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VERTIKALNA RASPODJELA ZOOPLANKTONA U VELIKOM JEZERU OTOKA MLJETA

VERTICAL DISTRIBUTION OF ZOOPLANKTON IN THE BAY VELIKO JEZERO ON THE ISLAND OF MLJET

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UVOD

Radi boljeg poznavanja ekologije planktona, a u vezi ispitivanja produktivnosti mljetskih jezera (Buljan, 1957) izvršena su i povremena ispitivanja dnevne vertikalne raspodjele zooplanktona u ovom zatvorenom morskom zaljevu. (Slika 1.)

Vertikalna raspodjela sveukupnog zooplanktona u Jadranu nije bila posebno ispitivana sve do pred kratko vrijeme, kada se na tome sistematski započelo raditi kod Dubrovnika i od čega je do sada objavljen rad o godišnjoj vertikalnoj raspodjeli zooplanktona u južnom dubokom Jadranu (Hure, 1955).

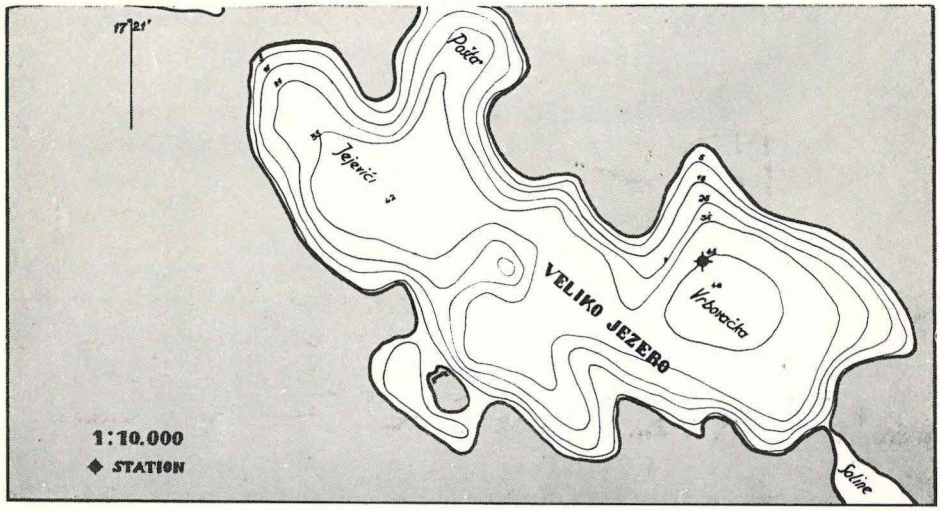
U ovom prilogu donosimo neke nove podatke za važnije zooplanktonte iz Velikog jezera koji ujedno spadaju u tipične neritske vrste. Pri obradi materijala nešto veća pažnja obraćena je kopepodu *Calanus helgolandicus* jer je on zbog svoje biomase i hranljive vrijednosti, pored kopepoda *Pseudocalanus elongatus,* najvažnija vrsta u jezeru (Vučetić, 1957), a i od većeg je značaja za jadranski plankton (Gamulin, 1954). Osim toga jedna analiza želučanog sadržaja srdela ulovljenih u Velikom jezeru (27. VII 1954) pokazala je da je u želučanom sadržaju bilo 72% *Calanus-a* pored 26% dekapodnih larva i 2% moluska larva.

Razmotreno je djelovanje temperature i saliniteta na vertikalnu raspodjelu zooplanktona.

MATERIJAL I METODIKA

Za ova ispitivanja služili smo se mrežom tipa Nansen 8/72 sa zatvaračem. Vertikalne lovine uzete su za slojeve debljine od 10 m, osim noćne lovine u julu koja je iz tehničkih razloga uzeta za debljinu sloja od 15 m (U tabeli I označena zvjezdicom).

Koristim priliku da se na ovom mjestu zahvalim dr. D. Cushingu (Engleska), prof. dr. T. Gamulinu i kolegi dr. J. Huri koji su mi za vrijeme pisanja ovog rada pomogli svojim savjetima.



Sl. 1. Veliko jezero na otoku Mljetu (1:10.000), postaje Vrbovačka (45 m.), Jejevići (38 m.).

Fig. 1. Deep bay Veliko jezero on the Island of Mljet (1:10.000) stations Vrbovačka (depth 45 m.), Jejevići (depth 38 m.).

TABELA I

TABLE I

Postaja Station	Datum Date	Sat uzimanja proba Time of sampling Dnevne Day	Noćne Night	Slojevi Depth intervals
Vrbovačka (dubina 45 m) depth 45 m	20. VIII 1952.	0600	2400	0—10, 10—20, 20—30, 30—40 m
„	„	1200		„
„	„	1800		„
Jejevići (dubina 38 m) depth 38 m	6. V 1952.	1200		0—10, 10—20, 20—30 m
„	9. VI 1952.	1200	2200	„
„	16. VII 1952.	1300	2200*	„
„	24. I 1953.	1300	2100	„
„	23. V 1953.	1130		„
„	26. XI 1953.	1200	2300	„

* Ova proba uzeta je u slojevima od 0—15 i 15—30 m.
This sample was taken in the layer from 0—15 and 15—30 m.

