COO-2581-1

MARINE PASTURES: A BY-PRODUCT OF LARGE (100 MEGAWATT OR LARGER) FLOATING OCEAN THERMAL POWER PLANTS

PROGRESS REPORT

for Period February 1, 1975 - January 31, 1976

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C O N T E N T S

ABSTRACT

Our on-shore experimental area for primary- and secondary-producers was completed 1 November 1975. The system is built around six 2000-liter concrete tanks ("reactors"), to which deep water (from 870 m) is supplied while surface water is pumped from a shallow-water line extending 100 ft north of the beach facility in St. Croix. An experimental rack has been built which is capable of holding 90 separate test populations. Flow into reactors and experimental rack is regulated by constant-head devices.

The system design provides flexibility for controlled manipulation and investigation of a wide variety of parameters at various trophic levels.

Based on preliminary results of experimentation with continuous culturing of phytoplankton in mixtures of deep and surface water, we can say that a 70:30 (deep/surface) mixture is optimal for producing algal blooms which will sustain rapid growth of Tapes semidecussata in on-shore controlled growth conditions (see Abstract, Appendix A).

An open-ocean structure has been designed for growing bivalves, and is anchored off-shore near the intake of the deep-water pipeline. The structure is being tested for stability, durability and ease of handling. A second design (for non-attaching shellfish) is being built.

A modified computer program has been developed to search NODC data tapes containing measurements to within 10% of the ocean bottom on a seasonal basis. We have computed parameters, listed and stored seasonal data, and will refine an existing program to plot T' on a Mercator projection map of the region from 17°-19°N; 64°66°W.

Physico-Chemical Study of the Fate and Effects of Deep Water Discharged at the Surface

(Frank Aikman)

SUMMARY

NODC hydrographic data tapes contain measurements to within 10% of the ocean bottom on a two-season basis, and FORTRAN programs have been written to search these tapes for stations in specified locations, to compute pertinent parameters, and to store, list and plot these data.

By modifying these existing programs to our needs, we will be able to plot isothermal maps of T', the amount of warming required to bring 800-m water into density equilibrium with the surface water, and will overlay these isothermal plots onto existing NOAA/C&GS Mercator maps at the same scale.

To-date we have developed an altered program which has searched the data tape of interest to us (containing data from 17° to 19°N and from 64° to 66°W), computed parameters, listed summer and winter data on the printer, and stored this data on a summary tape. We are now in the process of refining a program that will read the summary tape and plot T' on a grid that can be superposed over a Mercator projection map. It is expected that these isothermal plots will be completed before the end of December 1975.

We will then consider the problem of making a primitive approximation of the predicted fate of deep water discharged at the ocean surface.

November 1975

Primary Production in Different Mixtures of Surface and Deep Water: Growth Responses of Natural Phytoplankton to Deep-Water Enrichment

(James Petersen)

SUMMARY

Batch-culture enrichment experiments using different proportions of deep water as the nutrient enrichment source and surface water as the inoculum were carried out. Yield of phytoplankton is proportional to nitrate uptake and increases with increasing deep-water percentage 1 µg-at NO_3-N yielded about .26 µg chlorophyll *a*. Specific growth rate increased with initial nitrate concentration and is described by the Michaelis-Menten equation. Values for K_s (µg-at NO_3-N $liter^{-1}$) and u_{max} (doublings per day) were 1.55 and 3.55, respectively.

INTRODUCTION

Floating off-shore power plants will discharge tremendous volumes of nutrient-rich deep water at the surface which will stimulate phytoplankton productivity. The operations at the Lamont-Doherty Marine Biological Station in St. Croix have shown that phytoplankton grown with deep water as the nutrient source is a satisfactory food source for shellfish in a mariculture system. The extent to which phytoplankton productivity will be increased in the open ocean, surface waters by deep-water enrichment will depend upon (1) the fate of the deep water after discharge (in turn dependent on the salinity of the deep water and the surface water, and on temperature); (2) the rate at which deep water is diluted by surface water; (3) the depth of the mixed layer, (4) the

size and species composition of the phytoplankton crop.

In this preliminary study, batch-culture conditions were studied using surface water as the phytoplankton inoculum and deep water as the nutrient source. As the ratio of deep water to surface water increases we would expect the yield of phytoplankton to increase due to increased nutrients. But the size of the phytoplankton inoculum would be less and therefore we would expect an increase in the lag period of the growth response of the phytoplankton. It was the purpose of these experiments to determine the proportion of deep water-surface water mixtures which minimize the lag period of growth and maximize exponential growth. These experiments also examined differences in growth response using reef water and off-shore water as the inoculum. This was done to see if it is reasonable to assume that reef water may be used in following studies until such time as off-shore surface water is easily available.

MATERIALS AND METHODS

Three batch-culture enrichment experiments were run (June, 1975) to determine the effects of nutrient-rich deep water on the surface-water phytoplankton productivity. Deep water was supplied by the 870-m deep pipeline and surface water was collected near shore (reef water) and from five miles off-shore.

Water was mixed in the following proportions of surface water: Experiment 1 (reef water) 100, 95, 85, 70, 40, and 0 per cent; Experiment 2 (off-shore water) 100, 85, 70, 40, 20, and 0 per cent; and Experiment 3 (two series, reef and off-shore water) 40, 15, and 5 per cent. Duplicates of each mixture were incubated in 20-liter jerricans (twelve) under natural sunlight at near-surface-water temperatures (26 ± 1°C) maintained by floating the jerricans in a large concrete reactor with continuously

flowing deep water. The effects of deep-water enrichment were assessed in terms of cell density, chlorophyll a concentration, taxonomic composition, and changes in nutrient concentration.

Each experiment ran until the maximum yield was obtained as determined by chlorophyll a concentration (4 to 8 days). Samples of surface and deep water were taken at the beginning of each experiment to determine initial nutrient concentration (NO_3, NO_2, NH_3, PO_4, SiO_4) and salinity. Samples were collected each day in two 300-ml glass-stoppered bottles from each jerrican beginning at 0815 hr. Twenty to 200 ml were filtered onto a Whatman glass-fiber filter (Type GA/E) for fluorometric determination of chlorophyll a and phaeopigments; 250 ml were filtered and saved in glass (refrigerated) and in plastic (frozen) bottles for nutrient analysis with a Technicon AutoAnalyzer (AA-II); 125 ml were preserved with Utermöhl's solution and refrigerated for cell counts and taxonomic classification. Cell counts were done for each mixture in Experiments 1 and 2 and for the 5% mixture in Experiment 3 on those samples for which chlorophyll a concentrations had reached a maximum. Cells were either concentrated and counted in a 3-ml settling chamber on in an inverted microscope or counted directly using a Eosinophil counting chamber.

