 %).

The zooplankton density decreased with 1.5 folds in depth. Protozoa reduced 1.8 folds. Copepoda also more slightly (1.7 times) represented, meroplankton and

*P. polyphemoides* – 1.5 times. From the copepods *A. clausi* increased in the upper layers, and the other representatives maintain equal distribution along the vertical range. The benthic larval abundance enhanced in the upper layer due to the increased of *Cirr. nauplii* while the larvae of *polychaets* had insignificant dynamics in vertical direction.

At noon hours (11.30), in the surface numerical abundance of 4677 ind/m$^3$ was registered. The Meroplankton contributed the biggest part of the abundance structure was (1539 ind/m$^3$ or 42 %), followed by *N. scintillans* with 23 %, copepods – 19 % and *P. polyphemoides* with 16 %. The biggest abundant from the benthic larval had *Cir. nauplii* – 1069 ind/m$^3$. Subclass Copepoda was characterized again with the highest abundance of sexually mature *A. clausi* which are 3 times more than their younger stages, *O. similis* and *Harpacticoida sp*.

In depth, the abundance increased mainly on the account of *N. scintillans* – 51 %, followed by *P. polyphemides* – 18 % and *Cirr. nauplii* – 15 %.

*N. scintillans* showed 7.7 higher density in the layer between 20-10 meters. *P. polyphemoides*, Copepoda and meroplankton demonstrated the same tendency in different range: Cladocera - 8.2; Copepoda - 2.2 and benthos larvaton - 1.2. *Cirripedia nauplii* exhibited an increase of abundance in depth 1.6 times, mussels larvae – 1.2, Copepoda *A. clausi* – 2. The results revealed that *L. veliger* was comparatively evenly distributed in the vertical range.

At the afternoon hours, in the layer between 10 - 0 m, the registered zooplankton abundance was 3691 ind/m$^3$. *N. scintillans* was significantly donated the zooplankton structure with 2193 ind/m$^3$ (59 %) with concomitant meroplankton – 19 % and copepods – 16 %.

The total abundance between 20-10 m accounted to 1145 ind/m$^3$. Meroplanktons were represented with maximum density – 624 ind/m$^3$ (50 %). Two folds less was the abundance of *P. polyphemoides*. Copepods participated with 17 %. Most poorly, *N. scintillans* was presented – 8%. The zooplankton abundance decreased approximately 3 times in the lower layer. *N. scintillans* demonstrated maximum reduction - over 21 folds. The other groups showed slightly change in their abundance: meroplankton - 1.3 and Copepoda - 2.8. Only *P. polyphemoides* showed tendency to adhere toward depth. It had 2.7 higher abundant in the bottom layer than in the surface one. Meroplankters were characterized with the most even distribution in the vertical range. Figure 1 shows daily vertical distribution of