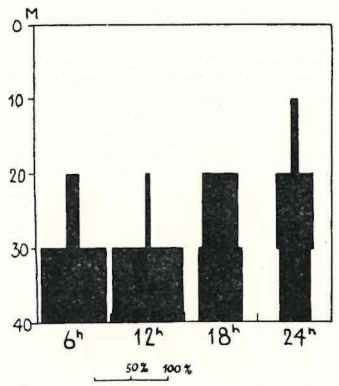
Na postaji Vrbovačka 20. augusta 1952. g., u intervalima od 6 h, uzete su probe koje su poslužile za dobivanje podataka o dnevnoj vertikalnoj raspodjeli sveukupnog zooplanktona. Na temelju dnevno noćnih lovina u maju, junu i julu 1952. g. i januaru, maju i novembru 1953. g., na postaji Jejevići, dobiveni su podaci o sezonskoj vertikalnoj raspodjeli kopepoda *Calanus helgolandicus, Pseudocalanus elongatus* i *Paracalanus parvus*. Ukupno je obrađeno brojčano 45 lovina, od toga na postaji Jejevići 18 dnevnih i 11 noćnih, a na postaji Vrbovačka 12 dnevnih i 4 noćne. Uz ove podatke donosimo i neke podatke za temperaturu, salinitet i prozirnost (Secchi ploča) dok detaljnije o topografsko-hidrografskim prilikama ovog područja izneseno je u Acta Adriatica Vol. VI.

REZULTATI

Postaja Vrbovačka

Da bi utvrdili dnevnu vertikalnu raspodjelu i eventualno dnevno vertikalno migriranje sveukupnog zooplanktona u Velikom jezeru, uzete su planktonske probe u augustu 1952. g. na postaji Vrbovačka, u intervalima od 6 h. Brojačno izražene količine zooplanktona za pojedine slojeve donesene su na tabeli II.

Iz same tabele je očito da se svi planktonski organizmi nisu nalazili jednoliko rasprostranjeni tokom dana. Pri samoj dnevnoj svjetlosti *Calanus helgolandicus* (adultni) nije nađen na površini od 0—10 m, ni u sloju od 10—20 m (Sl. 2). Mali broj primjeraka nađen je u podne u sloju od 20—30 m, a koncentracija većeg broja u sloju od 30—40 m ukazuje na njegovo povlačenje prema dnu za najjače dnevne svjetlosti. Već u 18 h utvrđen je skoro podjednak broj primjeraka u slojevima od 20—30 m i 30—40 m. Kasnije, u ponoć, dolazi do još jačeg pomicanja prema površini i tada je veći broj primjeraka nađen u sloju od 20—30 m nego od 30—40 m, a jedan mali broj čak je zatečen u sloju od 10—20 m.

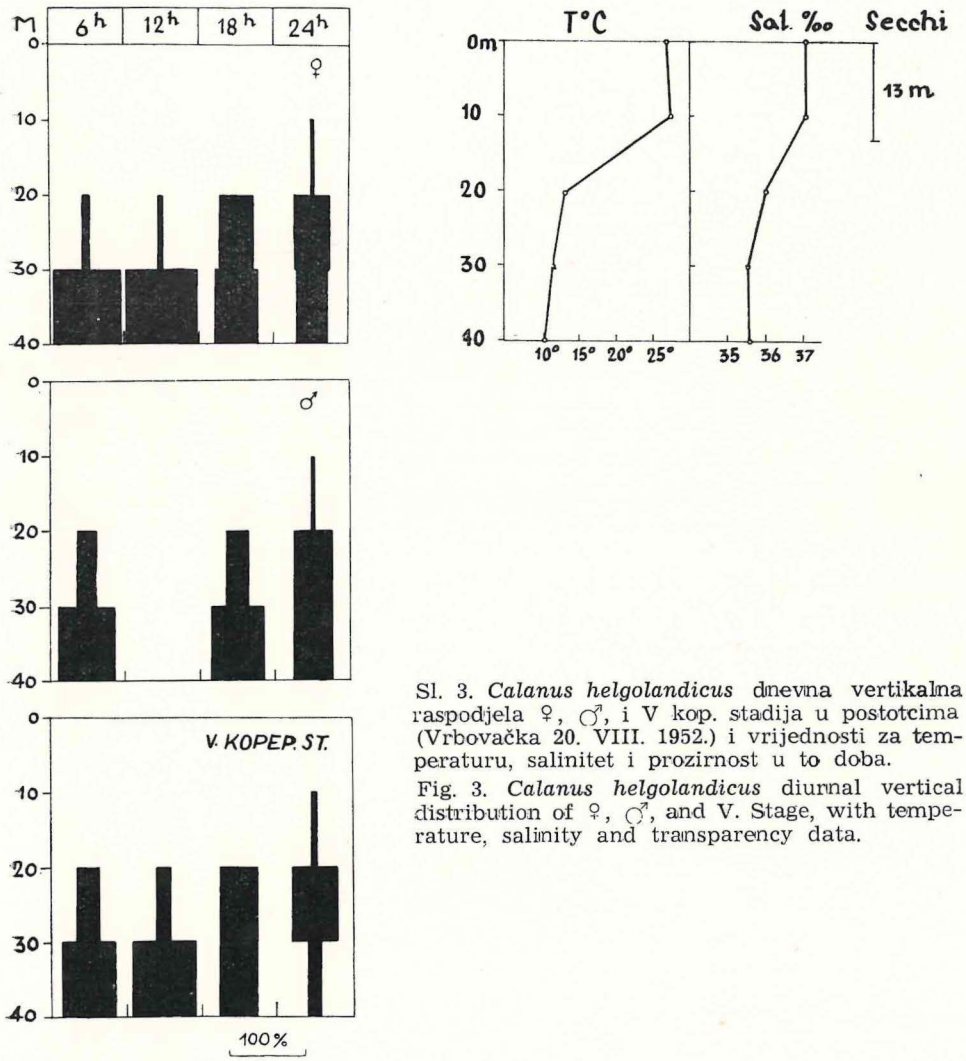


Sl. 2. *Calanus helgolandicus* dnevna vertikalna raspodjela (u postotcima).
Fig. 2. *Calanus helgolandicus* diurnal vertical distribution (in percentage).