RESULTS AND DISCUSSION

Table 1 gives the initial nutrient concentrations for each of the experiments. The 100% and 0% surface water samples showed little increase in chlorophyll a over the time course of Experiments 1 and 2. This would be expected in the 100% surface water due to lack of nutrients, and in the 0% surface water due to a lack of inoculum and/or "biological conditioning" factors. Except for the 5% surface-water mixtures in Experi-

TABLE 1. INITIAL NO_3, PO_4, SiO_4, SALINITY, AND N:P RATIOS FOR ALL MIXTURES, ALL EXPERIMENTS

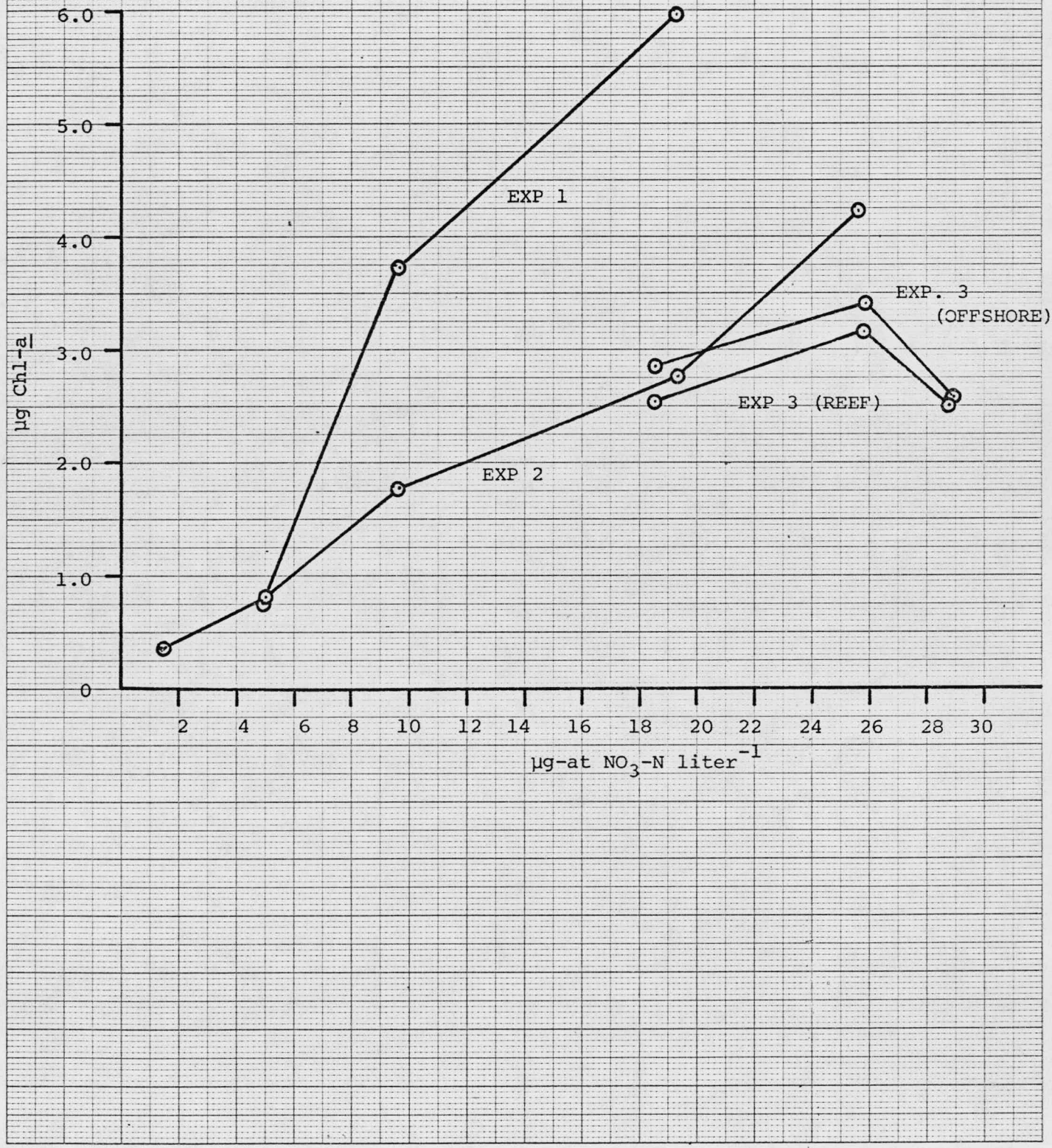
EXPERIMENT	% SURFACE WATER	NO_3	PO_4	SiO_4	SALIN (°/oo)	N:P
1 (REEF)	100	.2	.3	1.5	35.653	
	95	1.8	.4	2.2		4.5
	85	5.0	.5	3.4		10.0
	70	9.7	.78	5.4		12.5
	40	19.3	1.26	9.3		15.3
	0	32.1	1.9	18.5	34.489	
2 (OFFSHORE)	100	.2	.24	5.7	35.511	
	85	5.0	.48	7.4		10.3
	70	9.7	.73	9.3		13.3
	40	19.3	1.23	13.0		15.7
	20	25.6	1.6	15.5		16.0
	0	32.0	1.9	18.6	34.489	
3 (REEF)	40	18.3	1.2	12.1		15.4
	15	25.9	1.56	15.6		16.6
	5	29.0	1.72	17.1		17.1
(OFFSHORE)	40	18.4	1.2	12.1		15.4
	15	25.9	1.57	15.6		16.6
	5	29.0	1.72	17.1		17.1
100% REEF WATER		<.1	.21	3.5	35.596	
100% OFFSHORE WATER		.15	.24	3.5	35.539	

ment 3, there was a direct relationship between "total yield" measured as chlorophyll a concentration, and initial nitrate concentration. In general, the maximum chlorophyll a concentration showed the following pattern for equivalent initial nitrate concentrations: Experiment 1 greater than Experiment 2 greater than or equal to Experiment 3 (Fig. 1). Nearly all of the nitrate was taken up in all mixtures of Experiment 1 by the time the chlorophyll a maximum was reached, but there were still significant amounts of nitrate remaining at the chlorophyll a maximum in Experiments 2 and 3 for mixtures of surface water less than or equal to 40%. While the chlorophyll a maximum was expected to be proportional to the initial nitrate concentration, a much better correlation is achieved by relating chlorophyll a concentration to nitrate uptake ($r = .91$). The yield of chlorophyll a in μg liter^{-1} for each μg-at NO_3-N liter^{-1} taken up was as follows: Experiment 1: .31; Experiment 2: .23; and Experiment 3: .24 for 40 and 15 per cent, and .12 for 5 per cent.