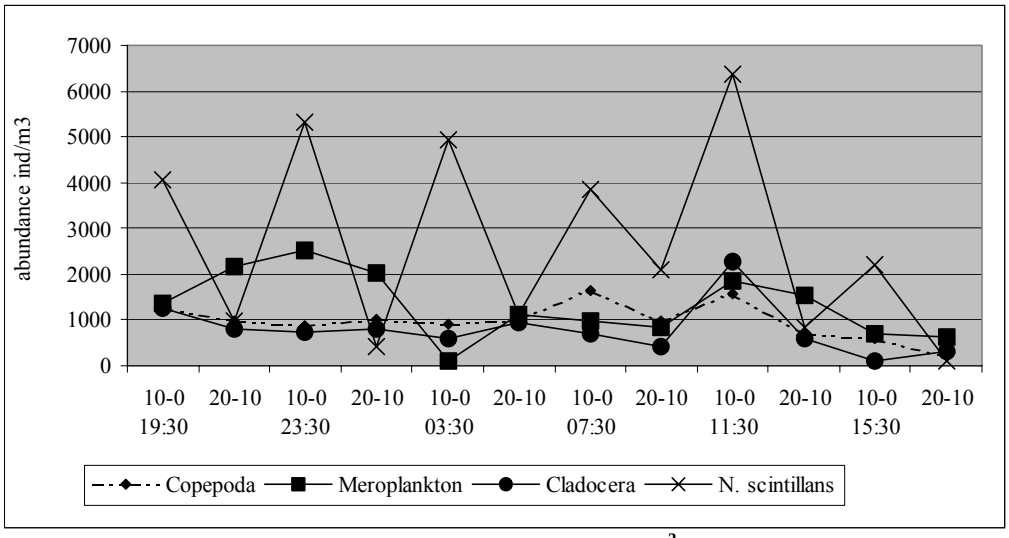



**Fig. 1. Daily dynamics of zooplankton abundance (ind/m$^3$) in Varna Bay (May,2001)**

the zooplankton groups. The largest fluctuations of *N. scintillans,* contributed mostly of the overall zooplankton abundance in the surface layer and diminished in depth. Certain dynamics was observed on the representatives of the benthic larval, while the species of subclass Copepoda and *P. polyphemoides* were almost evenly distributed.

Considering distribution of the main zooplankton groups along the vertical range within 24 hours period, it is interesting to trace the dynamics of the species which dominate in the structure of the zooplankton community. The chart on figure 2 shows that within the time inerval from 19.20 to 7.30, the adult form of *A. clausi* predominated in the upper 10 m layer. The species was not characterised with essential vertical dynamics. Similar peculiarities of vertical migration in open sea have been also observed by Konsulov who has established that *A. clausi* performs daily vertical migrations with narrow vertical range in spring, adhering to the surface layer during the night, early morning hours and at nightfall (K o n s u l o v, 1990).

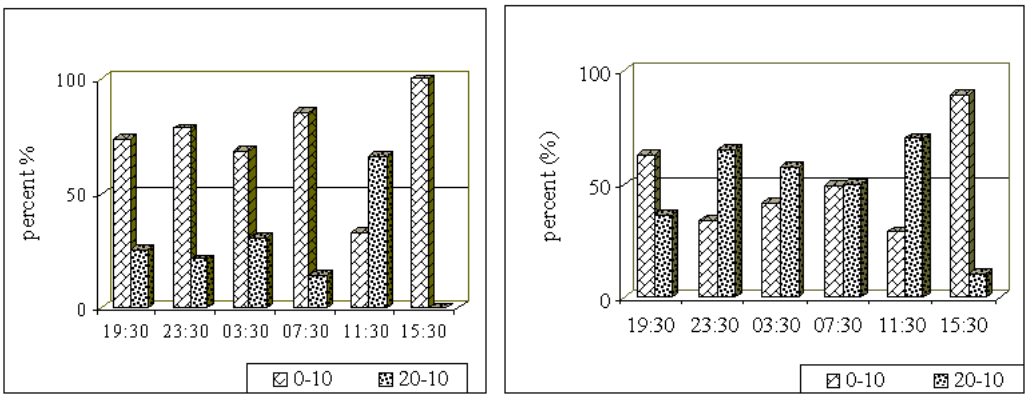
During the first night hours *A. clausi* showed tendency to keep closer to the surface and after midnight almost insignificant movements in reverse direction were observed. Early in the morning the adults of *A. clausi* predominate in the surface layers. During the period the tendency to upward migration was most strongly expressed. Concentration of the species in the upper 10 m was observed.

*A. copepodit* was characterized with more clearly expressed dynamics in vertical direction (figure 2 B). At the end of the day they keep closer to the surface 10 m layer. Until midnight, the young stages of *A. clausi* moved significantly to the deeper layers. The tendency in their vertical distribution was the converse of that of the adult forms (at 23.30 they inhabit mainly the deep layers). Until the early morning hours (7.30) a part of the *A. copepodit* was moving lightly to the surface but their biggest share had retained in the deep of 10 meters.

During the evening and night hours *A. nauplii* was more highly represented in depth than in the surface. In the morning they demonstrated similar distribution in both layers as a result of their slight movement towards the surface. The observed vertical distribution differs from the open sea one, where *A. nauplii* retained almost equal and the greatest abundance was in the 0-10 layer (K o n s u l o v, 1991) (figure 3A).