Tab. II VELIKO JEZERO — VRBOVAČKA (20. VIII 1952.)
DNEVNA VERTIKALNA RASPODJELA ZOOPLANKTONA
DIURNAL VERTICAL DISTRIBUTION OF ZOOPLANKTON

Slojevi: Depth intervals:	0—10 m				10—20 m				20—30 m				30—40 m			
Sat: Time of sampling:	6h	12h	18h	24h	6h	12h	18h	24h	6h	12h	18h	24h	6h	12h	18h	24h
Calanus helgolandicus	—	—	—	—	—	—	—	198	116	56	645	1118	688	1333	774	1032
Paracalanus parvus	2232	672	504	560	700	252	364	510	136	33	86	—	—	—	—	—
Pseudocalanus elongatus	—	—	—	—	86	28	28	68	5168	4455	4147	5203	7952	12212	1931	9372
Centropages Kröyeri	784	252	392	588	84	28	118	68	—	—	—	—	—	—	—	—
Oithona nana	168	84	196	28	196	112	56	34	—	231	387	1075	284	426	568	142
Sagitta setosa	280	224	476	252	644	924	728	714	347	330	322	468	235	418	486	165
Decapoda 1.	28	28	—	196	84	56	56	68	272	—	43	—	—	—	—	—
Oicopleura dioica	—	—	—	—	780	140	140	34	170	363	258	129	284	284	142	142
Evadne spinifera, E. tergestina	184	336	140	84	34	28	224	374	—	—	—	—	—	—	—	—
Obelia dichotoma	—	—	—	—	—	—	—	68	34	66	93	86	—	142	—	—
Bougainvillia autumnalis	112	84	—	—	28	—	—	—	—	—	—	86	—	—	—	—
Muggiaea kochi	168	56	224	140	812	532	756	544	68	165	129	172	—	426	—	—
Lamellibranch 1.	—	—	—	896	1120	10304	11816	34000	40800	33000	43000	43000	50000	50000	50000	50000
Gastropoda 1.	336	336	140	784	5808	9044	5516	9520	4050	3950	4300	215	3900	4300	785	1500

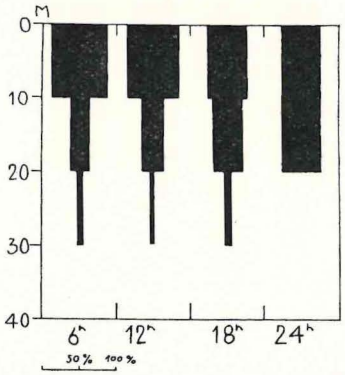
Dnevna vertikalna raspodjela ženki, mužjaka i V kopepoditskog stadija *Calanus-a* uz podatke za temperaturu, salinitet i prozirnost mora donesena je na slici 3. Pošto je broj mužjaka u lovini uzetoj u 12 h bio malen nismo ga uzeli u obzir. Podnevna koncentracija u najdubljem sloju od 30—40 m i pomicanje koncentracije po noći u sloj od 20—30 m, jasno ukazuje na vertikalno dnevno migriranje kod ženka i V kopepoditskog stadija, a donekle i kod mužjaka.



Sl. 3. *Calanus helgolandicus* dnevna vertikalna raspodjela ♀, ♂, i V kop. stadija u postotcima (Vrbovačka 20. VIII. 1952.) i vrijednosti za temperaturu, salinitet i prozirnost u to doba.

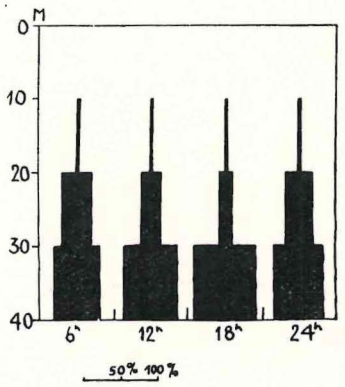
Fig. 3. *Calanus helgolandicus* diurnal vertical distribution of ♀, ♂, and V. Stage, with temperature, salinity and transparency data.

Paracalanus parvus, čije su najveće količine utvrđene stalno u blizini površine od 0—10 m i 10—20 m, bio je u nešto manjem broju po danu i u sloju od 20—30 m dok ga noću nije bilo ni u tom sloju ni dublje (Sl. 4).



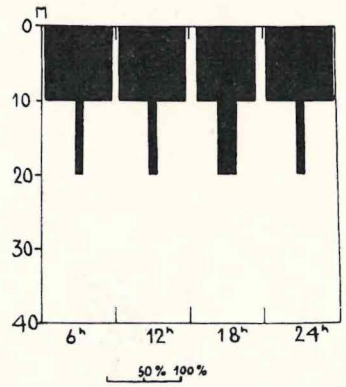
Sl. 4. *Paracalanus parvus* — dnevna vertikalna raspodjela (u postotcima).
Fig. 4. *Paracalanus parvus* — diurnal vertical distributin (in percentage).

Pseudocalanus elongatus nije bio nađen u površinskom sloju od 0—10 m, ni po danu ni po noći, a samo pojedinačni primjerci ulovljeni su u sloju od 10—20 m. U sloju od 20—30 m dolazi ih nešto više u 6 h i 24 h dok su najveće količine stalno zapažene u sloju od 30—40 m, a naročito u 12 i 18 h, što ukazuje da se koncentracija za dnevne svjetlosti pomakla prema dnu. (Sl. 5).



Sl. 5. *Pseudocalanus elongatus* — dnevna vertikalna raspodjela (u postotcima)
Fig. 5. *Pseudocalanus elongatus* — diurnal vertical distribution (in percentage)

Centropages kröyeri u većim količinama stalno je bio u sloju od 0—10 m i nešto manje od 10—20 m dok dublje nije ulovljen nijedan primjerak. (Sl. 6). Kopepod *Oithona nana* dolazi u svim slojevima.



Sl. 6. *Centropages Kröyeri* — dnevna vertikalna raspodjela (u postotcima).
Fig. 6. *Centropages Kröyeri* — diurnal vertical distribution (in percentage).