The chlorophyll a to phaeopigment ratio may indicate to what extent grazing by microzooplankters may have been a factor in reducing the chlorophyll a maximum. In Experiment 1 this ratio was less than 2 at the chlorophyll a maximum, and in Experiment 2 this ratio was greater than 2 at the maximum. In those cases where the nitrate became depleted after the chlorophyll a maximum had been reached, the ratio of chlorophyll a to phaeopigments often became greater than 4.

Since natural populations of phytoplankton take up 10 to 15 times more nitrogen than phosphorus, we might expect phosphate to become limiting in those cases where the N:P ratio is greater than 15:1 (Table 1). In all mixtures of 40% surface water or less, the ratio of nitrogen uptake to phosphate uptake at the chlorophyll a maximum was less than 15:1. In those cases where this ratio is greater than 15:1, there may

FIGURE 1



have been luxury consumption of nitrate or growth of low-phosphate or phosphate-deficient forms. Table 2 gives these N:P ratios for uptake.

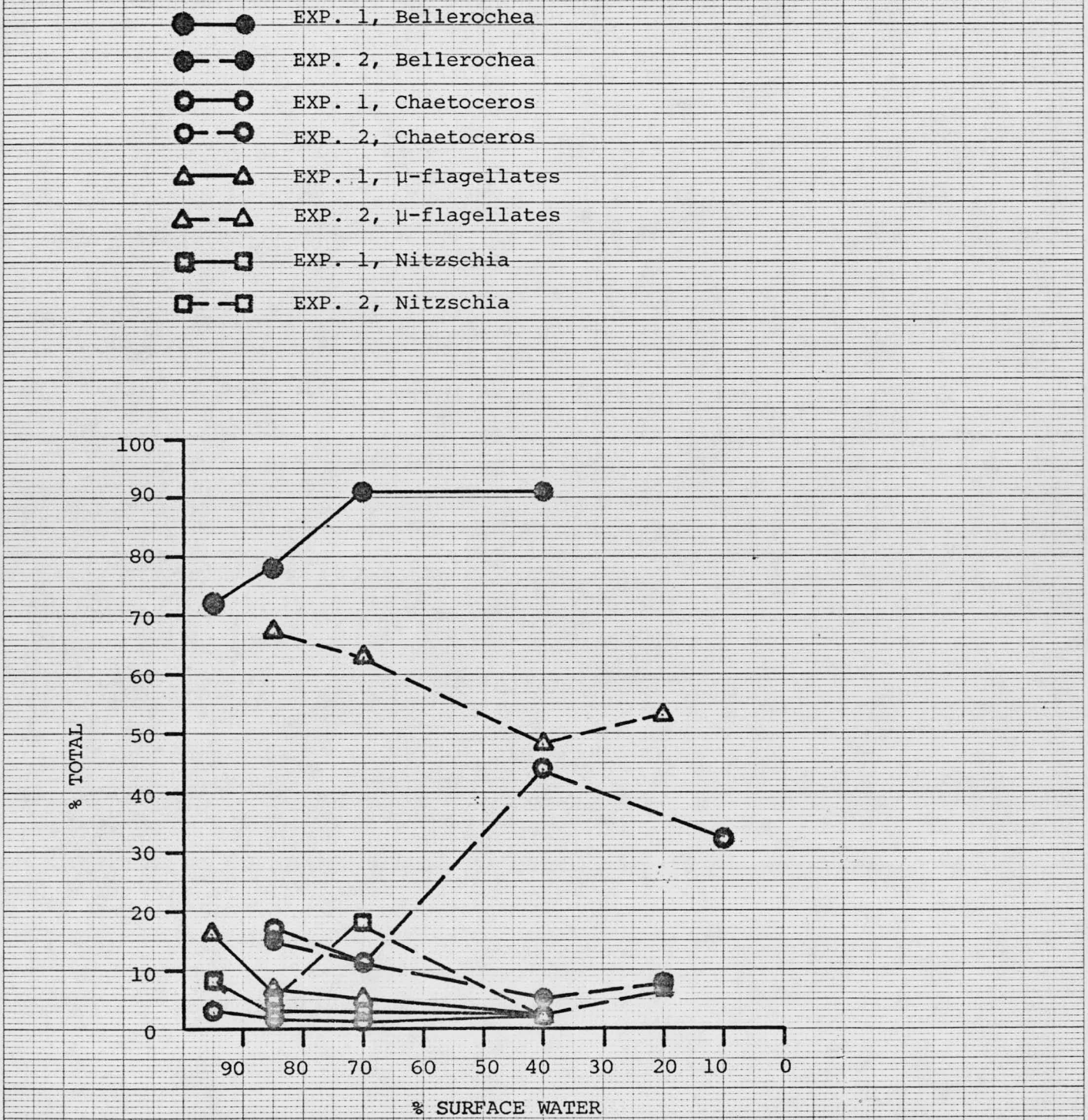
There is good correlation between cell number and chlorophyll *a* concentration ($r = .87$) and this correlation is even better ($r = .96$) if a relatively low value for cell number for the 40% sample in Experiment 1 is deleted (1 µg Chl-*a* = approx. 40×10^6 cells). It was felt that this high correlation justified the use of the chlorophyll *a* data for the calculations of specific growth rates. There is an increase in specific growth rate (u_2 = doublings/day), an increase in the lag period before exponential growth is achieved and an increase in the time before maximum yield is reached with increasing initial nitrate concentration or decreasing surface-water inoculum (Table 2). In a comparison of reef and off-shore water, Experiment 1 achieved maximum yield a day before maximum yield in Experiment 2, but in Experiment 3, reef water showed a day lag over off-shore water. It is difficult therefore to say anything about differences in lag periods due to the differences in reef and off-shore water mixtures. The initial nutrient concentrations and chlorophyll *a* concentrations were very similar for both reef and off-shore water in Experiment 3. For Experiments 1 and 2 the relationship between highest observed specific growth rates and initial nitrate concentration (S) is hyperbolic and can be fitted by the Michaelis-Menten equation. A linear transformation (u_2/S versus u_2) provides values for the half-saturation constant, K_s (where $u_2 = u_{max}/2$), and for u_{max}. K_s (µg-at NO_3-N liter^{-1}) and u_{max} (doublings/day) were as follows: Experiment 1, $K_s = 1.67$ and $u_{max} = 3.66$; Experiment 2, $K_s = 1.29$ and $u_{max} = 3.49$; and Experiments 1 and 2 (pooled data), $K_s = 1.55$ and $u_{max} = 3.58$.

