000-3254-6
CONF-720922--2

Trophic dynamics and niches of salt marsh foraminifera

John J. Lee and William A. Muller

To be presented at the XVII International Congress
of Zoology;

Monaco, 25-30 September 1972

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

INTRODUCTION

It boggles the mind to even conceive of understanding the complex interrelationships in the salt marsh communities which are the habitat for many species of foraminifera. Nevertheless, we have, for some time, been interested in evaluating some of the factors which control the productivity of foraminifera in the salt marshes and other shoal water communities. The problem of productivity is an old one which has been approached from both the field and laboratory by many protozoologists and paleocologists (Berger 1969, Boltovskoy 1964, 1970, Bradshaw 1955, 1957, 1961, Brooks 1967, Buzas 1965, 1968, 1970, Lee et al. 1966, 1969, Lynts 1966, Murray 1963, 1965, 1967, Myers 1942a, b, 1943, Phleger 1960, 1964, 1966, 1970 and Ramanathan 1970). Field studies suggest that environmental factors such as current, nutrients, salinity, bottom sediments, and especially temperature restrict and control the overall distribution patterns of benthic species. Whenever it has been studied, it has been found that within the appropriate gross environmental conditions the foraminifera have a very patchy (Boltovskoy and Lena 1969, Buzas 1968, 1969, 1970, Lynts 1966, Lee et al. 1966, Madera and Lee 1972, Phleger 1966) and seasonal (Boltovskoy 1964, Buzas 1969, Murray 1965, 1967, Phleger and Lankford 1957, Ramanathan 1969, 1970, Walton 1955) distribution.

Myers (1942, 1943) in a very general way drew attention to the seasonal cycles of phytoplankton and correlated foraminiferan production to the abundance of food. Subsequent laboratory studies by Bradshaw (1955, 1961) and Lee et al. (1963, 1966, 1969), Lee and McEnery (1970), Muller (1972), Muller and Lee (1969) have shown the importance of numbers and types of food organisms in determining the growth and reproductive rates of littoral benthic forms. Lee et al. (1960) and Buzas (1970) have concluded that the foraminifera they studied seem to be opportunistic species (MacArthur and Levins 1964). Interspecific and intraspecific competition for feed also play an important role in limiting foram productivity (Lee et al. 1966, Muller and Lee 1969, Muller, 1972). The highly productive salt marsh psammolittoral and epiphytic communities which we have studied (Lee et al.

1969, 1972, Matera and Lee 1972, Tietjen unpublished report) undergo rapid changes in community structure throughout the summer. Successive blooms of different species of diatoms, foraminifera, and nematodes seem to characterize summer communities.

One of the conclusions made by Teal in his classical study of energy flow in Georgia salt marshes (1962) was that community stability is achieved because "among the detritus-algae feeders there are only a few important species and they all have a very unrestricted diet." Our evidence on population structure and succession within the microbial and micrometazoan assemblages agreed with MacArthur's suggestion (1955) that a more efficient pathway to community stability is achieved through having many species, each with restricted diets. Theoretically a young, rapidly changing community is potentially a more productive one.

It seemed to us that a study of trophic dynamics and energy flow of those species of foraminifera whose niches are best known (Muller 1972) might help clarify the seeming conflict between Teal's (1962) conclusions and ours.

MATERIALS AND METHODS

The experimental organisms were isolated from field collections taken at Towd Point, North Sea Harbor in Southampton, Long Island and cultured as described previously (Lee et al. 1961, 1963, 1970, Muller and Lee, 1969). Gnotobiotic cloned stock cultures of the 3 species were grown in pyrex screw capped test tubes (20 x 125 cm) with 10 ml of erdschreiber (pH 8.0 and salinity 26 %). Phaeodactylum tricornutum (39) and Amphora sp (5) were the only algae in the Allogromia stock cultures. Rosalina leei were grown with Nannochloris sp (41) and Amphora sp (5). S. hyalina were grown with Amphora (5) on erdschreiber butts with a shallow sea water overlay. All stocks and experiments were incubated in the light, $\sim 200 \mu\text{w}/\text{cm}^2$ (18 hr light/6 hr dark) at 25 C. Inocula for experiments were 5 A. laticollaris, 20 R. leei and 50 S. hyalina. The carrying capacity of each species in these culture conditions was calculated from the average number of individuals at maximum density in 100 replicate tubes. Respiration was measured with the aid of a Gilson differential respirometer.