Hetognat *Sagitta setosa* primjećen je u nešto većem broju u sloju od 10—20 m. U blizini površine stalno su bili prisutni samo spolno nezreli primjerci dok su odrasli nađeni bliže površini samo u lovini iz 24 h.

Dekapodne larve zadržavale su se, uglavnom, u slojevima od 10—30 m, ali tu postoje izvjesne razlike za pojedine vrste (vidi K u r i a n, 1956).

Kopelat *Oicopleura dioica* na samoj površini od 0—10 m nije primjećen dok je u svim ostalim slojevima prilično jednakomjerno rasprostranjen.

Kladoceri *Evadne spinifera* i *Evadne tergestina* dolaze samo od 0—20 m.

Hidromeduza *Obelia dichotoma* utvrđena je samo za vrijeme noćnih sati u sloju od 10—20 m dok je stalno bila zastupana u sloju od 20—30 m, a u samo podne nađene su veće količine i u sloju od 30—40 m. *Bougainvillea autumnalis* bila je za dnevne svjetlosti u slojevima od 0—10 i 10—20 m, a u noćnoj lovini u sloju od 20—30 m.

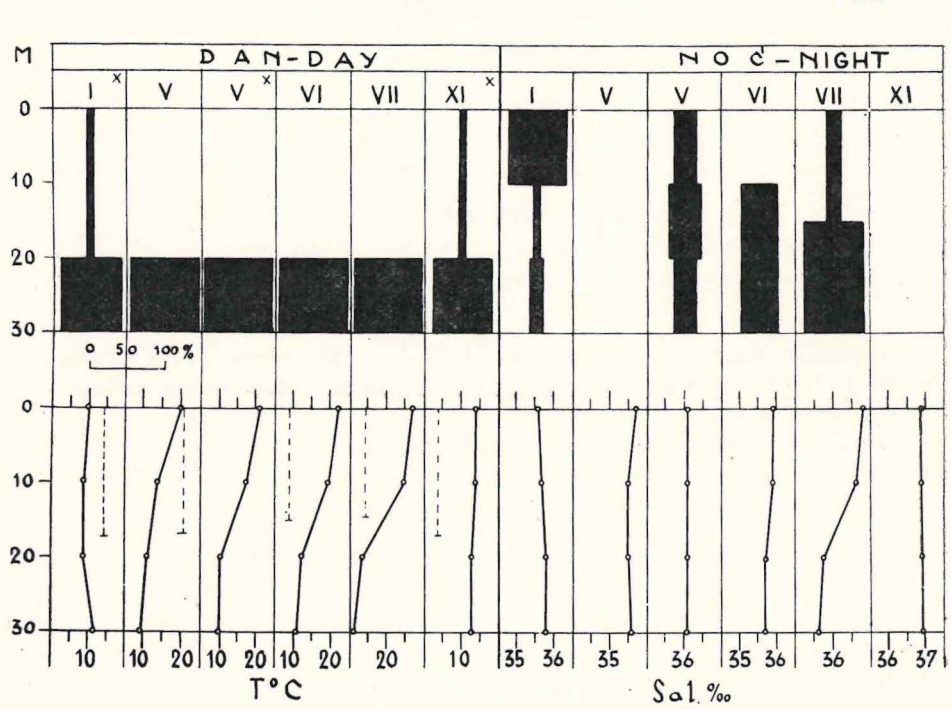
Kod sifonofore *Muggiaea kochi* zapaženo je da je jednoliko raspoređena od 0—30 m tokom dana, a pri dnu (30—40 m) nađena je jedino u podne.

Lamelibranhiatne larve dolaze u sloju od 0—10 m samo po noći dok ih je najveći broj za dnevne svjetlosti bio u sloju od 30—40 m. Gastropodne larve nalazile su se i pri površini, ali u dubljim slojevima dolaze stalno u većim količinama.

Postaja J e j e v i ć i

Na temelju lovina uzetih na postaji Jejevići u maju, junu i julu 1952. g. i januaru, maju i novembru 1953. g. dobiveni su podaci o godišnjoj vertikalnoj raspodjeli sveukupnog zooplanktona od čega su ovdje doneseni samo podaci za tri značajnije vrste kopepoda uz podatke za temperaturu, salinitet i prozirnost mora.

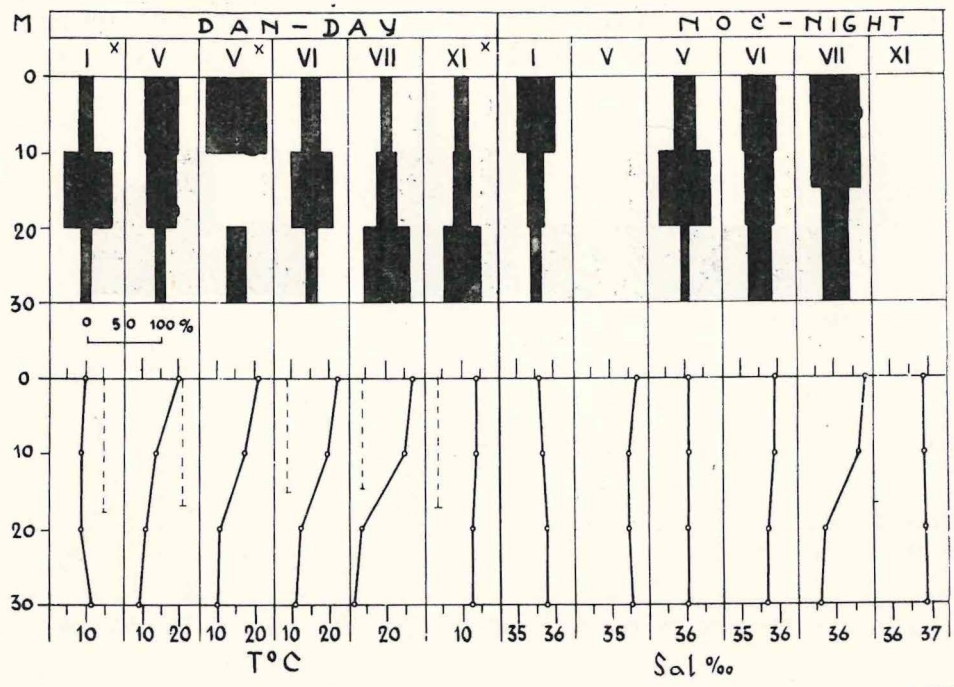
Calanus helgolandicus (Sl. 7) primjećen je na ovoj postaji za dnevne svjetlosti u površinskim slojevima od 0—10 i od 10—20 m samo u januaru i novembru dok je stalno u najvećem broju utvrđen u sloju od 20—30 m. Po noći koncentracija uz samu površinu primjećena je u januaru. U maju 1953. g. ulovljene su izvjesne količine i u površinskom sloju, a u junu jednakomjerno su bili zastupani od 10—30 m. U julu dobiveni su neki primjerci u noćnom potezu od 0—15 m, ali je moguće da ti svi primjerci potječu iz sloja od 13—15 m.