Figure 2 shows the relative taxonomic composition of the phytoplankton populations at maximum yield. A small centric diatom, *Bellerochea* sp.

TABLE 2. NITRATE UPTAKE (µg-at NO_3-N/l) AT MAXIMUM CHLOROPHYLL A CONCENTRATION (µg/l), MAXIMUM SPECIFIC GROWTH RATES (DOUBLING/DAY) N-UPTAKE, P-UPTAKE RATIO, CELL DENSITY (10^6/l) (LAG BEFORE MAXIMUM YIELD IN PARENTHESIS)

EXPERIMENT	% SURFACE WATER	ΔN	CHL-A	CELL #	μ_2	ΔN:ΔP
1 (REEF)	95	1.8	.40(3)	15.0	2.1	8.9
		1.8	.34(3)		2.7	
	85	5.0	.85(4)	62.7	2.1	20.8
		5.0	.82(4)		2.1	
	70	9.7	3.72(4)	121.2	3.1	18.3
		9.7	3.72(4)		3.2	
	40	18.3	6.22(4)	123.2	4.2	17.1
		18.0	5.66(4)		3.8	
2 (OFFSHORE)	85	5.0	.98(4)	41.0	2.6	10.0
		5.0	.88(5)		2.9	
	70	9.7	1.98(5)	88.0	2.9	22.6
		9.7	1.51(5)		3.2	
	40	12.3	2.55(5)	114.0	3.3	13.2
		13.7	2.92(5)		3.3	
	20	16.4	4.53(6)	127.0	3.3	13.6
		14.2	3.96(6)		3.3	
3 (REEF)	40	10.9	2.55(5)		3.1	10.7
	15	15.6	3.15(6)		3.1	12.6
	5	29.0	2.83(8)	114.0	3.5	16.8
		5.9	2.41(6)		3.6	15.6
(OFFSHORE)	40	10.9	2.84(4)		3.5	13.7
	15	11.1	3.11(5)		3.2	11.1
	15	12.7	3.68(5)		3.0	15.1
	5	28.7	2.94(7)	75.0	3.0	17.1
				(2.06 µg-at Chl-a)		

FIGURE 2



(STX-114), dominated (greater than 70%) in all mixtures of Experiment 1. The genera Nitzschia and Chaetoceros were also present. In the second experiment μ-flagellates and other small forms made up greater than 50 per cent of all the samples, but in the 40 and 20% mixtures, Chaetoceros increased in importance to 44 and 32 per cent, respectively. In Experiment 3, the taxonomic composition of the 5% surface mixtures of reef and off-shroe water were much more similar. In both cases the order of dominance was μ-flagellates, Chaetoceros, Nitzschia. While the first two experiments showed a great difference in taxonomic composition, these differences are probably due to the occasional appearance of STX-114 in the deep water. The results of the third experiment are probably more typical.

It would seem that on the basis of chlorophyll a yield, initial nutrient concentrations, salinity, taxonomic composition based on Experiment 3, and growth kinetics, that reef water could be substituted for off-shore water in preliminary studies.

CONCLUSIONS

While in general the total yield was proportional to the total nitrate supplied, in all cases for mixtures of 40% surface water or less, the nitrate was not depleted before maximum yield was obtained. The ratio of N:P was greater than 15:1 in the 40% (or less) surface water mixtures. This ratio is greater than the uptake ratio of N:P in phytoplankton populations. The nitrate taken up by the time maximum yield had been obtained was 10 to 15 μg-at NO_3-N $liter^{-1}$ and the N:P ratio was 10-15. The specific growth rate was also just about maximal at the 40% surface water mixture and beyond this level there was usually an additional one-day lag before maximum yield was reached. The 40% surface-water mixture

thus seems to optimize phytoplankton growth in terms of nutrient utilization, maximum growth rates, and minimum lag to maximum yield.

In terms of a continuous-flow system, if u_{max} could be maintained, a turnover time of less than eight hours may be possible. A total of more than 45 µg-at NO_3-N/liter/day would be supplied and this would produce about 10 µg Chl-*a*/liter/day or 400 x 10^6 cells/liter/day, which would be available to a mariculture system.

October 1975

Secondary Producer Testing: Growth of Juvenile Tapes semidecussata Fed from Continuous Cultures of Phytoplankton Resulting from Mixtures of 70% Deep and 30% Surface Water

(Scott Laurence)

SUMMARY

Continuous cultures of phytoplankton resulting from the mixture of 70% deep and 30% surface water were fed to trays containing 100 juvenile Tapes semidecussata each. At a turnover rate of .46 per day the 757-liter DW/SW (deep water/surface water) culturing vessels produced a mean of 4.25 µg Cla/l. Animals fed from these cultures at a mean rate of 15.4 ml/10 secs increased in weight by an average of 672%, with a mortality of less than 1%, over a 29-day period. Conversion of nitrogen from the deep and surface water mixtures to shellfish meat was approximately 17%.