The production of populations of each species was calculated by the following formula:

$$\text{Production} = 80\% \times D_w \times f_n$$

80% = estimate of carbon percentage of dry weight

D_w = dry weight of a single individual of the species
of foraminifera under discussion

f_n = the size of the population of the species of
foraminifera under discussion at a given time, t_n .

Radioactive tracers were used in qualitative and quantitative feeding studies (Lee et al. 1966). Foraminifera for these studies were washed 10 times with sterile media and any food adhering to the surface of the animals was removed with glass needles. Care was taken to select organisms of approximately the same size for each experiment.

Except when population size was a variable in tracer feeding studies, the following test populations were used: 10 Allogromia, 20 Rosalina, and 50 Spiroloculina. Previous studies (Lee et al. 1966, Muller and Lee, 1969) showed that these were the minimum inocula for statistically meaningful data. Each experiment was done 4 or 6 times.

Potential foods were inoculated into appropriate media with ^{32}P (0.5-1 $\mu\text{Ci/ml}$) as a label, and incubated in strong light for 24 hrs. As in previous experiments (Lee et al. 1966) this level of radionuclide was adjusted to $\sim 0.1 - 1$ count/min/cell. Labeled food cells were harvested by centrifugation and washed 5 times in sterile unlabeled sea water. The population density of each food species was determined by counting an aliquot with a hemocytometer. The appropriate number of food cells was inoculated into the foraminiferan cultures and incubated for 24 hrs. The foraminifera were harvested by gentle agitation with a vortex mixer, allowing the animals to settle, and removing the supernatant fluid. Autoclaved dead organisms were used as controls. The process was repeated 5 times. The foraminifera were placed in scintillation vials with a minimum of water carry over, dried, and mixed with 15 ml of scintillation fluid. Radioactivity was measured by means of a Beckman liquid scintillation counter.

The biomass of the algae eaten was determined by measuring the volumes of 100 individual logarithmically growing algae cells. Log phase cells were chosen for measurement since they were used in the tracer feeding studies. Previous studies (Lee et al. 1966) had shown that fewer stationary phase cells are eaten by foraminifera than cells in any other phase. The biomass of the algae eaten was converted to grams carbon by assuming that $\sim 80\%$ of the biomass was water.

RESULTS

Under optimum laboratory conditions the reproductive rate of A. laticollaris is rapid ($T_g = 8$ days) and after 1 month the carrying capacity is reached. The carrying capacity for A. laticollaris is large and sometimes exceeds 2600 organisms per 10 ml of media. Although the carrying capacity changed, depending upon the parental inoculum, the intrinsic rate of increase (r) during the logarithmic phase is the same. A. laticollaris has the largest value of r (2.533 org/day) of all the foraminifera tested. The sizes of individual populations varied greatly during the logarithmic growth phase, reflecting the various asexual reproductive pathways which can occur during the life cycle of this organism (Lee, McEnery and Rubin 1969). The carrying capacity of R. leei in optimum laboratory conditions, is 1350 organisms per 10 ml, but almost 2 years (540 days) were required to reach this population. The intrinsic rate of increase was correspondingly smaller (0.272 org/day). Under optimum conditions the carrying capacity (3600 org/day) of S. hyalina cultures is reached in about 30 days. The intrinsic rate of increase is equal to 1.472 org/day which is intermediate to those of A. laticollaris and R. leei. The large range in the sizes of individual populations probably can be best explained as dampening oscillations of the means carrying capacity.

