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PRIMARY ORGANIC PRODUCTION, DISTRIBUTION, AND REPRODUCTION OF BACTERIA IN THE MIDDLE ADRIATIC EUPHOTIC ZONE

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INTRODUCTION

After the first, preliminary, study of the primary production in the Adriatic carried out in 1958 at several stations of the middle Adriatic (Cviić 1963), some further detailed measuring of the primary production of the middle Adriatic and further preliminary measuring of the open and north Adriatic have been carried out. The works have been undertaken as a part of a complex work plan regarding the determination of the general productivity of the Adriatic. Besides determining the primary production, the author has also determined the distribution and reproduction of the marine bacteria, one of the first links of the sea feeding chain, whose role in the productivity, i. e. regeneration, of the nutritious salts, has become more and more noticeable. Except these two factors this work gives us the fluctuation of two more factors: phosphate and temperature. This has been done in order to get a picture of their mutual activity and dependence, i. e. to obtain the completest possible picture of the production course in the waters of the Adriatic and thus add to the explanation and knowledge of the general productivity of the Adriatic waters.

The research has been done in the middle Adriatic, i. e. at the stations »Vis«, »Pelegrin«, and »Kaštelanski zaljev« (Bay of Kaštela). The station »Vis« (N 42°59'8 E 16°19'7, about 106 m deep) has the characteristics of being in the open Adriatic far from the express influence of the mainland. Further work was carried out at the station »Pelegrin« (N 43°11'5, E 16°19'5, about 78 m deep). This station is under the influence of the mainland, but it lies in the area of the upcoast Adriatic currents which wash the Adriatic coast south-east — east-west. The third station at which a more detailed work was carried out was »Kaštelanski zaljev« (N 43°31'3 E 16°22'0, about 38 m deep). This station lies in an enclosed bay and is under the direct influence both of the mainland and of the fresh waters poured into the Bay of Kaštela by the river Jadro. The work at the above mentioned three stations was done from February to August 1959, with 5 examinations per each station.

One preliminary examination per each station was carried out at the stations »Gargano«, »Rovinj«, and »Lim«. The »Gargano« (N 42°08'0 E 16°10'0, about 124 m deep) is the station of the open Adriatic without any influence of the mainland. One examination per each station was carried out in the north Adriatic in front of Rovinj and in the Lim Channel, which are under the direct influence of the mainland. All the stations are seen in the Fig. 1. The stations »Sušac«, and »Maslinica«, at which the primary production was determined in 1958, can also be seen there. (Ibid).

We owe a great debt of gratitude to Dr. Miljenko Buljan, chief of the Hydrochemical Laboratory of the Institute for Oceanography and Fishery, who has put at our disposal yet unpublished data on phosphate and temperature, and has offered us expert help. Our warmest thanks are due to Ojdana Gašpić, and Mladen Alajbeg, the microbiologic laboratory technicians, who, as usual, have assisted us considerably with technical elaboration and laboratory work. At the final revision and correction Prof. Ljubica Cviić was a great help to us and we are deeply indebted to her.

MATERIAL AND METHODS

At the determination of the primary production we used the method of the radioactive C^{14} (Steeman Nielsen 1952). The examinations were done by means of bottles exposed at some determined depths. The length of the examination was about 6 hours. The determination of the thickness of the euphotic zone was done with Secchi disc, and the resulting depth was multiplied by the factor 2.6 because the Adriatic is particularly transparent. The radioactivity of the membrane filters was determined in Denmark (The International Agency for C^{14} Determination, Charlottenlund). In order to make the light conditions more comparable the measurings were always done when the sky was clear from 10 or 11 a. m. on.

The determination of the distribution of bacteria was done by the membrane filter method (Razumov 1931, 1955, Cviić 1960). The bacterial biomass was computed from the obtained results of the number of the bacteria in one unit of the sea water volume, under the condition that the weight of one milliard of bacterial cells is 0,25 mg.

The bottle-method was used in the reproduction of bacteria and bacterial biomass. The sea water from a certain depth was divided into two bottles of 100 cm^3. The data of the number of the bacteria were taken from the water sample, and then the bottles were lowered again down to a determined depth and were left there for six hours. At each determination two bottles were taken in order to control the results. Six hours later the bottles were pulled out, and the samples for the determination of the bacteria number on the membrane filters were taken out. From the data of the bacteria number at the beginning of the experiment, and the bacteria number in a determined volume after six hours we computed the bacteria and the bacterial biomass increase in the determined sea water volume, at a determined depth.

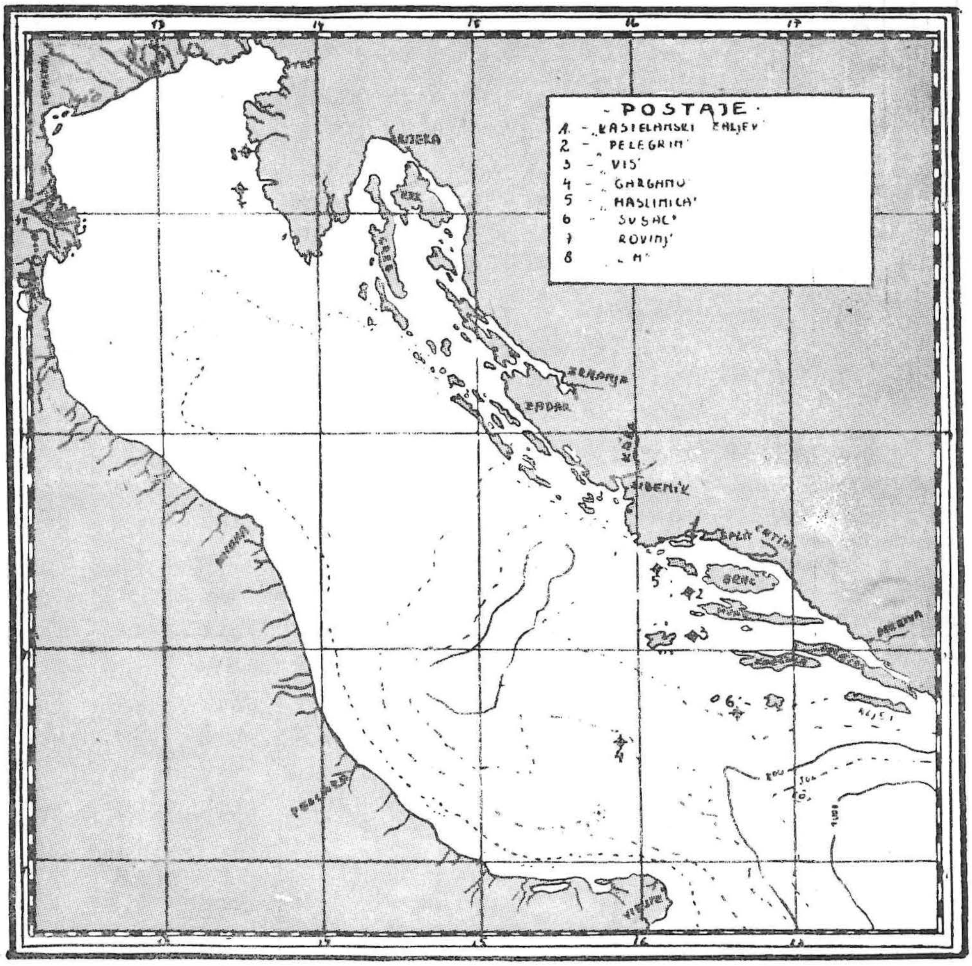

Fig. 1. Middle and north Adriatic area. Numbers 1—8 denote the stations at which the primary organic production has been determined.