INTRODUCTION

Early data on the batch studies described above indicated that despite the lack of experimental facilities a small study on the growth of bivalves fed from mixtures of 70% deep water and 30% surface water would prove useful. The study was designed to provide information on the proper parameters to be manipulated in later studies, and we were most interested in obtaining some idea of the efficiency of nitrogen conversion from the DW/SW mixtures to shellfish meat, and of those factors which most influenced this conversion efficiency. We were also interested in obtaining information on the stripping efficiency by

Tapes and the daily fluctuation in culture density. This information would aid us in designing optimal flow rates, culture densities and optimal numbers and configurations of shellfish in the growing trays. Lastly, we were interested in a comparison of the extracted Cla, in vivo fluorescence and turbidity measures of flow in and out of the shellfish trays. Using extracted Cla as a standard of comparison, the accuracy, reliability and convenience of in vivo fluorescence and turbidity as indicators of culture density were examined. In order that some idea of the efficacy of the DW/SW mixtures as sources of food for shellfish be obtained, comparisons were made between Tapes semidecussata grown from these mixtures and T. semidecussata fed from monocultures of phytoplankton grown in deep water only.

METHODS

Cylindrical 757-liter polyethylene tanks were used as culturing vessels. Although only two such tanks were available, preliminary work indicated that a continuous flow of phytoplankton could be maintained for feeding shellfish by filling one "polytank" and allowing it to attain peak density, as measured by turbidity, for two consecutive days. It was then started on continuous flow, and the first polytank was drained, scrubbed with a weak chlorine solution, rinsed and refilled. The tanks were alternated in this way throughout the 29-day study, and food was always available to the shellfish with this arrangement. A continuous flow of surface water to the activated tank was maintained by filling a 380-liter tank daily with a gasoline-powered pump which brought the reef water through a floating polyethylene pipe of 1-1/2" I.D. The intake of this pipeline was located approximately 60 ft.

offshore. The 380-liter tank fed into the culturing vessel via gravity flow. Deep water was continuously available from the deep-water (870 m) pipeline. Once the phytoplankton culture was activated, a ratio of 70% deep to 30% surface water was sustained. The cultures were continuously aerated. For purposes of comparison, shellfish were also fed from a mixture of the pool cultures maintained for the Artificial Upwelling project. Equal proportions of culture from Pool 1 (containing Chaetoceros curvisetus, STX-167, grown on unenriched deep water) and from Pool 2 (which supplied, on alternate weeks, Thalassiosira pseudonana (3H) or Bellerochea polymorpha (STX-114), both grown on enriched deep water) were available continuously.

The polytank cultures were gravity-fed into two shellfish trays approximately 46 cm x 30 cm x 10 cm deep. Outflow was from a point 6.5 cm from the bottom of the tray. An identical arrangement was used for the pool-fed shellfish. Flow rates were controlled with garden-hose ball valves and consistency of flow was maintained with constant-head devices. Flow into the "mixture" trays averaged 15.4 ml/10 sec. over the 29-day period of the study, and the turnover rate in these trays was approximately 97 minutes. Flow into the pool-fed trays averaged 18.2 ml/10 sec. and turnover rate was approximately 82 minutes.

Juvenile Tapes semidecussata, approximately 3 months old and spawned in our hatchery, were used. These were the only shellfish available at the time the study was begun. The animals were placed directly onto a nylon mesh screen glued to a circular PVC ring, 16 cm in diameter. This tray was put into the larger tray and facilitated removal of the animals for inspection, measurement and for tray cleaning. One hundred animals were placed in each tray. From each group, 25 were randomly selected for length measurements on days 0, 14 and 29, and an average

wet weight was found by weighing the entire population, also on days 0, 14 and 29. At the end of the study, 50 animals from each tray were shucked and average wet meat and dry shell weights were taken. The meat from each tray sample was dried in an oven at 100°C for 20 hrs and dry weights and percentage nitrogen in the dry weight was measured by CHN analysis. Samples (400 ml) from each polytank, from the mixture of Pools 1 and 2, and from the inflow and outflow of all four shellfish trays were collected daily at 0800 hr. Turbidity and *in vivo* fluorescence readings were performed on each sample using a Monitek turbimeter and Turner Model III fluorometer, respectively. A 5 to 50 ml sample from the shellfish tray inflows and outflows was removed with a volumetric pipette and filtered through a Gelman glass-fiber filter (A/E) under low suction. The filters were placed in darkened containers and frozen for analysis of extracted *Cla* late the same day.

All *Cla* readings were taken on a Turner fluorometer, calibrated earlier on a Beckman spectrophotometer, according to the methods described by Strickland and Parsons (1962). Every second day, 100 ml of sample from the inflow and outflow of each shellfish tank was placed in a settling chamber with 3 ml of Utermohl solution. The top 90 ml of water was carefully siphoned off the following day and the remainder refrigerated for later cell counting. All cell counts were performed under 200X using a Spiers-Levy Eosinophil counting chamber. Flow rates were measured and adjusted and temperatures in each tank were taken daily at 0800 and 1400 hrs.

The experiment was conducted over a 29-day period. The bivalves were visually inspected daily for signs of mortality and disease. No animals died during the study, and visual examination of fresh meat at the end of the study revealed no obvious signs of disease. The

larger animal trays were cleaned of accumulated feces, pseudofeces and settled phytoplankton once weekly. Algal growth on the sides of the trays was evident during the first few days of the study; this was prevented by covering each tray with flat pieces of PVC.