Sl. 7. *Calanus helgolandicus* — sezonska vertikalna raspodjela uz podatke za temperaturu, salinitet i prozirnost.

Fig. 7. *Calanus helgolandicus* — seasonal vertical distribution with temperature, salinity and trasparency data.

Kod *Paracalanus parvus* (Sl. 8) primjećena je, po danu u januaru koncentracija u sloju od 10—20 m, a po noći pri površini od 0—10 m. U maju ova vrsta opažena je u većem broju po danu pri površini od 0—10 m, a po noći u sloju od 10—20 m. U junu veće količine nađene su u sloju od 10—20 m po danu, a po noći od 0—10 m. Najveće količine, za dnevne svjetlosti u julu, nađene su pri dnu, a po noći na samoj površini. U novembru, po danu, također maksimalni broj dobiven je za najdublji sloj od 20—30 m.



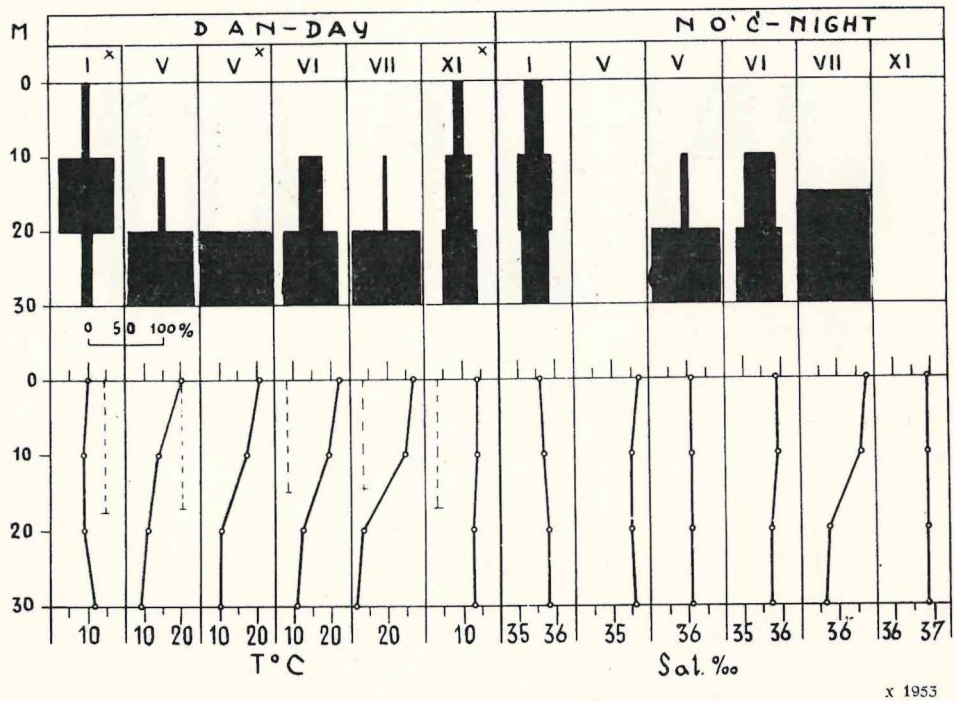
Sl. 8. *Paracalanus parvus* — sezonska vertikalna raspodjela uz podatke za temperaturu, salinitet i prozirnost.

Fig. 8. *Paracalanus parvus* — seasonal vertical distribution with temperature, salinity and trasparency data.
za temperaturu, salinitet i prozirnost.

Peudocalanus elongatus (Sl. 9) pri površini je nađen samo u januaru i novembru, po danu i po noći. Maksimalni broj primjeraka u januaru, u dnevnoj, kao i u noćnoj lovini, bio je u sloju od 10—20 m. U maju, junu i julu sasvim neznatne količine dobivene su za slojeve od 10—20 m, dok su znatno veće količine stalno zapažene pri dnu od 20—30 m, po danu, kao i po noći.

DISKUSIJA REZULTATA

Planktonski organizmi u Velikom jezeru, pored toga što je to mali i plitki bazen, pokazali su dosta jasno različitu vertikalnu raspodjelu tokom godine kao i dnevno vertikalno pomicanje. Različito godišnje vertikalno rasprostranjenje i vertikalno dnevno migriranje tumači se na više načina (Cushing, 1951., 1955), i to, jedni istraživači daju prednost temperaturi (Nikitin, 1929), a drugi uzimaju svjetlost kao odlučujući faktor. Iz eksperi-



Sl. 9. *Pseudocalanus elongatus* — sezonska vertikalna raspodjela uz podatke za temperaturu, salinitet i prozirnost.