The respiration rates of 3 species of foraminifera used in the present study are similar (Fig. 1). The rates ranged from 0.5-4.5 $\mu\text{l/mg}$ body weight/hr within the temperature range 15-35 C. The respiratory rate of A. laticollaris is low (0.5 $\mu\text{l/mg/hr}$) when the temperature is less than 21 C. Between 21-35 C respiration increases sharply to 4.2 $\mu\text{l/mg/hr}$ at 35 C. The respiratory rate of R. leei increases from 0.7 $\mu\text{l/mg/hr}$ at 15 C to 4.5 $\mu\text{l/mg/hr}$ at 25 C and then declines to 2.8 $\mu\text{l/mg/hr}$ at 35 C. The rate of respiration of S. hyalina gradually increases from 1.0 $\mu\text{l/mg/hr}$ at 15 C to 4.4 $\mu\text{l/mg/hr}$ at 35 C. Of all the species tested, the rate of carbon turnover is highest for R. leei. At optimum temperature (25 C) 8.67 $\mu\text{g C/foram/week}$ are respired. The maximum carbon turnover for A. laticollaris was at 35 C.

(3.78 $\mu\text{g C/foram/week}$; Table 1). Carbon turnover was slowest in S. hyalina. At optimum temperature (30-35 C) only 0.198 $\mu\text{g C/foram/week}$ was respired (Table 3). The carbon turnover of populations of the foraminifera were also different. At 35 C 10.2×10^{-3} g C/week were respired by a population of ~2700 A. laticollaris (Table 1). The respiration of ~1300 R. leei (11.22×10^{-3} g C/week) was slightly higher than a population of A. laticollaris over twice the size (Table 2). Even though a test tube population of S. hyalina may be ~3700 organisms, the respiration (0.7×10^{-3} g C/week) of the population was ~8-10% of that of A. laticollaris and R. leei (Table 3).

Foraminifera are selective feeders. Of the 28 species of diatoms and chlorophytes tested only 4-5 were consumed in significant quantities ($40-150 \times 10^{-5}$ mg/foram/day) by the foraminifera. Two species of algae Phaeodactylum tricornutum (39) and Amphora sp (5) were eaten in large amounts by all the foraminifera. In synxenic culture A. laticollaris ate almost 5 times more Amphora sp (5) (1.5×10^{-3} /animal/day) than most other species tested. Four other species, Phaeodactylum tricornutum (39), Amphora sp (RF-8) and Nannochloris sp (41 and Pb-6) were also eaten in large amounts ($5.6 - 8.0 \times 10^{-4}$ mg/animal/day). Although great numbers of bacteria were eaten, their biomass ($0.1-8.3 \times 10^{-6}$ mg/animal/day) was negligible when compared to the algae.

Two of the algal species, Amphora sp (RF-8), and Nannochloris sp (41) which were eaten by Allogromia in large amounts were not eaten by the other foraminifera. R. leei ate 2 species of algae, 93 and Pb-13, that the other foraminifera did not consume in large amounts. Pb-13 was eaten in the greatest amounts (6.4×10^{-4} mg/foram/day) followed by Amphora sp (5) and unidentified chlorophyte (93). In terms of total biomass the other algae were eaten in less significant amounts (range $1-35 \times 10^{-5}$ mg/animal/day).

The feeding of S. hyalina on algae was unusual; only 1 species of alga, Amphora sp (5) was an important food source ($\sim 1.2 \times 10^{-4}$ mg). The biomass of most of the others was <20% of the number of Amphora sp (5) eaten. The biomass ($0.2-1.0 \times 10^{-6}$ mg/animal/day) of bacteria consumed was similar to that of R. leei and was not significant from a carbon budget view point.

The conversion of ingested carbon into body tissue is small for all species. The ecological growth efficiency (P/I) for A. laticollaris is highest during the first and second weeks of growth (12.24-10.16%) when the population is in the logarithmic growth phase (Table 4). As anticipated, the E_e is $< 1\%$ after 7 weeks when the population has reached its carrying capacity. Population of R. leei grow erratically (Lee et al. 1963, Muller and Lee, 1969) and so the E_e of the population varies considerably (Table 5). During the first week the E_e was 21.58%; the second week it was down to 5.38%, while the third week it returned to 10.75%. The rate of ingestion of populations of S. hyalina is similar to the other species tested, but net production is so small that the E_e of the species is always $< 10\%$ and may be as small as 0.07% when the populations reaches its carrying capacity (Table 6).