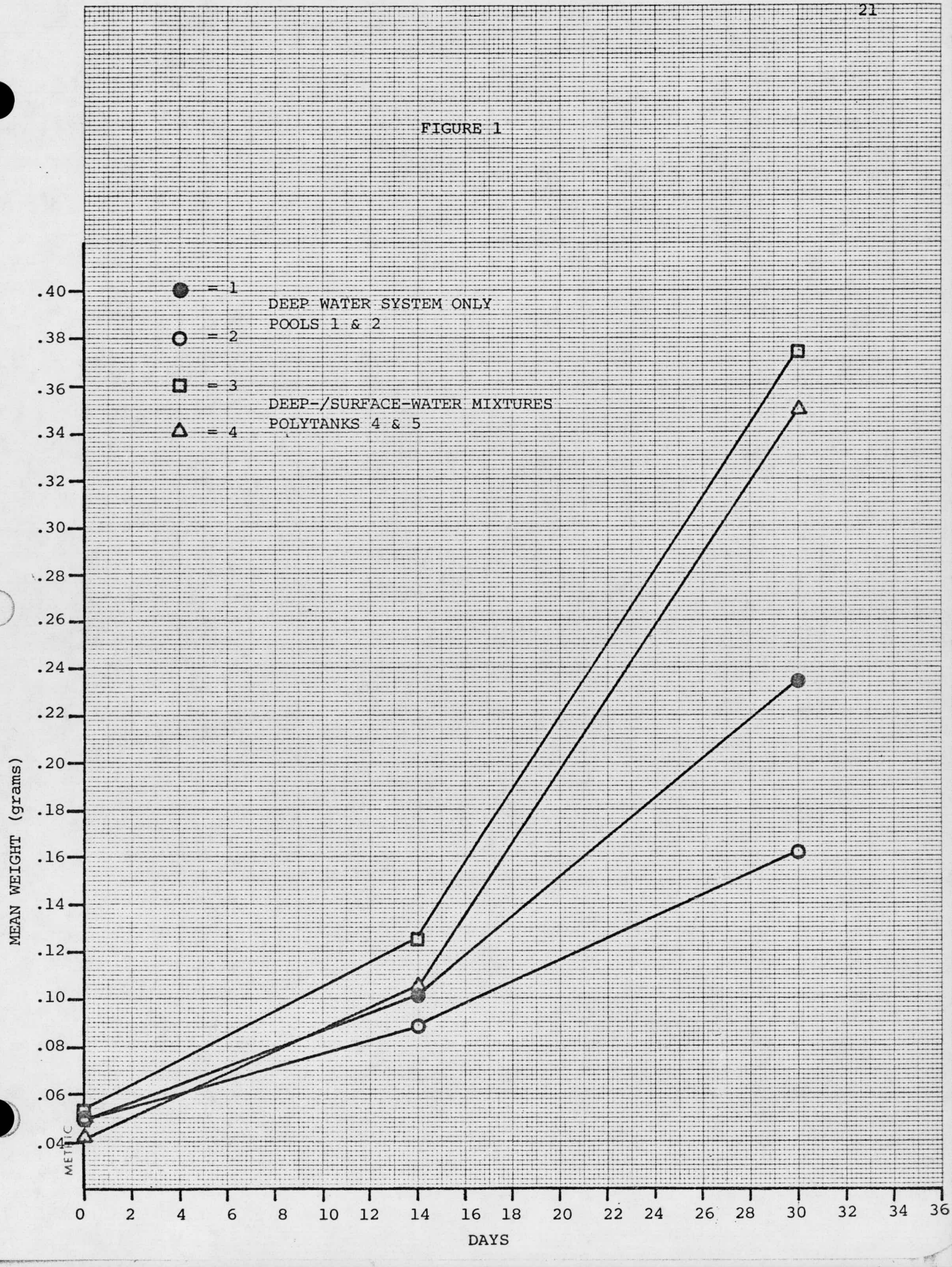
RESULTS AND CONCLUSIONS

Animals in Trays 1 & 2 (pool-fed) averaged .051 g in weight on day 0. Average length was 6.65 mm and 6.64 mm, respectively. Animals from Tray 3 averaged .054 g in weight on day 0 and those from Tray 4, .041 g; average lenghts were 6.78 and 6.5 mm, respectively. At the end of two weeks (day 14) animals from Trays 1 and 2 averaged .101 and .089 g in weight and 8.13 and 7.90 mm in length. Values for Trays 3 and 4 were .126 g and .102 g (weight), 9.0 mm and 8.25 mm (lengths). On day 29, animals from Trays 1 and 2 weighed .234 and .162 g, with respective lengths of 11.18 and 9.96 mm, while the mixture-fed animals weighed an average of .374 g (Tray 3) and .349 g (Tray 4), lengths were 13.34 mm and 13.11 mm, respectively.

On day 14, pool-fed animals had gained 86.3% of their original weight, while the mixture-fed animals gained 141.05%. By day 29, the figures were 288.23% and 671.90%, respectively.

For all groups of animals, weight and length gain was much greater during the second two weeks of the study (Figs. 1,2). The change in weight for the first two weeks divided by the average weight for that period $(\frac{\Delta w}{\mu w})$ was .63 for Tray 1, .54 for Tray 2, .80 for Tray 3 and .87 for Tray 4. During the second two weeks, weight gain in proportion to average weight for the period increased for all animals, and was again greater for animals fed from the DW/SW mixtures. These ratios were .78, .56, .99 and .99, respectively.

FIGURE 1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POLYTANKS 4 & 5
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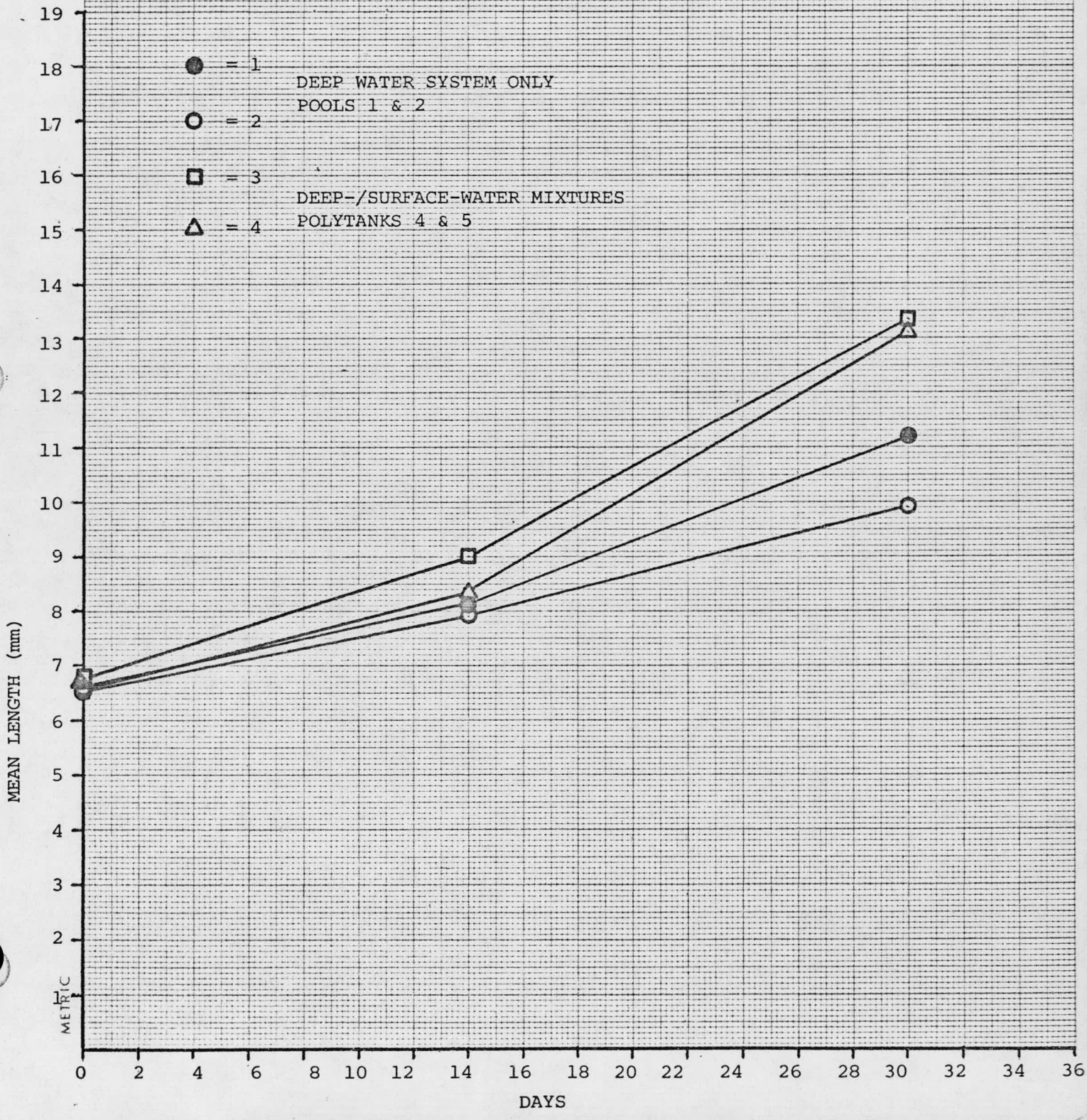
DAYS