Fig. 9. *Pseudocalanus elongatus* — seasonal vertical distribution with temperature, salinity and transparency data.

menata proizlazi (Hardy & Paton, 1947) da svijetlo, iako je važno, nije jedini faktor koji djeluje na dnevne vertikalne migracije. Gamulin (1959) donosi da *Calanus helgolandicus* u otvorenom Jadranu dolazi ljeti samo u dubljim slojevima s temperaturom od 13.8—15.2° C i napominje da bi mogla biti temperatura ili kakav drugi uzrok ovakvoj vertikalnoj raspodjeli. Po podacima Hure (1955) granična temperatura, unutar koje se ova vrsta može naći, negdje je oko 13° C. Nikitin (1929) za *Calanus finmarchicus* u Crnom moru, donosi da ne dolazi u slojevima, koji imaju temperaturu preko 15° C, a za *Pseudocalanus elongatus* preko 13° C.

Da je svijetlo imalo izvjesnu ulogu u dnevnom pomicanju kopepoda *Calanus helgolandicus* u Velikom jezeru, očito je kad se vidi (Sl. 2) kako su male količine, u augustu za vrijeme najjačeg osvjetljenja u podne, ostale u sloju od 20—30 m, dok je glavna koncentracija bila u slojevima od 30—40 m. Kasnije, kako svijetlo slabi, *Calanus* se približava sloju od 20—30 m i čak jedan mali broj nađen je u ponoći u sloju od 10—20 m. U sloju od 0—10 m nije zapažen, ni po danu ni po noći niti jedan primjerak u ovoj sezoni. Ako to uporedimo s temperaturom mora u to doba (Sl. 3) utvrdit ćemo da je tempe-

ratura površinskih slojeva iznosila 26—27° C. Temperaturna granica, do koje su došli, bila je između 13—15° C, što ukazuje da termoklinu nisu prešli.

Iz godišnje vertikalne raspodjele dobilo se da se *Calanus* zadržavao po danu u dubljim slojevima, osim u januaru i novembru kad je nađen u svim slojevima, od površine do dna. Gledajući na temperaturni režim mora u to doba (Sl. 7), moglo se utvrditi da je u to doba nastupila horotermija, a i osvjetljenje je slabije. Iznimno nešto jača koncentracija na samoj površini po noći nađena je u maju 1953. g. Ovo je, ujedno, jedina proba uzeta za doba mjesečine pa je moguće da je to uzrok koncentracije, ali također, može biti i u vezi sa ishranom (Wimpenny, 1938; Gauld, 1951, 1953) ili pak mriješćenjem (Marshall & Orr, 1955, 1960). Upoređujući podatke o vertikalnom rasprostranjenju s podacima o salinitetu, nikakav odnos nije utvrđen, ni kod ove vrste, kao ni kod ostalih.

Paracalanus parvus ne pokazuje neke pravilnosti u vertikalnom pomicanju s obzirom na osjetljivost prema temperaturi i svijetlu dok po svemu sudeći *Pseudocalanus elongatus* mnogo je osjetljiviji, naročito na temperaturu. Stalno je bio tokom godine, po danu, kao i po noći, u dubljim slojevima (negdje do 13° C), a jedino je nađen na površini u januaru i novembru za vrijeme homotermije, kad je ujedno osvjetljenje bilo znatno slabije. U junu je nađen jedan mali broj primjeraka u sloju od 10—12 m, ali je moguće da su se svi ti ulovljeni primjerci nalazili ispod granične temperature od oko 13° C, jer je taj sloj imao temperaturu od 12—18° C.

ZAKLJUČCI

Istraživanjem dnevne vertikalne raspodjele sveukupnog zooplanktona, u ljetnoj sezoni, utvrđeno je da se izvjestan broj organizama nalazio stalno u blizini površine (*Paracalanus parvus, Centropages Kröyeri, Evadne spinifera, Evadne tergestina, Mugiaea kochi* i dekapodne larve), dok su se drugi zadržavali u dubljim slojevima bliže dnu (*Pseudocalanus elongatus, Calanus helgolandicus, Oicopleura dioica* i lamelibranhiatne larve), a neki su opet zapaženi u svim slojevima (*Oithona nana, Sagitta setosa* i gastropodne larve.)

Po prisustvu, kao i po različitoj koncentraciji organizama tokom dana u pojedinim slojevima, utvrdili smo dnevno vertikalno migriranje kod nekih vrsta. I to, intenzivnije pomicanje primjećeno je u toplim mjesecima (maju, junu, julu) kad postoji temperaturno slojanje mora i kad je osvjetljenje jače. Međutim za vrijeme homotermije (januar, novembar), a i kad je osvjetljenje slabije, ove vrste nađene su u svim slojevima, od dna do površine i po danu, kao i po noći.

Kod *Calanus helgolandicus* primjećeno je da za vrijeme najviših temperatura mora u augustu, kod noćnog pomicanja prema površini, nije prešao graničnu temperaturu od 13—15° C.

Za *Pseudocalanus elongatus*, koji je po svemu sudeći više stenoterman utvrđena je još nešto niža granična temperatura od oko 13° C.

Paracalanus parvus nije pokazao nikakve pravilnosti u vertikalnom rasprostranjenju u odnosu na promjene temperature mora.

Nikakva korelacija nije utvrđena između vertikalnog rasprostranjenja organizama i promjena saliniteta morske vode.

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VERTICAL DISTRIBUTION OF ZOOPLANKTON IN THE BAY VELIKO JEZERO ON THE ISLAND OF MLJET

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INTRODUCTION

As part of the investigations of productivity in the bay Veliko jezero (on tle Island of Mljet) occasional studies of the diurnal vertical distribution of zooplankton have been carried out in order to complete the knowledge of plankton ecology.

Special investigations on the vertical distribution of zooplankton in the Adriatic Sea have not been carried out until lately when a systematic attempt, (Hure, 1955) in the vicinity of Dubrovnik, resulted in a paper on the annual vertical distribution of zooplankton in the deep South Adriatic.