*O. similis* was found mainly in the deep 10 m layers. At the evening and morning hours it was presented in the surface layers while at night it is concentrated entirely in the depth (figure 3 B).

*N. scintillans* was concentrated mostly in the upper 10m layer. In the open sea, during spring, the species prefers the layer between the surface and the thermocline boundary



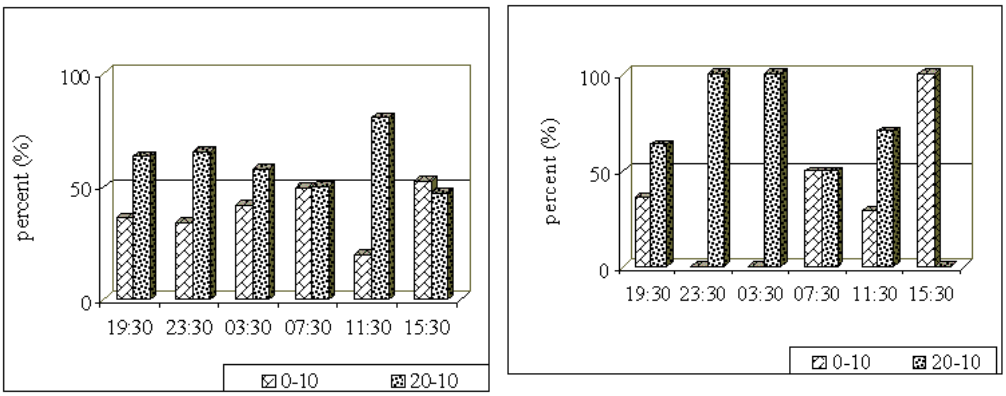

**a)** **b)**

**Fig. 2. Daily abundance dynamics of the adult forms of *A. clausi* (a) and *A. copepodit* (b)**

(K o n s u l o v, 1991). This is a possible reason for distribution of *N. scintillans* observed in the Bay because the thermocline was within the frames of the 0-10 meters. Further, relatively dynamics was noticed after midnight (23.30-3.30) but the last movement wasn't been particularly intensive and the tendency of high concentration of the *Noctiluca* in the surface wasn't changed (figure 4 A).

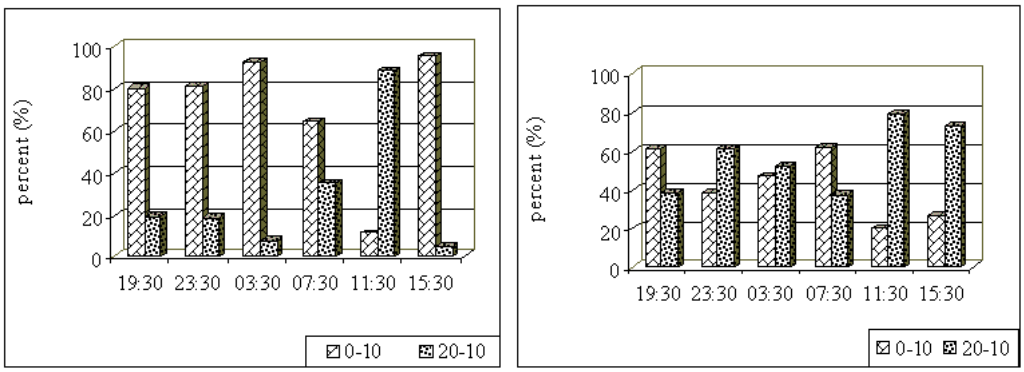
Significant daily variability was demonstrated of *P. polyphemoides*. At 19:30 the species showed higher numerical abundance in the surface water, while in the latest hours up to 23.30 it moved intensively toward the depth. In midnight the species inhabited mainly the deep ten meters. In the period between midnight and in the morning, *P. polyphemoides* moved slowly towards the surface and at 7.30, the same vertical distribution as at the end of the day was observed. This significant change in the vertical distribution during the different parts of the day differs from the established one by Konsulov that the species adheres preferably to the layer embracing the space from the surface to the lower thermocline boundary (figure 4 B).