Date	Depth m	Station »Vis«			Station »Pelegrin«			Station »Kaštel. zaliv«		
		Production mg C/m³ per day	P-PO₄ mg/t	Sea tempe-rature	Production mg C/m³ per day	P-PO₄ mg/t	Sea tempe-rature	Production mg C/m₃ per day	P-PO₄ mg/t	Sea tempe-rature
February 1959	0	0,768	1,6	13,5	1,848	1,8	13,8	9,456	2,2	10,0
	10	2,496	—	13,5	5,184	1,7	13,8	39,000	2,0	12,4
	25	1,944	0,0	13,4	5,112	0,7	13,7	3,336	1,0	14,2
	50	0,336	1,9	13,5	2,112	2,6	13,8	1,344	2,6	14,1
	70	—	0,6	13,7	0,744	1,7	13,8	—	—	
March 1959	0	5,712	1,2	13,7	1,344	2,8	13,8	8,352	1,9	12,7
	10	5,496	4,3	13,7	4,464	2,9	13,1	30,048	3,6	13,0
	25	3,288	1,6	13,5	5,808	2,8	13,1	20,448	4,4	13,2
	50	6,072	1,8	13,7	2,596	1,2	13,1	4,992	1,2	13,6
	70	1,848	1,5	13,6	2,304	1,9	13,2	—	—	—
April 1959	0	0,984	2,4	15,4	1,904	2,5	15,1	7,944	0,6	13,8
	10	2,568	1,3	14,9	4,776	3,5	15,1	23,376	1,2	13,6
	25	—	0,6	14,9	6,000	6,1	14,9	19,840	0,8	13,8
	50	2,184	0,9	14,8	3,600	3,5	14,4	6,456	1,6	13,9
	70	2,280	0,0	14,7	—	0,3	14,1	—	—	—
June 1959	0	2,976	1,2	20,4	1,968	1,0	21,34	62,488	2,4	23,2
	10	2,112	1,2	19,7	2,712	2,0	18,80	60,984	1,0	20,2
	25	2,856	0,6	16,1	3,360	2,7	17,38	9,072	2,0	16,2
	50	1,467	1,2	15,7	2,832	2,0	15,72	4,608	1,9	15,3
	70	1,776	0,0	15,1	1,464	4,1	15,1	—	—	
August 1959	0	2,640	2,0	23,3	—	—	—	16,888	1,2	24,0
	10	3,808	3,4	22,0	—	—	—	20,208	1,7	17,0
	25	2,088	2,0	16,5	—	—	—	7,176	1,[illegible]	15,1
	50	1,200	2,3	15,6	—	—	—	4,584	4,0	14,9
	70	1,416	1,2	14,6	—	—	—			

Tab. 1. Primary production (mg C/m³/day), amount of free phosphates (P—PO₄ mg/t), and temperatures at the middle Adriatic stations »Vis«, »Pelegrin«, and »Kaštelanski zaljev« (the denoted depth is orientational only; exact depths for each station are given on Tab. 2.).

EXAMINATION RESULTS

I. *Primary Production*

It has been stated in the first work on the research of the primary productivity of the Adriatic waters (C v i i ć 1963) that the Adriatic photosynthetic processes are rather small in size, i. e. that the Adriatic is a low productivity area. The present work deals with a more detailed examination of the primary productivity of the Adriatic sea.

The obtained data are shown on Tab. 1., and Fig. 2. Fig. 2. shows the vertical distribution of the production. A common characteristic is noticeable in all the three stations, i. e. »Kaštelanski zaljev«, »Pelegrin«, and the station »Vis«. In all the cases but one (Vis in June), the productivity on the surface was lower than at the depth of 15 or 25 m, and with the further increase of depth, the productivity was again on the decrease in all the cases. We can, therefore, prove with certainty that the production maximum, i. e. that the most lively photosynthetic activity, takes place in the layer 10 to 25 m deep.

If we compare the production quantity of each station, then the data show us that the highest productivity was at the station »Kaštelanski zaljev«, the second place in the production quantity was occupied by the station »Pelegrin«, while the lowest productivity for all the five measurings was found at the station »Vis«. This can be explained by the fact that the stations »Kaštelanski zaljev«, and »Pelegrin« are under the direct influence of the mainland, viz. under the fresh water influx substances from the river Jadro (the Bay of Kaštela), and the river Neretva (Pelegrin). These fresh waters are rich in organic substances and this material reaches the upper Adriatic areas with upstream currents.

Date of the sample	Station »Vis«			Station »Pelegrin«			Station »Kaštel. zaliv«		
	Depth Surface Bottom m	Thickness of the euphotic layer m	Production g C/m² per day	Depth Surface Bottom m	Thickness of the euphotic layer m	Production g C/m² per day	Depth Surface Bottom m	Thickness of the euphotic layer m	Production g C/m² per day
February 1959	110	75	0,079	80	70	0,20	38	36	0,56
March 1959	112	55	0,19	77	60	0,075	37	36	0'60
April 1959	109	60	0,11	79	60	0,19	37	35	0,54
June 1959	107	60	0,10	78	55	0,11	38	35	1,01
August 1959	103	55	0,085	—	—	—	36	35	0,37
Average:			0,112			0,143			0,61

Tab. 2. Primary organic production (g C/m²/day) in the euphotic zone at the stations »Vis«, »Pelegrin«, and »Kaštelanski zaljev«.