DISCUSSION

The ecological growth efficiency (E_e) of the 3 species tested is highest during the logarithmic phase of growth. The E_e of both A. laticollaris and S. hyalina declines steadily to $< 1\%$ at ~ 70 days. Neither species is tolerant of crowded conditions (Muller 1972) and both are characteristically rare species in the field (Lee et al. 1969, Matera and Lee 1972). In nature (after a severe drought) and in the laboratory when conditions are optimal, that is competition is low and the appropriate species of food are present, both species bloom and then decline to very low levels. Only Rosalina leei shows signs of being a generalist. It had some microenvironmental dependence in common with all the other common species in the marsh except Elphidium translucens (Lee et al. 1969) and was moderately abundant in the environment throughout the summer. Unlike the other species tested the E_e of R. leei remained fairly high ($> 5\%$) for the duration of the experiment. In the present study respiration of R. leei exceeded the carbon uptake from Amphora sp (5) when it was the sole labeled food source. This is further evidence that this species has different feeding requirements than the other 2 species. It needs to feed on mixtures of algae to satisfy its carbon budget.

It would be presumptuous to extrapolate productivity figures for the entire foraminiferan assemblage of the community. In terms of tissue growth efficiency (E_t) the foraminifera studied (i.e., A. laticollaris $\sim 18\%$) were approximately as productive as the nematodes ($\sim 25\%$) and the crabs (17%) studied by Teal and Kanwisher (1961) and Teal (1962). In view of the high standing crops, turnover of species, and high E_e of salt marsh foraminifera it is clear that they can play a significant role in the carbon budget and nutrient cycling within the detritus-microbial assemblages of salt marshes. All lines of evidence we have gleaned this far from tracer feeding (Lee et al. 1966, Muller 1972), standing crops (Lee et al. 1969, Matera and Lee 1972), competition and niche width (Muller 1972), and energetic considerations suggest that the species of foraminifera we have studied are very opportunistic and well adapted to play important trophic roles in the very rapidly changing

food webs in the communities of which they are an important part. Since energetic considerations are in agreement with our previous data it seems more reasonable to believe that stability and high rates of productivity in the microbial and micrometazoan assemblages of salt marshes is achieved through species diversity.

LITERATURE CITED

- Berger, W. H. 1969. Ecologic patterns of living planktonic foraminifera. Deep-Sea Res., 16:1-24.
- Boltovskoy, E. 1964. Seasonal occurrences of some living foraminifera in Puerto Deseado (Patagonia, Argentina). J. Cons. perm. int. Explor. Mar. 39:136-145.
- Boltovskoy, E. 1970. Distribution of the marine littoral foraminifera in Argentina, Uruguay and Southern Brazil. Int. J. Life in Oceans and Coastal waters, 6(4):335-344.
- Boltovskoy, E and Lena, H. 1969. Microdistribution des foraminiferes benthoniques vivants. Revue de Micropaleontologie 12:177-185.
- Bradshaw, J. S. 1955. Preliminary laboratory experiments on the ecology of foraminiferal populations. Micropaleontology, 1:351-358.
- Bradshaw, J. S. 1957. Laboratory studies of the rate of growth of the foraminifera *Streblus beccarii* (Linne) var. *tepida* (Cushman). J. Paleontol. 31:1138-1147.
- Bradshaw, J. S. 1961. Laboratory experiments on the ecology of foraminifera. Contrib. Cushman Founda. Foramin. Res. 12:87-106.
- Brooks, A. L. 1967. Standing crop, vertical distribution and morphometrics of *Ammonia beccarii*. Limnol. Oceanog. 12:667-684.
- Buzas, M. A. 1965. The distribution and abundance of foraminifera in Long Island Sound. Smithsonian Inst. Misc. Collections 149:1-94.
- Buzas, M. A. 1968. On the spatial distribution of foraminifera. Contrib. Cushman Found. Foramin. Res. 19:1-11.
- Buzas, M. A. 1969. Foraminiferal species densities and environmental variables in an estuary. Limnol. Oceanog. 14:411-422.
- Buzas, M. A. 1970. Spatial homogeneity: statistical analyses of uni-species and multispecies populations of foraminifera. Ecology, 51:871-879.
- Lee, J. J., Freudenthal, H. D., Muller, M., Kossoy, V., Pierce, S., and Grossman, R. 1963. Growth and physiology of foraminifera in the laboratory: Part 3 - Initial studies of *Rosalina floridana* Cushman. Micropaleontology, 9:449-466.
- Lee, J. J. and McEnery, M. 1970. Autogamy in *Allogromia laticollaris*. (Foraminifera). J. Protozool. 17:184-195.
- Lee, J. J., McEnery, M., Pierce, S. Freudenthal, H. D. and Muller, W. 1966. Tracer experiments in feeding littoral foraminifera. J. Protozool. 13:659-670.