FIGURE 2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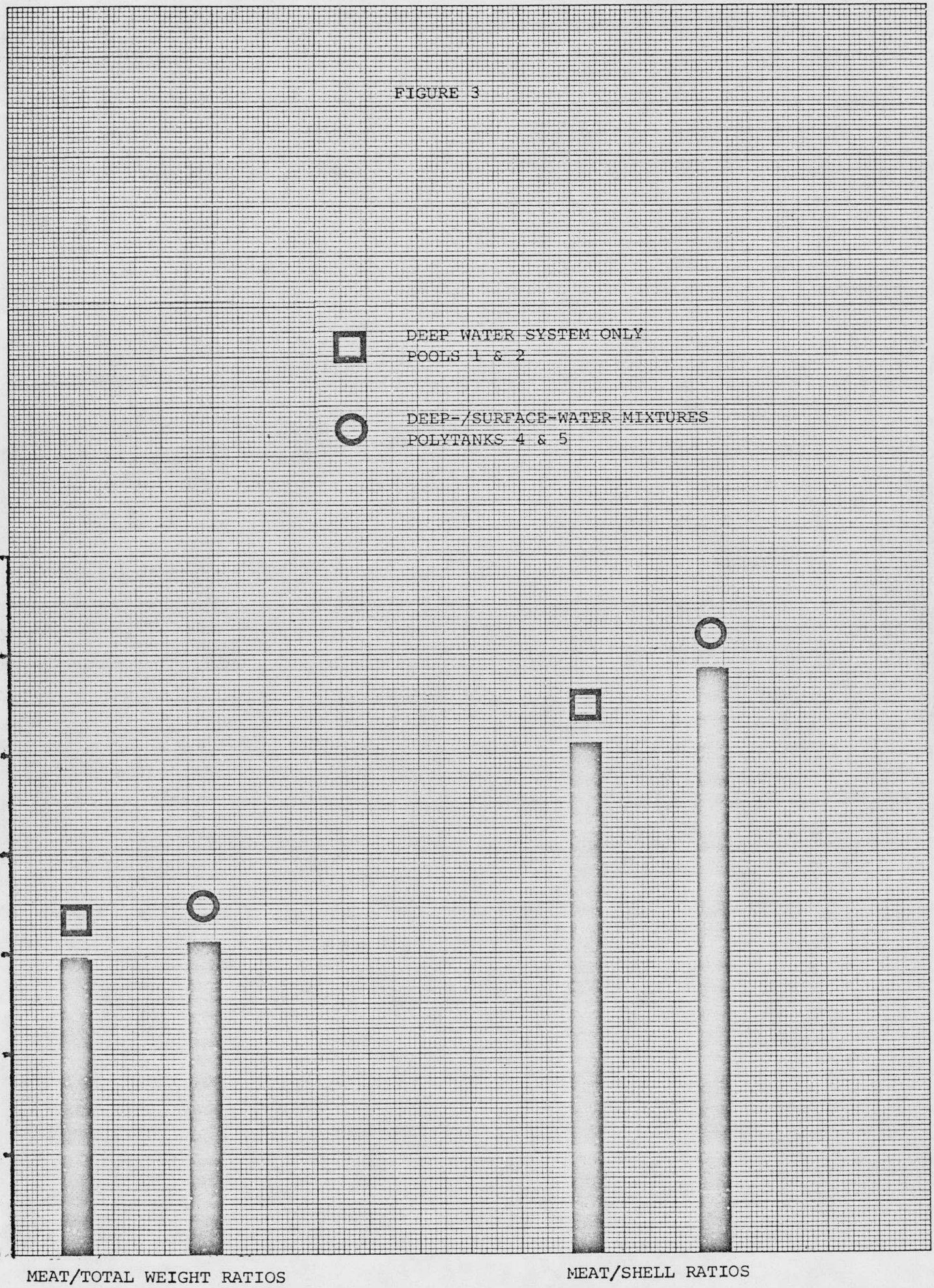
Average wet weight (meat and liquor) of the shucked animals was .07 g, .05 g, .12 g and .11 g, respectively. Percentage dry weights were 24.32, 23.50, 22.50 and 22.22, while net % nitrogen of the dried meat was 7.58, 7.32, 7.35 and 7.28. Wet weight of shucked meat/dry weight of shell ratios were .51 for pool-fed animals and .58 for those fed from the DW/SW mixtures. The wet weight of the meat, expressed as % of total (meat + shell) wet weight, was 29.68% for pool-fed Tapes and 31.51% for the mixture-fed animals. In general then, results indicated that Tapes semidecussata grows at a rapid rate when fed phytoplankton resulting from mixtures of 70% deep and 30% surface water.