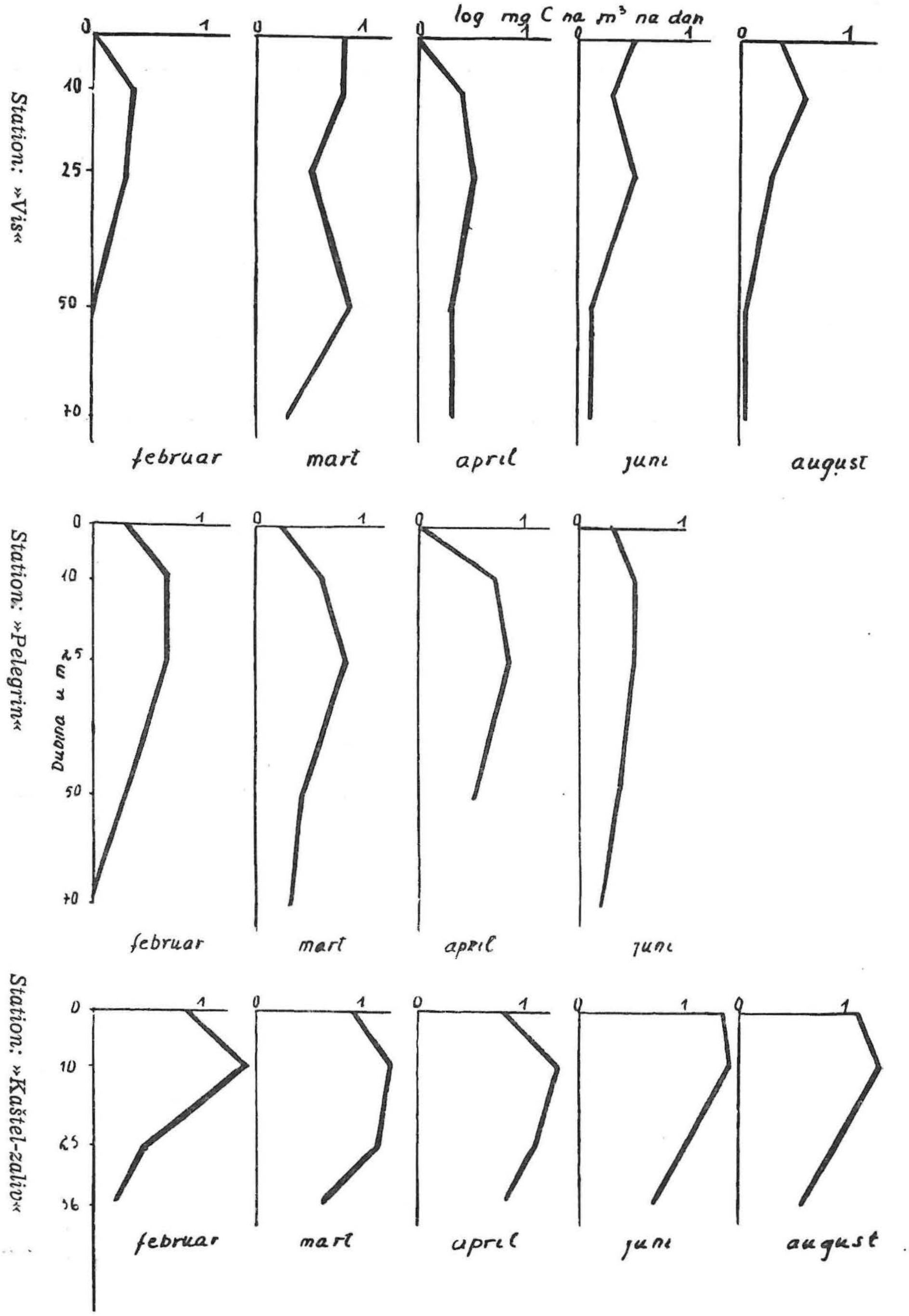

Fig. 2. The vertical distribution of the primary organic production (mg C/m³/day) at the stations of the middle Adriatic.

Primary production for the whole column of the euphotic zone of $1m^2$ surface shows us (Tab. 2) that the production g C/m^2 per day was the richest in June 1959 (0,40 g C/m^2/day), while in other months it was more or less equal with very little fluctuation (about 0,25 g C/m^2/day). The productivity, being a photosynthetic process, is in close connection with the quantity of light, so it is quite logical that the quantity of the produced organic material in individual months during the year shows more or less pronounced seasonal fluctuation. The total productivity per unit of sea water volume at the three above mentioned stations, viz. for the middle Adriatic region, mesaured from February to August 1959, is on an average 0,29 g C/m^2 per day.

Among the nutritient salts decisive for the quantity of the production besides nitrogen there is phosphorus, namely the phosphates. As the ratio N:P in the sea is more or less constant (Redfield 1934, Cooper 1937 and others), according to the consumption, viz. the quantity of phosphates ($P—PO_4$) we can conclude the quantity, viz. the approximate consumption of nitrogen $N—NO_3$). According to Cooper's statement the ideal ratio N:P, if the concentrations are shown in microgram-atom/1, is 15, but it varies from one region to another.

Tabl. 1. shows the quantities of free phosphates found at the time of determining the primary organic production at the three stations. Comparing the fluctuation of the quanties $P—PO_4$ with the fluctuation of the production C at individual stations in individual months it strikes us that in many cases at definite depths the relation between the quantity of the produced C and the quantity $P—PO_4$ is in inverse ratio. Besides a rank production there is want of phosphates. At some depths quantities of the phosphates were thoroughly consumed by the photosynthetic processes. In general the quantities of $P—PO_4$ were larger at the station »Kaštelanski zaljev« than at the stations »Vis« and »Pelegrin«, which corresponds to the quantity of the primary organic production. From the obtained data we can see that in the layers of a richer production there was a decrease in the quantity of the phosphates, which might mean that in these layers there was a larger production, i. e. consumption, of nitrate, or that the regeneration of the phosphates was very slow.

Tabl. 1. shows the data of temperature fluctuation at individual stations and depths. Although the temperature variation has a strong influence on the rate of respiration and the rate of photosynthesis at complete lighting up, we must emphasize that this influence is not a direct but an indirect one. Low temperatures, as seen on Tabl. 1., influence the production in the sense of slowing down. In warmer months, June and August, when the surface temperatures were up to 23 °C, and the vertical temperature distribution showed a thermocline, the primary production was on an increase. This was surely the result of the positive influence of temperature on the bacterial regeneration of nutritious salts.

For the sake of preliminary examination of the productivity of other parts of the Adriatic, one examination of the primary production per each station was done at »Gargano«, »Rovinj«, and »Lim« (Tab. 3). At the station »Gargano« in June 1959 there was a rather high productivity.

The highest production was found in the surface layer, but with the increase of depth the production decreased. The production per 1 m^2 of the euphotic zone was 0,21 g $C/m^2/day$. A high production, in relation to the production in the middle Adriatic, was found at the stations »Rovinj« and »Lim«, 0,31 g $C/m^2/day$ in the waters of Rovinj, and 0,20 g g $C/m^2/day$ in the waters of Lim. This high productivity phenomenon at the station Gargano might be explained by the influence of the fresh waters from the mainland at the stations »Rovinj« and »Lim«.