- Lee, J. J., M. McEnery and H. Rubin. 1969a. Quantitative studies on the growth of Allogromia laticollaris (Foraminifera). J. Protozool. 16:377-395.
- Lee, J. J., Muller, W. A., Stone, R. J., McEnery, M. and Zucker, W. 1969b. Standing crop of foraminifera in sublittoral epiphytic communities of a Long Island salt marsh. J. Marine Biol. 4:44-61.
- Lee, J. J. and Pierce, S. 1963. Growth and physiology of foraminifera in the laboratory. Part 4 - Monoxenic culture of an allogromiid with notes on its morphology. J. Protozool. 10:404-411.
- Lee, J. J., Pierce, S., Tentchoff, M. and McLaughlin, J. J. A. 1961. Growth and physiology of foraminifera in the laboratory: Part 1- Collection and maintenance. Micropaleontology. 7:461-466.
- Lynts, G. W. 1966. Variation of foraminiferal standing crop over short lateral distances in Buttonwood Sound, Florida Bay. Limnol. Oceanogr. 11:562-566.
- MacArthur, R. H. and Levins, R. 1964. Competition, habitat selection, character displacement in a patchy environment. Proc. Nat. Acad. Sci., 51:1207-1210.
- Matera, N. J. and Lee, J. J. 1972. Environmental factors affecting the standing crop of foraminifera in sublittoral and psammonlittoral communities of a Long Island salt marsh. Limnol. Oceanogr. 17 (in press).
- Myers, E. H. 1935. Culture methods for the marine foraminifera of the littoral zone. Trans. Amer. Microscop. Soc. 54:264-267.
- Myers, E. H. 1936. The life cycle of *Spirillina vivipara* with notes on morphogenesis, systematics and distribution of the foraminifera. J. Royal Soc. 61:120-146.
- Myers, E. H. 1937. (Culture methods for marine foraminifera of the littoral zone). Culture Methods for Invertebrate Animals (P.S. Galstoff, ed.) Comstock, Ithaca.
- Myers, E. H. 1942a. A quantitative study of the productivity of the Foraminifera in the sea. Proc. Am. Philos. Soc. 84:325-341.
- Myers, E. H. 1942b. Biological evidence as to the rate of which tests of foraminifera are contributed to the sediments. J. Paleontol., 16:397-398.
- Myers, E. H. 1943. Life activities of foraminifera in relation to marine ecology. Proc. Amer. Phil. Soc. 86:439-358.
- Muller, W. A. 1972. Graphic representation of niche width and its application to salt marsh littoral foraminifera. Ph.D. thesis, City University of New York.