*Cirripedia nauplii* also revealed essential daily dynamics. At 19:30 they prevailed in the lower 10 meters. At midnight *Cirripedia* showed different vertical distribution - the larval had the biggest share in the surface layer compared to the bottom. This suggests their intensive movement towards the surface



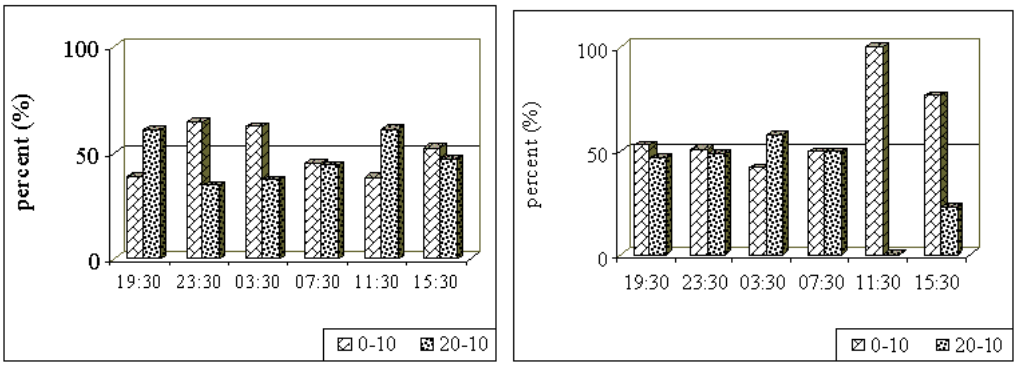

**a)** **b)**

**Fig. 3. Daily abundance dynamics of *A. nauplii* (a) and *O. similis* (b) in percents (%)**




**a)** **b)**

**Fig. 4. Daily abundance dynamics of *N. scintillans* (a) and *P. polyphemoides* (b) in percents**




**a)** **b)**

**Fig. 5. Daily dynamics of Cirripedia nauplii (a) and Polychaeta larvae (b) in percents**

during the first hours of the night. The tendency of their vertical distribution was kept during the next hours up to 3:30. Until morning, a part of *Cirr. nauplii* have already moved to the bottom and in the morning hours they characterized with comparatively similar vertical distribution of two sites as a result (figure 5 A).

*P. larvae* showed insignificant differences which manifested comparatively more even distribution along the vertical range. From the end of the day to the second half of the night (3.30) Polychaeta revealed tendency to move towards the bottom. A part of the larval started to move upward in the morning hours (7.30). They were almost equally presented in both layers. In the light part of the day, *P. larvae* were registered with almost 100% participation in the upper layer, while in the early afternoon hours they migrated to the bottom (figure 5 B).

**Conclusion**

To summarize the results, the following conclusions could be given:

1. The observed daily dynamics do not fully agree with the typical picture of the daily vertical zooplankton migration. The reason for that may be the shallow depth of the station (20m), the law temperature gradient of the thermocline (average 0.4°C), as well the homogeneity of the environmental conditions observed at both layers.
2. The greatest variability demonstrate *N. scintillans* which dominates in the surface layer and its numerical abundance decreases in depth.
3. A certain dynamics is also observed among the representatives of the benthic larval and *P. polyphemoides* while the species of subclass Copepoda show almost even distribution.

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*Постъпила на 06.01.2003 г.*

# Денонощна динамика на зоопланктона във Варненския залив (май 2001 г.)

*Кремена Б. Стефанова*

## (Резюме)

В моретата и океаните се извършват съществени денонощни изменения във вертикалното разпределение на зоопланктона. Денонощната вертикалан миграция на зоопланктона е динамично явление, свързано с екологичната и биологичната адаптация на водните организми.

Целта на изследванията е да се проследи вертикалната денонощна динамика на зоопланктонните организми във Варненския залив през пролетта на 2001 година. Установена е вариабилността на отделните групи и видове зоопланктон през денонощието. Въз основа на получените резултати може да се направи изводът, че наблюдаваната денонощна динамика не съвпада напълно с типичната картина на денонощна вертикална миграция на зоопланктона поради неголямата дълбочина, малката величина на температурния градиент на термоклина, както и на еднородността в условията на средата, наблюдавани в двата хоризонта.