Generally speaking we can say that in our examinations the stations nearer the mainland showed a higher productivity than the stations far from the mainland. The highest productivity was found in the Bay of Kaštela where the production approached the high productive zones in oceans.

Comparing the general organic productivity of the Adriatic waters, according to the middle Adriatic data, with the data of the productivity which Steeman Nielsen (1957) has got for different oceanic and sea regions, it appears that the Adriatic is, on an average, region of low productivity, but that the productivity in individual regions, of littoral waters equals the productivity of some richer oceanic waters. If we take the general average of the Adriatic productivity as being 0,29 g $C/m^2/day$, then the Adriatic region belongs to the third group of the sea regions according to their richness; but if we take individual regions, e. g. the Bay of Kaštela or the north Adriatic regions, then, according to their production, the Adriatic waters might be set in the second or even the first category of oceanic waters. Of course these examinations have given only the first insight into the general primary productivity of the Adriatic waters, and further examinations will show a more detailed picture.

II. *Bacteria distribution and Reproduction*

The distribution of bacteria, both in vertical and horizontal sense, inside the euphotic zone of the middle Adriatic was examined simultaneously with the examination of the basic productivity of that region, and with the examination of some other ecologic factors. The results of the examination are seen on the Tab. 4, 5, and 6, and on the Fig. 3. The vertical, horizontal, and seasonal fluctuation of the bacterial population at the time of the examination, from February to August 1959, shows all the basic regularity of the fluctuation of the bacterial population up to now established for this and other regions. The data seen on Fig. 2. show that at all the three stations the bacterial maximum was found in the layer at the depth of 25 to 50 m, with only one exception, in August at the station »Kaštelanski zaljev«, where the maximum appears at the bottom of the euphotic zone. If we compare the distribution of the bacterial biomass at the stations »Kaštelanski zaljev«, »Pelegrin«, and »Vis«, we can notice that the richest bacterial settlement was on an average in the Bay of Kaštela, and the poorest one at the station »Pelegrin«. The average quantity of the biomass in the unit of the water volume at the station »Vis« is approaching the one at the station »Pelegrin«.

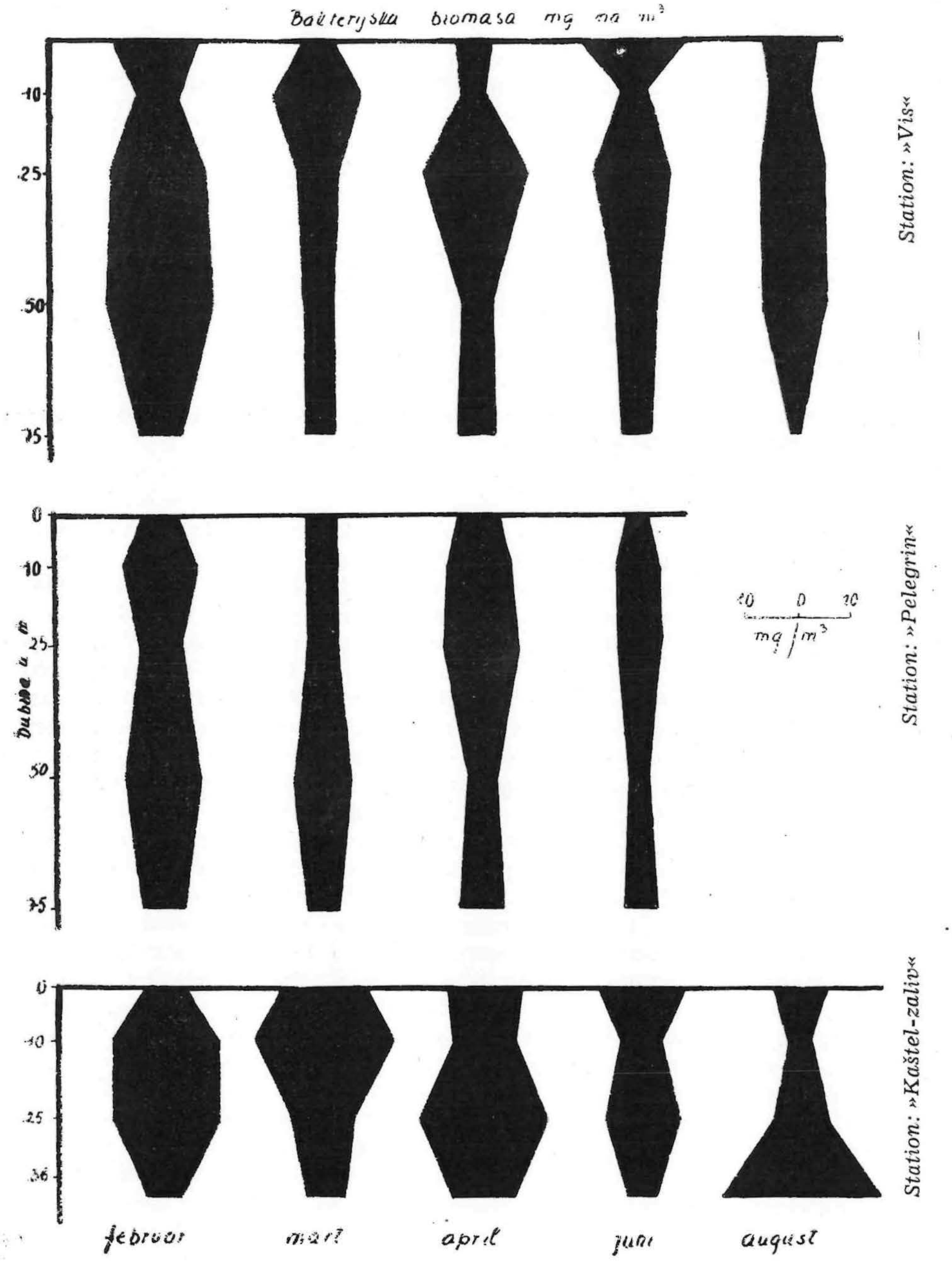

Fig. 3. Vertical and horizontal distribution of the bacterial biomass in the middle Adriatic.

Station „Gargano" June 1959			Station „Rovinj" April 1959			Station „Lim" April 1959		
Depth	Production mg C/m³ per day	Production g C/m² per day	Depth	Production mg C/m³ per day	Production g C/m² per day	Depth	Production mg C/m³ per day	Production g C/m² per day
0	8,904		0	11,736		0	12,144	
10	6,480		10	16,632		5	13,728	
25	4,512	0,21	20	9,672	0,31	10	16,104	0,20
50	3,936		29	5,952		14	15,672	
75	2,712							

Tab. 3. Primary organic production (mg C/m^3/day and g C/m^2/day) at the stations »Gargano«, »Rovinj« and »Lim«.