- Muller, W. A. and Lee, J. J. 1969. Apparent indispensability of bacteria in foraminiferan nutrition. *J. Protozool.* 16:471-478.
- Murray, J. W. 1963. Ecological experiments on foraminifera. *J. Marine Biol. Assoc. U. K.* 43:621-642.
- Murray, J. W. 1965. Significance of benthic foraminiferids in planktonic samples. *J. Paleontol.*, 39:156-157.
- Murray, J. W. 1967. Production in benthic foraminiferids. *J. Nat. Hist.* 1:61-68.
- Phleger, F. B. 1960. Ecology and distribution of recent foraminifera. Johns Hopkins Press, Baltimore, Md.
- Phleger, F. B. 1964. Patterns of living benthonic foraminifera, Gulf of California. *Mar. Geology of the Gulf California - A Symposium, Memoir No. 3, Amer. Assoc. Pet. Geologists*, pp. 377-394.
- Phleger, F. B. 1966. Patterns of living marsh Foraminifera in South Texas coastal lagoons. *Bol. Soc. Geol. Mexicana* 28:1-44.
- Phleger, F. B. 1970. Foraminiferal populations and marine marsh processes. *Limnol. Oceanogr.* 15:522-534.
- Phleger, F. B. and Bradshaw, J. S. 1966. Sedimentary environments in a marine marsh. *Science.* 154:1551-1553.
- Phleger, F. B. and Lankford, R. R. 1957. Seasonal occurrences of living benthonic foraminifera in some Texas bays. *Contrib. Cushman Found. Foramin. Res.*, 8:93-105.
- Ramanathan, R. 1969. Seasonal variations in foraminifera abundance and their relation to the substrate in Vellar estuary, Madras. *J. Geol. Soc. India*, 10:254-272.
- Ramanathan, R. 1970. Quantitative differences in the living benthic foraminifera of Vellar Estuary, Tamil Nadu. *J. Geol. Soc. India*, 11:127-141.
- Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. *Ecology* 43:614-624.
- Teal, J. M. and Kanwisher, J. 1961. Gas exchange in a Georgia salt marsh. *Limnol. Oceanogr.* 6:388-399.
- Walton, W. R. 1955. Ecology of living benthonic foraminifera, Todos Santos Bay, Baja California. *J. Paleontol.*, 29:952-1018.

TABLE 1

Respiration of Allogromia laticollaris

C	ml CO ₂ /mg/foram/hr	grams C/foram/day	Grams C respired by the population/week										10 ⁻³
			1	2	3	4	5	6	7	8	9	10	
10	0.1	1.2	.01	.03	.09	.17	.22	.23	.24	.24	.24	.24	
15	0.25	0.3	.02	.07	.21	.42	.54	.59	.61	.60	.61	.61	
20	0.50	0.6	.05	.14	.43	.83	1.08	1.17	1.22	1.19	1.22	1.22	
25	2.00	2.6	.18	.55	1.74	3.39	4.39	4.76	4.94	4.85	4.94	4.94	
30	4.00	5.2	.36	1.08	3.43	6.68	8.66	9.39	9.75	9.57	9.75	9.75	
35	4.20	5.4	.38	1.13	3.59	6.99	9.07	9.83	10.21	10.02	10.21	10.21	

TABLE 2

Respiration of Rosalina leei

C	ml CO ₂ /mg/foram/hr	10 ⁻⁷ Grams C/foram/day	Grams C respired by the population/month 10 ⁻³									
			1	2	3	4	5	6	7	8	9	10
10	0.40	1.1	.24	.32	.63	.95	1.59	2.50	3.74	4.04	4.12	
15	0.70	1.8	.41	.55	1.09	1.64	2.74	4.32	6.45	6.97	7.11	
20	1.6	4.1	.93	1.24	2.48	3.71	6.19	9.78	14.61	15.78	16.09	
25	4.5	10.3	2.60	3.47	6.94	10.41	17.35	27.41	40.95	44.24	45.11	
30	3.5	9.0	2.02	2.71	5.42	8.13	13.55	21.41	31.98	34.55	35.23	
35	2.8	7.2	1.62	2.16	4.32	6.48	10.80	17.06	25.49	27.54	28.08	

TABLE 3

Respiration of Spiroloculina

C	ml CO ₂ /mg/foram/hr	gms C/foram/day 10 ⁻⁸	Grams C respired by the population/week 10 ⁻⁴												
			1	2	3	4	5	6	7	8	9	10	11	12	13
10	0.5	0.3	.04	.13	.44	.61	.70	.77	.79	.81	.80	.81	.79	.80	.81
15	1.0	0.6	.09	.27	.90	1.26	1.44	1.57	1.62	1.66	1.64	1.66	1.62	1.64	1.66
20	3.8	2.4	.34	1.02	3.42	4.78	5.47	5.98	6.15	6.32	6.24	6.32	6.15	6.24	6.32
25	4.2	2.7	.37	1.13	3.78	5.29	6.04	6.61	6.80	6.99	6.89	6.99	6.80	6.89	6.99
30	4.4	2.8	.40	1.20	4.00	5.60	6.40	7.00	7.20	7.40	7.30	7.40	7.20	7.30	7.40
35	4.4	2.8	.40	1.20	4.00	5.60	6.40	7.00	7.20	7.40	7.30	7.40	7.20	7.30	7.40

TABLE 4

Energetic consideration of the growth of populations of Allogromia fed Amphora sp (5) at 25 C.