Some new data are here given on the more important zooplankton species, typically neritic ones, found in the waters of the bay Veliko jezero. Special attention was paid to *Calanus helgolandicus* since this copepod, together with te *Pseudocalanus elongatus,* not only belongs to the most important zooplankton species found in the bay owing to its biomass and nutritive value (Vučetić, 1957) but also has a prominent place among the zooplankton organisms occurring in the Adriatic Sea (Gamulin, 1954). An analysis of the contents of the alimentary tract in adult Sardine caught in the bay Veliko jezero (27. VII 1954) has revealed the following composition: *Calanus* (72%), decapod larvae (26%), and mollusc larvae (2%).

The effect of temperature and saiinity rate on the vertical distribution of zooplankton has also been considered.

MATERIAL AND METHOD

Nansen net (4/72) with closing device was employed during the investigations. The vertical hauls were taken at 10 m intervals with the exception of the July night haul in which for technical reasons a 15 m were used (marked with an asterisk in Table I).

Samples giving data illustrating the diurnal vertical distribution of total zooplankton were taken, at six hours' intervals, at the Vrbovačka

station on 20th August, 1952. The zooplankton hauls that were taken both by day and by night at the Jejevići station in May, June and July 1952, and in January, May and November 1953, yielded data demonstrating the seasonal vertical distribution of *Calanus helgolandicus, Pseudocalanus elongatus,* and *Paracalanus parvus.* The 45 counted samples include 29 ones taken at the Jejevići station (18 by day, 11 by night) and 16 ones taken at Vrbovačka station (12 by day and 4 by night). Some temperature, salinity and transparency data (the latter obtained with a Secchi disk) are also given along with the above-mentioned ones. A detailed survey of the topographic and hydrographic conditions of the areas has been published in the Acta Adriatica, Vol. VI.

RESULTS

Vrbovačka Station

In order to find out the vertical distribution and possibly also the diurnal vertical migration of total zooplankton in the bay Veliko Jezero, plankton samples were taken at six hours' intervals at the Vrbovačka station in August 1952. Numerically expressed quantities of zooplankton found in various layers are given in Table II.

As evident from the mentioned table, there was no uniform distribution of plankton organisms in the course of a day. Adult *Calanus helgolandicus* did not occur either in the surface layer (0—10 m) or in the 10—20 m one in the daytime (Fig. 2). A small number of specimens occurred in the 20—30 m layer at noon while a higher concentration was found in the 30—40 m layer indicating that a withdrawal of the species towards the bottom takes place in broad daylight. The quantities found in the 20—30 m and 30—40 m layers were almost identical, however, as early as 6 P. M. A more pronounced movement towards the surface occurred at midnight since a larger number of individuals was found in the 20—30 m layer than in the 30—40 m one. A smaller number of individuals occurred even in the 10—20 m layer.

The diurnal vertical distribution of *Calanus* females, males, and V. Stage is given in percentage in Fig. 3. The number of males found in the noon haul was so small that it was not taken into account. The concentration in the layer (30—40 m) occurring at noon, and the shifting of the concentration to the 20—30 m layer at night evidently indicates a diurnal vertical migration of females, V Stage, and, to some degree, of males too.

The largest quantities of *Paracalanus parvus* regularly occurred in the neighbourhood of the surface (in the 0—10 m and 10—20 m layers). Its abundance was somewhat less in the daytime even in the 20—30 m layer while no specimens were found by night either in the 20—30 m layer or deeper (Fig. 4).

The surface layer (0—10 m) contained no *Pseudocalanus elongatus* either by day or by night, and only single individuals were found in the 10—20 m layer. This species was more abundant in the 20—30 layer at 6 A. M. and at

midnight while the highest concentration regularly occurred in the 30—40 m layer, particularly at noon and 6 P. M. This indicates that the concentration shifts towards the bottom by day and in the opposite direction by night and the morning (Fig. 5).

Large quantities of *Centropages Kröyeri* were regularly present in the 0—10 m layer; lesser quantities were found in the 10—20 m layer but no specimens occurred in the deeper layers (Fig. 6). The copepod *Oithona nana* was present in all the layers.

The chaetognath *Sagitta setosa* occurred in considerable quantities in the 10—20 m layers. Sexually immature individuals permanently were found near the surface. Adult specimens were present near the surface at the time of the midnight haul only.

Decapod larvae were generally found in the 10—30 m layers, but the species differ somewhat in their behaviour (see K u r i a n, 1956).

The occurrence of the copelatan, *Oicopleura dioica* was not observed at the surface (0—10 m) but it is rather uniformly distributed in the remaining layers.

The cladocerans *Evadne spinifera* and *Evadne tergestina* occur in the 0—20 m layer only.

The hydromedusa *Obelia dichotoma* was found in the 10—20 m layer at night only, but it always occurred in the 20—30 m layer; larger quantities were present also in the 30—40 m layer at noon.

Bougainvillea autumnalis occurred in the 0—10 m and 10—20 m layers in the daytime and in the 20—30 m at night.

The distribution of the siphonophora *Muggiaea kochi* was a uniform one in the 0—30 m layers by day; its presence in the bottom layer (30—40 m) was observed at noon only.

Lamellibranch larvae occurred in the 0—10 m layer at night only; their greatest abundance by day was observed in the 30—40 m layer. Gasteropod larvae were found also in the surface layer, but they were regularly more abundant in the deeper layers.

J e j e v i ć i Station

On the basis of samples taken at Jejevići station in May, June and July 1952, and in January, May and November, 1953, some data have been obtained on the seasonal vertical distribution of total zooplankton in the bay Veliko Jezero. Those referring to the three most important copepod species are given in this paper, the seasonal changes in vertical migration are shown for the three species in relation to light, temperature and salinity.