These findings of the bacteria and bacterial biomass distribution agree, according to the regularity of the distribution and the quantities, more or less with the up to present statement in this region (C v i i ć 1965 and 1962).

We have studied the bacteria and the bacterial biomass reproduction by means of exposing the bottles with sea water at determined depths. The experiment lasted 6 hours, and each time bottles with filtrated and unfiltrated sea water were lowered down to a certain depth. This treatment was used to observe the difference in the development and reproduction of the bacteria iwithout the influence of other various organisms and, vice versa, under the influence of the phytoplanktonic, zooplanktonic, and other possible organisms whicch entered the bottle with the sea water sample. On the Tab. 4, 5, and 6 are shown the results of our examinations. It is characteristic of all the three stations that in the unfiltrated sea water samples, at the beginning of the experiment and after 6 hours, the biomass of the bacteria, as well as the very increase of the biomass per hour, showed great variations. In many cases in the unfiltrated samples after 6 hours no increase of the bacterial biodass was noticed. The phenomen of this great dynamics can be explained by the fact that in the unfiltrated samples ware found phytoplanktonic and zooplanktonic organisms which in different ways slowed down the reproduction of the bacterial flora. Even the very bacteria could have had this slowing down effect because of their autolysis, but in any case the more pronounced effect was that of the zooplanktonic organisms which take, as it is a well known fact, the bacteria as thein food. In the unfiltrated samples the slowing down effect of the development of the bacterial population could have had some *Actinomuycetes* whiah, as we already know, produce a considerable quantity of antibiotics (G r e i n and M e y e r s 1958). Further, the slowing down effect on the bacterial population in the above mentioned samples could have had various planktonic agae which, like *Chlorella* and some planktonic diatoms, produce antibiotics, and these stop

Station	Depth	Unfiltrated samples				Filtrated samples			
		Bacteria number per cm³	Biomass at the beginning mg/m³	Biomass after 6 hours mg/m³	Biomass increasse per hour mg/m³	Bacteria number per cm³	Biomass at the beginning mg/m³	Biomass after 6 hours mg/m³	Biomass increase per hour mg/m³
„Vis" Feb. 11, 1959.	0	62.000	15,50	12,67	—	14.943	3,72	11,60	1,31
	10	29.987	7,47	9,87	0,40	16.171	4,05	9,07	0,84
	25	70.493	17,62	7,17	—	32.970	8,22	10,82	0,43
	50	75.517	18,87	19,65	0,13	23.557	5,87	7,77	0,36
	70	29.359	7,32	9,27	0,32	60 916	15,2	27,62	2,07
„Vis" March, 10, 1959.	0	14.287	3,57			24.649	6,15		
	10	63.899	15,97			13.502	3,37		
	25	17.898	4,47			28 393	5,85		
	50	27.318	6,82			23.707	5,92		
	70	15.229	3,80			5.495	1,37		
„Vis" April, 15 1959.	0	20.096	5,02			29.465	7,37	9,67	0,38
	10	19.154	4,77			32.813	8,20	15,27	1,18
	25	123.402	30,85			45.530	11,37	7,80	—
	50	18.546	4,62			22.069	5,52	8,60	0,51
	70	31.086	7,77			17.470	4,37	9,15	0,79
„Vis" June, 17, 1959.	0	88.234	22,05	34,37	2,05	24.284	6,07	8,45	0,39
	10	19.311	4,82	12,47	1,28	22.765	5,70	6,52	0,13
	25	56.834	14,20	4,67	—	24.489	6,12	10,90	0,79
	50	29.830	7,45	3,05	—	13 970	3,47	8,22	0,79
	70	22 765	5,70	5,80	0,02	21.431	5,35	9,90	0,76
„Vis" August, 21 1659.	0	36.453	9,10			22.138	5,52		
	10	28 103	7,02			24.492	6,12		
	25	41.605	10,40			13 816	3,45		
	50	41 919	10,47			127.671	31,92		
	70	5.161	1,30			92.630	23,15		

Tab. 4. The number of bacteria (per cm³), biomass, and biomass increase in the filtrated and unfiltrated samples at the station »Vis«.

Station	Depth	Unfiltrated sample				Filtrated samples			
		Bacteria numder per cm^3	Biomass at the beginning mg/m^3	Biomass after 6 hours mg m^3	Biomass increase per hour mg/m^3	Bacteria number per cm^3	Biomass at the beginning mg/m^3	Biomass after 6 hour mg/m^3	Biomass increasse per hour mg/m^3
„Pelegrin" Feb, 12, 1959.	0	21 509	5,37	10,35	0,83	21 509	5,37	10,35	0,83
	10	51.182	12,80	4,35	—	17.182	4,30	12,85	1,43
	25	26.690	6,67	16,37	1,62	26.690	6,67	16,37	1,62
	50	52.595	13,15	17,92	0,79	31.595	7,90	13,17	0,88
	70	25.905	6,47	6,52	0,01	25.905	6,47	6,52	0,01
„Pelegrin" March, 9, 1959.	0	21.666	5,40	7,65	0,38	23.233	5,80	10,52	0,79
	10	19.311	4,82	1,40	—	27.004	6,75	10,45	0,62
	25	17.584	4,40	6,95	0,63	20 253	5,05	4,50	—
	50	38.151	9,52	5,45	—	14.287	3,57	4,27	0,12
	70	24 806	6,20	9,42	0,54	23.141	5,77	12,27	1,08
„Pelegrin" April, 16, 1959.	0	35.796	8,95	11,50	0,43	9 820	2,45	10,22	1,29
	10	42.680	10,67	9,22	—	3.765	0,95	5,60	0,78
	25	47.100	11,77	3,67	—	18.369	4,60	5,72	0,19
	50	21.823	5,45	9,72	0,71	22.451	5,60	5,95	0,06
	70	39.721	9.92	6,60	—	11.304	2,82	6,75	0,65
„Pelegrin" June, 20, 1959.	0	19 468	4,85	17,85	2,17	39.250	9,80	10,60	0,13
	10	27.632	6,90	10,15	0,54	17 113	4,27	2,90	—
	25	10.990	2,72	12,35	1.60	51.025	12,75	12,00	—
	50	19.468	4,87	49,52	7,24	5.278	1,32	7,12	0,97
	70	26.376	6,10	29,90	3,96	29 987	7,47		
„Pelegrin" August, 22, 1959.	0	13,345	3,32			28 260	7,07		
	10	39.721	10,22			33.755	8,42		
	25	27.789	6,95			20.881	5,22		
	50	72.691	18,17			5.338	1,32		
	70	51.025	12,75			47.571	11,90		