Week	Ingestion (mg)	Respiration (mg)	Assimilation I-R	Population dry weight (mg)	Net production for week (mg C)	$\frac{\%}{E_a} = \frac{A}{I}$	$\frac{\%}{E_t} = \frac{P}{A}$	$\frac{E_e}{P/I}$
1	1.05	0.18	0.87	0.16	0.16	82.86	18.39	12.24
2	3.15	0.55	2.60	0.48	0.32	82.53	12.31	10.16
3	9.98	1.74	8.24	1.20	0.72	82.56	8.74	7.21
4	19.43	3.39	16.04	2.40	1.20	82.55	7.48	6.18
5	25.20	4.39	20.81	3.36	1.16	82.58	5.57	4.60
6	27.30	4.76	22.54	4.00	0.64	82.56	2.84	2.34
7	28.35	4.95	23.40	4.24	0.24	82.54	1.03	0.85
8	27.83	4.85	22.98	4.37	0.08	82.57	0.35	0.29
9	28.35	4.95	23.40	4.24	-0.08	82.54	-0.34	0.28
10	28.35	4.95	23.40	4.32	0.08	82.54	0.34	0.29

TABLE 5

Energetic consideration of the growth of populations
of Rosalina fed Amphora sp (5) at 25 C.

Month	Ingestion (mg)	Respiration (mg)	Assimilation I-R	Population dry weight (mg)	net production for month mg C	% $E_a = A/I$	$E_t = P/A$	$E_e = P/I$
1	1.39	2.60	- 1.21	0.3	0.3	-87.05	-24.79	21.58
2	1.86	3.47	- 1.61	0.4	0.1	-86.56	- 6.21	5.38
3	3.72	6.94	- 3.22	0.8	0.4	-86.56	-12.42	10.75
4	5.58	10.41	- 4.83	1.2	0.4	-86.56	- 8.28	7.17
5	9.30	17.35	- 8.05	2.0	0.8	-86.56	- 9.94	8.60
6	14.69	27.41	-12.72	3.0	1.0	-86.59	- 7.86	6.80
7	21.95	40.95	-19.00	4.6	1.6	-86.56	- 8.42	7.29
8	23.72	44.24	-20.52	5.2	0.6	-86.51	- 2.92	2.53
9	24.18	45.11	-20.93	5.4	0.2	-86.55	- 0.95	0.83
10	24.18	45.11	-20.93	5.4	0	-86.55	0	0
11	24.18	25.11	-20.93	5.4	0	-86.55	0	0

TABLE 6

Energetic consideration of the growth of populations of Spiroloculina fed Amphora sp (5) at 25 C.

Week	Ingestion (mg)	Respiration (mg)	Assimilation I-R	Population dry Weight (mg)	Net production for week (mg C)	% $E_a = A/I$	% $E_t = P/A$	$E_e = P/I$
1	1.54	0.04	1.50	0.08	0.08	97.62	5.33	5.19
2	4.62	0.11	4.51	0.24	0.16	97.62	3.55	3.46
3	15.42	0.38	15.02	0.80	0.56	97.53	3.73	3.63
4	21.56	0.53	21.03	1.16	0.36	97.54	1.71	1.67
5	24.64	0.60	24.04	1.36	0.20	97.56	0.83	0.81
6	26.95	0.66	26.29	1.44	0.12	97.55	0.47	0.45
7	27.72	0.68	27.04	1.48	0.02	97.55	0.07	0.07
8	28.49	0.70	27.79	1.46	-0.02	97.54	0.07	0.07
9	28.11	0.69	27.42	1.48	0.02	97.55	0.07	0.07
10	28.49	0.70	27.79	1.48	0.0	97.54	0	0
11	27.72	0.69	27.03	1.48	0.0	97.51	0	0

Fig. 1

Allogromia laticollaris (25C)

Fig. 2

Rosalina leei (25C)

Fig. 3

Spiroloculina hyalina

Fig. 4

Fig. 5