Calanus helgolandicus (Fig. 7) occurred in the surface layers (0—10 m and 10—20 m) in the daytime only in January and November while it was regularly abundant in the 20—30 m layer. Night-time concentrations at the surface took place in January. Some quantities were found in the surface layer in May 1953, and the species was uniformly distributed in the 10—30 m

layer in June 1953. The night haul made in July 1953 revealed the presence of some individuals in the 0—15 m layer but it is possible that all of them belonged to the 13—15 m layer.

Daytime concentrations of *Paracalanus parvus* (Fig. 8) were observed in the 10—20 m layer in January while night-time ones took place in the surface layer (0—10 m). In May the daytime concentrations occurred at the surface (0—10 m) and night-time ones in the 10—20 m layer. There was an abundant daytime occurrence of this species in the 10—20 m layer in June while the night-time one was observed in the 0—10 m layer. The most abudant daytime occurrence in July was found in the bottom layer and the night-time one at the surface. The maximum quantity recorded by day in November was found in the deepest layer (20—30 m).

Pseudocalanus elongatus (Fig. 9) was found at the surface by day and night only in January and November. The maximum amount of individuals caught in the daytime and night-time in January were found in the 10—20 m layer. Insignificant quantities occurred in the 10—20 m layer during the May, June and July samples but considerably larger quantities were a regular daytime and night-time occurrence in the 20—30 m bottom layer.

DISCUSSION OF RESULTS

In spite of its being a small and shallow basin, the bay Veliko jezero has revealed a distinctively different vertical distribution of plankton organisms in the course of a year and diurnal vertical migration. There are various explanations of the different vertical distribution or vertical migrations (Cushing, 1951; 1955). Some biologists attribute the phenomenon to temperature (Nikitin, 1929) while others ascribe it to light. It is clear from experiment (Hardy & Paton, 1947) that light, although important is not the only factor influencing diurnal vertical migration. According to Gamulin (1939), the summer occurrence of the species *Calanus helgolandicus* in the waters of the Adriatic has been observed in the deeper layers only, at temperatures varying between 13,8°—15,2° C. Gamulin suggests that temperature or some other factor might perhaps be responsible for this vertical distribution. It results from data published by Hure (1955), that the upper temperature limit within which the above-mentioned species can be found lies somewhere in the region of 13° C. Nikitin found (1929) that, in the Black Sea, *Calanus finmarchicus* does not occur in layers whose temperature is above 15° C and *Pseudocalanus elongatus* in layers warmer than 13° C.

Small quantities of *Calanus helgolandicus* found in the 20—30 m layer in the deep bay Veliko jezero in high daylight in August (Fig. 2) and their main concentration in the 30—40 m layer demonstrate that light played some part in the daily migration of this species. As the light abated during the later part of the day, *Calanus* approached the 20—30 m layer; a small amount of individuals was even found in the 10—20 m layer at night. In the 0—10 m

layer no specimen occurred during this season either by day or by night. If we examine the temperature of the sea water at that time (Fig. 6) we shall find that the temperature recorded in the surface layer amounted to 26—27° C. The temperature limit reached by *Calanus* was 13—15° C indicates that the thermocline was not passed.

By surveying the seasonal vertical distribution we have seen that *Calanus* remained in the deeper layer by day, except in January and November when they occurred in all the layers from surface to bottom. The observation of the temperature at that time (Fig. 7) unabled us to establish that homothermal state had set in then and we may observe that the light had grown less intense. An exceptionally high night-time concentration at the sea surface took place in May 1953. That was the only sample taken in the moonlight so the concentration might have been favoured by the moonlight, but feeding could have also contributed to it (Wimpenny, 1938; Gauld, 1951, 1953), or there may have been some connection with spawning (Marshall & Orr, 1955, 1960). No relationship between salinity values and data illustrating the vertical distribution either of this species or others could have been established.

There is no regularity in the vertical migration of *Paracalanus parvus* suggesting a sensitivity either to temperature or light (Fig. 8), but the species *Pseudocalanus elongatus* is, in all probability, much more sensitive, particularly as regards temperature. It regularly occurred in the deeper layers (somewhere at 13° C) by day and by night alike and it was found at the surface only in January ad November during the homothermal state when the light was less intense. A small number of specimens occurred in the 10—20 m layer in June, but it is possible that all the caught individuals were actually situated below the 13° C limit since the temperature of the layer was between 12 and 18° C.

SUMMARY

It appears from the investigations of the daily vertical distribution of total zooplankton during the summer season that certain organisms regularly kept near the surface (*Paracalanus parvus, Centropages Kröyeri, Evadne spinifera, Evadne tergestina, Muggiaea kochi,* and decapod larvae) while others remained in the deeper layers near the bottom (*Pseudocalanus elongatus, Calanus helgolandicus, Oicopleura dioica* and lamellibranch-larvae). Some others, however, were observed in all the layers (*Oithona nana, Sagitta setosa,* and gastropod larvae).

A diurnal vertical migration of some species has been established on the basis of occurrence and different concentrations of zooplankton organisms in various layers in the course of 24 hours. A more intensive migration has been observed during the warmer months (May, June, July) when a thermal stratification of the sea water prevails and when the light is more intense.

In January and November, however, when the homothermal state prevails and when the light is less intense, those species occur in all the layers from surface to bottom by day and by night.

It has been observed with *Calanus helgolandicus* that this species does not pass the 13—15° C temperature limit during its night-time migration towards the surface at the time of the maximum temperature of sea water in August.

An even lower temperature limit (about 13° C) has been established in the case of *Pseudocalanus elongatus* which species seems to be stenothermal.

No regularity in the vertical distribution of *Paracalanus parvus* in connection with temperature chages of the sea water has been observed.

No correlation has been established between the vertical distribution of zooplankton organisms and fluctuation of salinity in the sea water.