Tab. 5. The number of bacteria (per cm^3), biomass, and biom ass increase in the filtrated and unfiltrated samples at the station »Pelegrin«

Station	Depth	Unfiltrated samples: Bacteria number per cm³	Unfiltrated samples: Biomass at the beginning mg/m³	Unfiltrated samples: Biomass after 6 hours mg/m³	Unfiltrated samples: Biomass increase per hour mg/m³	Filtrated samples: Bacteria number per cm³	Filtrated samples: Biomass at the beginning mg/m³	Filtrated samples: Biomass after 6 hours mg/m³	Filtrated samples: Biomass increase per hour mg/m³
Kaštel. zaljev Feb. 13, 1959.	0	36.267	9,07	16,22	1,19	61.230	15,30	43,87	4,76
	10	76.616	19,15	5,87	—	15.072	3,77	18,47	2,45
	25	80.541	20,12	23,65	3,92	20.096	5,02	5,22	0,03
	36	26.533	6,62	27,35	3,46	54.322	13,57		
Kaštel. zaljev March, 16, 1959.	0	70.493	17,62	14,10	—	18.683	4,67	4,62	—
	10	103.934	2,58	9,57	1,16	16.796	4,20	8,80	0,76
	25	53.694	12,32	8,70	—	67.353	16,82	16,47	—
	36	33.562	8,89	12,47	0,59	32.431	8,10	11,22	0,52
Kaštel. zaljev April, 24, 1959.	0	56.991	14,25	16,07	0,47	27.912	6,97	8,40	0,24
	10	44.588	11,15	9,65	—	21.509	5,37	11,30	0,98
	25	91.060	22,76	23,97	0,20	47.128	11,77	19,77	1,33
	36	54.950	13,74	15,55	0,30	24.499	6,12	8,00	0,31
Kaštel. zaljev June, 23, 1959.	0	66.725	16,68	18,97	0,38	39.868	9,97	12,67	0,45
	10	24.649	6,16	3,32	—	30.929	7,72	40,27	5,43
	25	50.868	12,72	15,07	0,43	21.980	5,47	14,62	1,53
	36	28.260	7,06	16,20	1,36	16.799	4,20	6,32	0,35
Kaštel. zaljev August, 24, 1959.	0	36.581	9,15			13.188	3,30		
	10	19.468	3,86			12.246	3,05		
	25	35.953	8,98			8.949	2,22		
	36	122.931	30,73			58.247	14,55		

Tab. 6. The number of bacteria (per cm³), biomass, and biomass increase in the filtrated and unfiltrated samples at the station »Kaštelanski zaljev«

considerably the bacterial activity (Steemann Nielsen 1955). The fluctuation in the reproduction of the bacterial biomass in the filtrated samples at all the three stations (Tab. 4, 5, and 6) is much smaller than in the unfiltrated samples. The sea water was filtrated through dense filter-papers which kept back all the organisms which could possibly have a slowing down effect on the reproduction of the bacterial biomass.

If we compare the cross section of the biomass reproduction in the filtrated and unfiltrated samples (Tab. 7) we can see that there are no great differences. But we must always bear in mind that the sea water itself, while being filtrated through a dense filter-paper, has lost some definite quantities of bacteria with the result that the increase in the filtrated samples was in fact greater than in the unfiltrated ones.

Stations	Unfiltrated samples			Filtrated samples		
	Biomass at the beginning mg/m³	Biomass after 6 hours mg/m³	Biomass inc ease per hour	Biomass at the beginning mg/m³	Biomass after 6 hours mg/m³	Biomass incre se per hour
»Vis«	9,87	11,89	0,70	7,73	10,75	0,78
»Pelegrin«	7,93	12,34	1,53	5,74	8,84	0,71
»Kaštelanski zaljev«	16,68	14,79	1,22	7,60	15,33	1,47

Tab. 7. Average values of the biomass and the biomass increase after the experiment of six hours in the unfiltrated and filtrated sea water samples.

The biomass increase per hour per sea water volume unit was from 0,70 to 1,53 mg/m^3 bacteria (Tab. 7). According to the obtained data the greatest increase was at the station »Kaštelanski zaljev«, which we can explain by the abundance of this region in organic materials as well as by the reason that because of its little depth it has higher temperature than the other regions. The general average bacterial biomass increase in the examined region of the Adriatic was 1,08 mg/m^3 per hour or 25,68 mg/m^3 per day, which shows a rather high increase if we compare it with the data of Kriss and Lambine (1955) for the oceanic region round the North Pole. The average bacterial biomass increase per day for this region was 3,5 mg/m^3. This great difference in the quantity of the reproduced bacterial biomass per time unit can be explained by the fact that the sea regions are in various temperature zones, and that the bacterial biomass in the waters round the North Pole fluctuated between 7, 8 and 0,007 mg/m^3, while in the Adriatic it fluctuated between 20,12 — 3,80 mg/m^3, as well as by the fact that the above mentioned authors used another method at the examination of the biomass increase, i. e. the method of submerged glass plates.

III. *Discussion*

According to some authors' opinion (K e t c h u m 1947, and others) the found quantities of nutritient salts in a certain sea layer do not necessary mean to and do not reflect the fertility of that environment. According to their opinion the found quantity is not important, but the rate of the regeneration of the consumed nutritient salts is. Yet we think that the found quantities of the nutritient salts in a determined region at a determined depth in their mutual comparison, and in the comparison with other factors could give an approximate orienting picture of their mutual influence, effect, and dependence of different ecological factors.

On Fig. 4 are shown the data of the vertical distribution of bacteria, the primary production, and the phosphates at the stations »Kaštelanski zaljev«, »Pelegrin«, and »Vis«. Although in the relation of these fluctuations any strictly determined regularity cannot be found, yet it gives us a possibility to draw a conclusion about the mutual relation between the above mentioned three factors at the time of examination.

The bacteria play a very important role in the cycle of the phosphorus in the sea. By destroying the organic phosphorus components, besides the regeneration of phosphorus, the bacteria, with their activity, produce acids that hasten the dissolving of the phosphates (R e n n 1937). The dissolubility of the phosphates in the sea is in a great part due to the function of pH, the property on which the bacteria, with their activity, can have a considerable influence by changing pH of the environment (C v i i ć 1956.b). On Fig. 3 the relation between the vertical distribution of the phosphate quantity and the bacterial population is very often in inverse ratio which means that the richer bacterial population coming with an abundant phytoplanktonic population uses great quantities of phosphates for its development besides those quantities used up by assimilation. The reason for the diminished or increased quantities of the phosphate could be the slow flow of the phosphates from the deep layers wherefrom they enter the euphotic zone by the vertical currents or by turbulency.

The relation between the bacteria, the phosphates, and the primary production according to Fig. 3 induces us to believe that the generally increased productivity decreases the quantity of the phosphates present, and thus also the quantities of nitrates. Although the regeneration of nitrate and phosphate is done in the euphotic zone itself through the effect of the enzymes, which are of vegetable, animal or bacterial origin, yet the main phosphate quantities come from the bottom sea layers where their intensive regeneration is being done. It is, namely, proved (C v i i ć 1956.a) that the bacterial population of the bottom waters releases 40 — 70 mg/m^3 of the free phosphates from the sea bottom mud, which represents a considerable

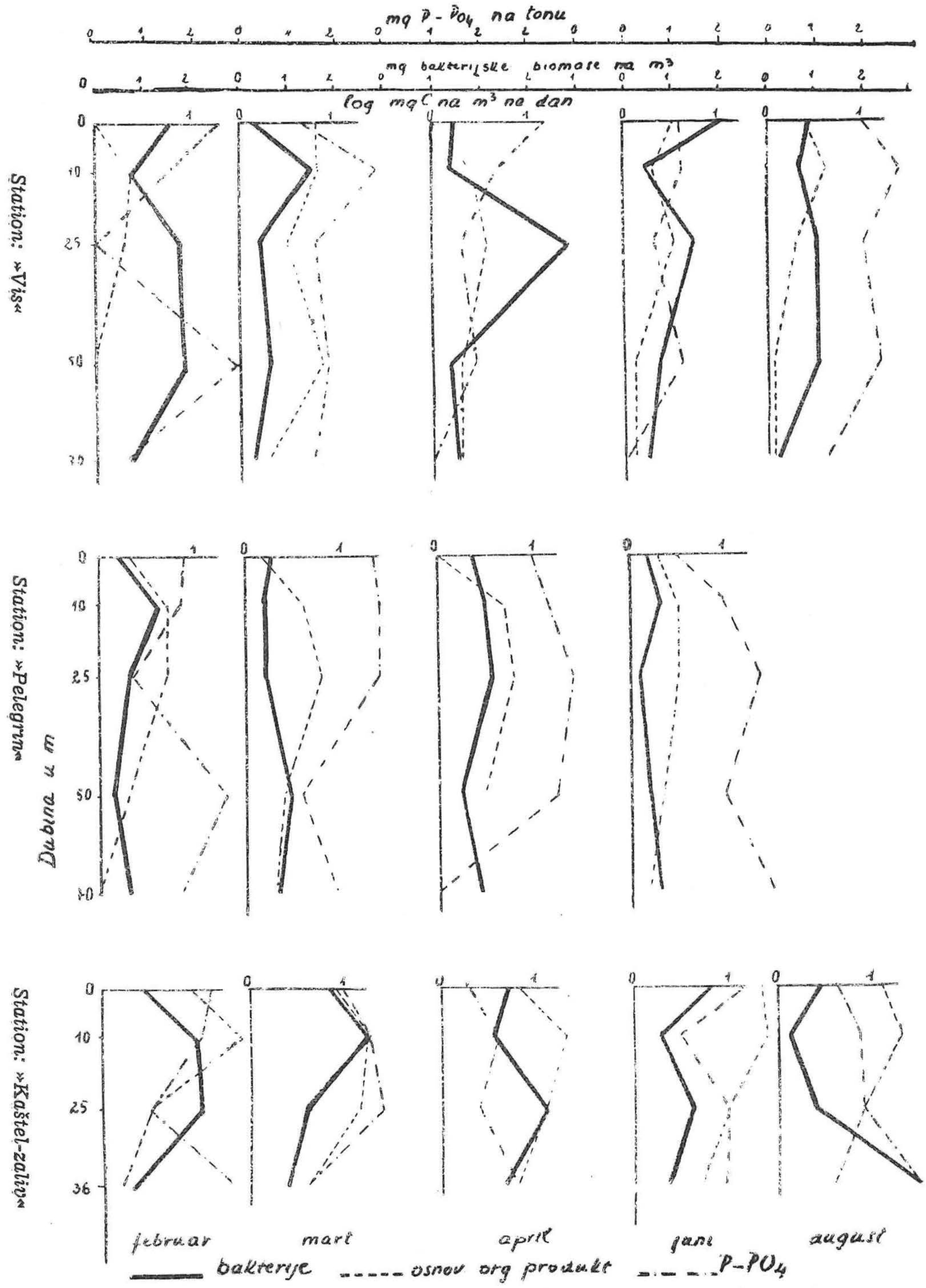

Fig. 4. Vertical distribution of the bacterial biomass, primary organic production, and the free phosphates (P—PO4) in the middle Adriatic.

amount of this nutritient salt. According to the findings of Ketchum (1947) the total assimilation of the phosphates at the time of the production is considered to be 8 g PO_4 (=2,7 g P) per m^2. From this only two per cent has its origin in the unorganic phosphates present in the photosynthetic layer, 73% has been transported to the surface from the bottom layer, and 25% has its origin in the destruction and the enzymatic action inside the surface layer. According to this author's data the computed daily consumption of 14 mg P per m^2 per day corresponds to 560 mg of assimilated C per m^2. In the Sargasso Sea, which is one of the regions with the lowest productivity, the daily regeneration of unorganic phosphate is 0,01 mg P/m^2 and in the Danish fjord Iselfjord Steeman Nielsen (1956) found that the concentration of phosphate is 1 mg P/m^3, while the organic production in that period was very high and varied between 250 and 520 mg C/m^3/day. If we compare these data with the data of the phosphate and organic production quantities in the explored area of the Adriatic, we can acertain that the Adriatic region, according to its phosphate quantities (which are from 6,1 to 0,6 mg/t), its rate of the phosphate regeneration, the assimilated phosphate quantity, and the quantity of the production of the basic organic material (which is from 112 — 610 mg/m^2/day), is more or less equal to the sea regions in the North Temperate Zone.

The data about the basic organic productivity in the examined region show us only the euphotic zone production according to the measurings with the Secchi disc, and do not denote the total productivity of the Adriatic waters. It has been, namely, proved that under the euphotic zone many autotrophic organisms, like diatoms, flagellates and the photosynthetic bacteria can be found. At the depth of 4,000 m cocolitophoridae have been found, and in the Black Sea Kriss and Rukina (1953) have found some active photosynthetic sulfuric bacteria at the depth of 2,500 m. Although some of the above mentioned organisms can also be heterotrophic (Lewin 1953, and Wood 1956), most of them are exclusively autotrophic. The phenomenon that the assimilation processes can be accomplished without the presence of light in deep sea is explained in various ways by various authors. Kriss and Rukina (1953) believe that the red and the green sulfuric bacteria use radioactive energy in their processes. Ferguson — Wood (1959) thinks that the strictly autotrophic organisms under the euphotic zone are either in the state of dying out, or that they have a very low need of light, or that for the photosynthetic processes they use another energy, not the sun's radiation. In any case, it has been stated that under the euphotic zone and the compensating depth the reduction of carbon dioxide, i. e. photosynthesis, is being accomplished. Its result is the production of organic material and only the total amount of the produced organic material in the euphotic zone and that in the deep layers represents the total production of the sea or oceanic water.

SUMMARY

In this work are given the data about the primary organic production and distribution, and the bacteria reproduction in the region of the middle and north Adriatic, at the stations »Kaštelanski zaljev«, »Pelegrin«, »Vis«, »Gargano«, »Rovinj«, and »Lim«.

The primary production determined with the radioactive C^{14} method for the entire column of the euphotic zone in the region under examination shows us that the production g C per m^3 per day was the richest in June 1959, i. e. it was 0,40 g C/m^3/day, while for the other months at all the stations it was more or less the same with very little fluctuation, and it was about 0,25 g C/m^3/day. The average productivity for the above mentioned three stations from February till August 1959 was 0,29 g C/m^3/day.

It has been generally shown that the productivity in the littoral waters, or in the waters under the direct influence of the mainland or other fresh waters (the Bay of Kaštela, and the north Adriatic) was higher than in the open Adriatic region.

The vertical and horizontal distribution of the bacteria and the bacterial biomass in the euphotic zone of the region under study has shown its greatest richness in the middle layer of the euphotic zone, while with the increase of depth it decreased. The station »Kaštelanski zaljev« which is under the direct influence of mainland and fresh waters, during the examination from February to August 1959 had the richest bacterial flora.

The bacteria reproduction showed that the biomass increase per sea water volume unit was from 0,70 to 1,53 mg per m^3 of bacteria per hour. The greatest bacterial biomass increase was found at the station »Kaštelanski zaljev«. The general average bacterial biomass increase in the examined region was 1,08 mg/m^3 per hour or 25,68 mg/m^3 per day.

The relation between the bacteria, phosphate, and the primary production in the examined region as ecological factors mutually closely connected and conditioned has been discussed. The analysis of the relation of these factors has shown that the bacterial population and the phosphate quantities found in a determined sea water layer are in inverse ratio, and the same relation has been stated for the quantities of the found phosphate and the primary production mg C/m^3/day.

The quantity of the phosphate regeneration and of the primary production in the Adriatic, and in some other sea and ocean regions has been compared. It has been stated that the Adriatic can be numbered among some regions with lower productivity in regard to the oceanic productivity, but that some littoral regions with their productivity aproach some more abundant regions in other seas.

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OSNOVNA ORGANSKA PRODUKCIJA, RASPROSTRANJENOST I RAZMNOŽAVANJE BAKTERIJA U EUFOTIČKOJ ZONI SREDNJEG JADRANA

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KRATKI SADRŽAJ

U radu su izneseni podaci o osnovnoj organskoj produkciji i rasprostranjenosti te razmnožavanju bakterija u području srednjeg i sjevernog Jadrana, na postajama »Kaštelanski zaljev«, »Pelegrin«, »Vis«, »Gargano«, »Rovinj« i »Lim«.

Osnovna organska produkcija određivana metodom radioaktivnog C^{14} za cijeli stupac eufotičke zone u istraživanom području pokazuje da je produkcija g C na m^3 na dan bila najbogatija u junu 1959. god., tj. da je iznosila 0,40 g C/m^3/dan, dok je za ostale mjesece na svim postajama bila približno jednaka sa veoma malim kolebanjima, a iznosila je oko 0,25 g C/m^3/dan. Ukupna prosječna produktivnost za spomenute tri postaje od februara do augusta 1959. god. iznosila je 0,29 g C/m^3/dan.

Općenito se pokazalo da je produktivnost u priobalnim vodama, ili vodama pod direktnim utjecajem kopna ili slatke vode (Kaštelanski zaljev i sjeverni Jadran), veća nego u području otvorenog Jadrana.

Vertikalna i horizontalna rasprostranjenost bakterija i bakterijske biomase u eufotičkoj zoni istraživanog područja pokazala je najveće bogatstvo u srednjem sloju eufotičke zone, dok je sa povećanjem dubine bila u opadanju. Postaja »Kaštelanski zaljev«, koja je pod direktnim utjecajem kopna i slatke vode, imala je u vrijeme istraživanja od februara do augusta 1959. god. najbogatiju bakterijsku floru.

Razmnožavanje bakterija pokazalo je da prirast biomase na sat na jedinicu volumena morske vode iznosi od 0,70 do 1,53 mg na 1 m^3 bakterija. Najveći prirast bakterijske biomase nađen je na postaji »Kaštelanski zaljev«. Opći prosječni prirast bakterijske biomase u ispitivanom području bio je 1,08 mg/m^3 na sat ili 25,68 mg/m^3 na dan.

Diskutirani su odnosi između bakterija, fosfata i osnovne organske produkcije u istraživanom području, kao ekoloških faktora međusobno usko povezanih i uslovljenih. Analiza odnosa ovih faktora pokazala je da bakterijska populacija i količina fosfata, nađenih u određenom sloju morske vode, stoje u obrnutom razmjernom odnosu, a isti odnos je utvrđen i za količine nađenih fosfata i količine osnovne organske produkcije mg C/m^3/dan.

Uspoređena je količina regeneracije fosfata i količina osnovne organske produkcije u Jadranskom moru i nekim područjima drugih mora i oceana. Utvrđeno je da Jadransko more možemo ubrojiti među manje produktivna područja s obzirom na produktivnost oceana, ali da pojedina priobalna područja dostižu po produktivnosti bogatija područja u ostalim morima.

Dr VLAHO CVIIĆ (1909—1963)

Being a research worker of the Institute for Oceanography and Fishery from 1947. and Director of the Institute from 1956. until his death on June, 1. 1963, Dr Cviić worked intensively both on the organization of research work and on the sea bacteriology. He was a pioneer in the work on the Adriatic: he was the first to study the bacteria of the Adriatic sea and he carried out the first measurings of the primary organic production in the Adriatic. He specialized at the Scripps Institute, USA, where he took on the working methods in the marine bacteriology and applied them in the Adriatic. His doctor's dissertation which he defented in Belgrade in 1956. at the Serbian Academy of Science deals with the bacteria distribution in the Middle Adriatic waters and the influence of some ecologic factors.

The late Cviić not only did scientific work but also popularized science. He was president of the Biologic Commission for organizing the scientific work in SR Croatia, president of Croatian Natural Science Society, Split branch, as well as a public social worker. Being a popularizer of natural sciences he wrote the book »Bacteria in the Sea«. He also wrote a number of popular articles in the periodicals PRIRODA, and MORSKO RIBARSTVO (Nature; Sea-fishery).

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