Nitrogen Conversion

We obtained a gross estimate of nitrogen conversion from the total nitrogen at NO_3 + NO_2-N and NH_3-N in the deep and surface water mixtures to the shellfish meat in the Tapes fed from these mixtures. Assuming that total N in the deep water/surface water mixture was 23.4 µeq. l^{-1}, and that during the 29-day study approximately 3,858.6 liters of water flowed through Tank 4 (the population with the greatest % increase in weight) and further assuming that the % wet meat weight/total wet weight % dry meat/total wet meat weight and % N/total dry meat weight are 34.4%, 23% and 7.28%, respectively, the conversion efficiency was determined to be approximately 17%. However, since the average stripping efficiency of tank 4, as estimated by cell counts, was approximately 46.5%, this conversion efficiency is clearly conservative and could probably be nearly doubled by increasing the total weight/volume ratios of the animals in the tray. Further, no attempt was made to analyze or increase nitrogen conversion by phytoplankton, nor was any use made of the nitrogen excreted by the shellfish. We are presently aiming for a nitrogen conversion efficiency of 40% at the shellfish trophic level,

FIGURE 3



and of 50-60% if such products as the seaweed Hypnea musciformis are grown in the shellfish effluent.

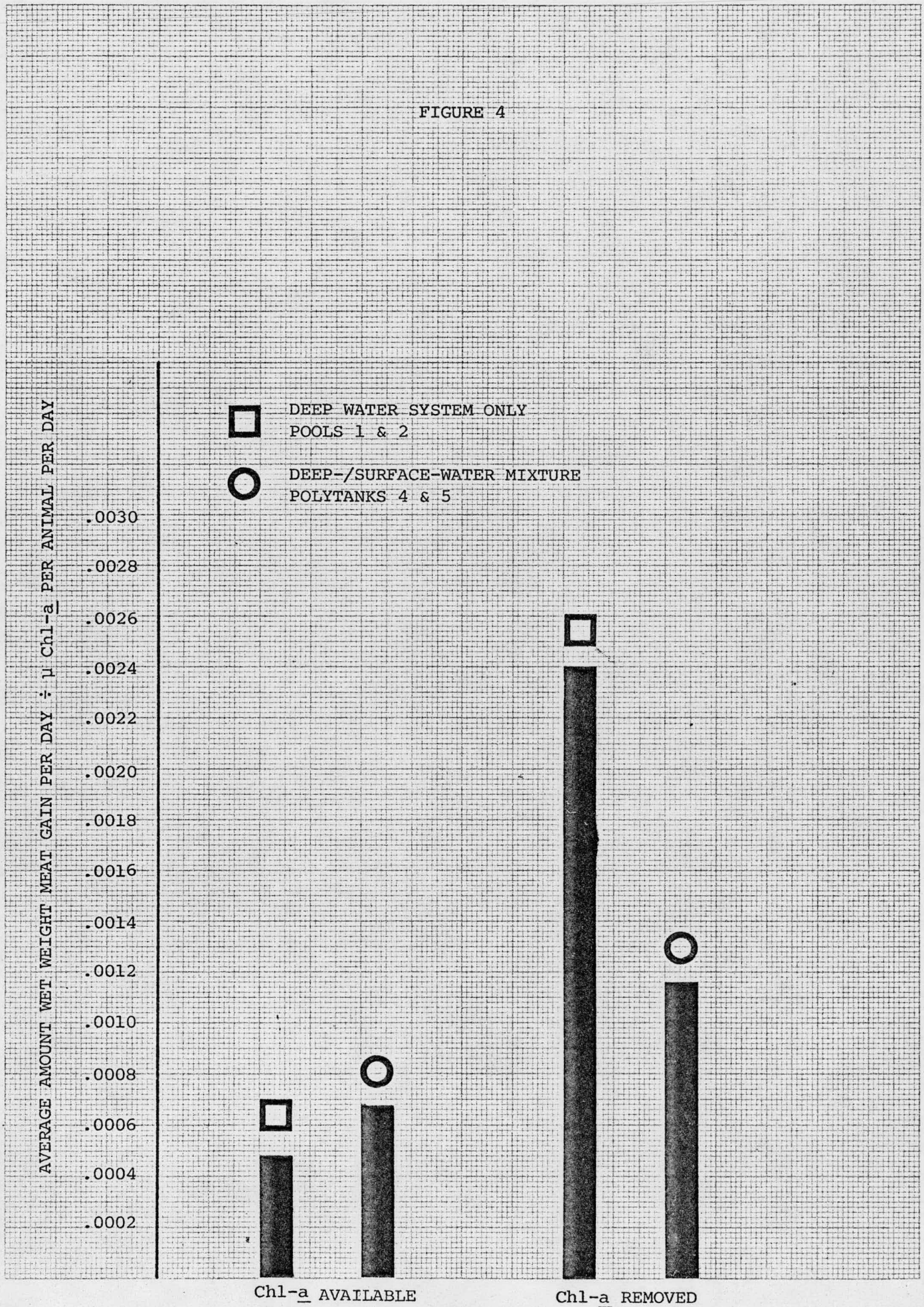
Chlorophyll a Determinations

Extracted Cla was used to determine relative stripping by the shellfish versus phytoplankton density and for determining phytoplankton growth in the 70% deep water/30% surface water culture vessels. The mean productivity for this series of cultures was 4.23 μ Cla/l with a S.D. of 3.33 μ Cla/l. This was attained at a turnover rate of .46 per day (a rate which is lower than the 1.0-2.0 turnovers per day which could probably be obtained for these cultures under ideal conditions).

Since the outflow from the shellfish trays was taken from the top, most pseudofeces settled to the bottom of the tank; therefore, the stripping efficiencies here are not accurate indicators of the actual amount of food consumed in each tank. (Note: our present studies allow for constant homogeneous mixing of the water in the tray, and the outflow therefore represents a much closer approximation of the amount of material not utilized by the shellfish). However, we may assume that the relative stripping efficiencies as measured here are at least roughly proportional to actual stripping. Further, in comparing the pool- and mixture-fed animals (see Figs. 4, 5), we may assume that the relative amount of pseudofeces and settled phytoplankton in the tank were roughly equivalent; weekly cleaning did not reveal any noticeable difference in the total amount of accumulation.

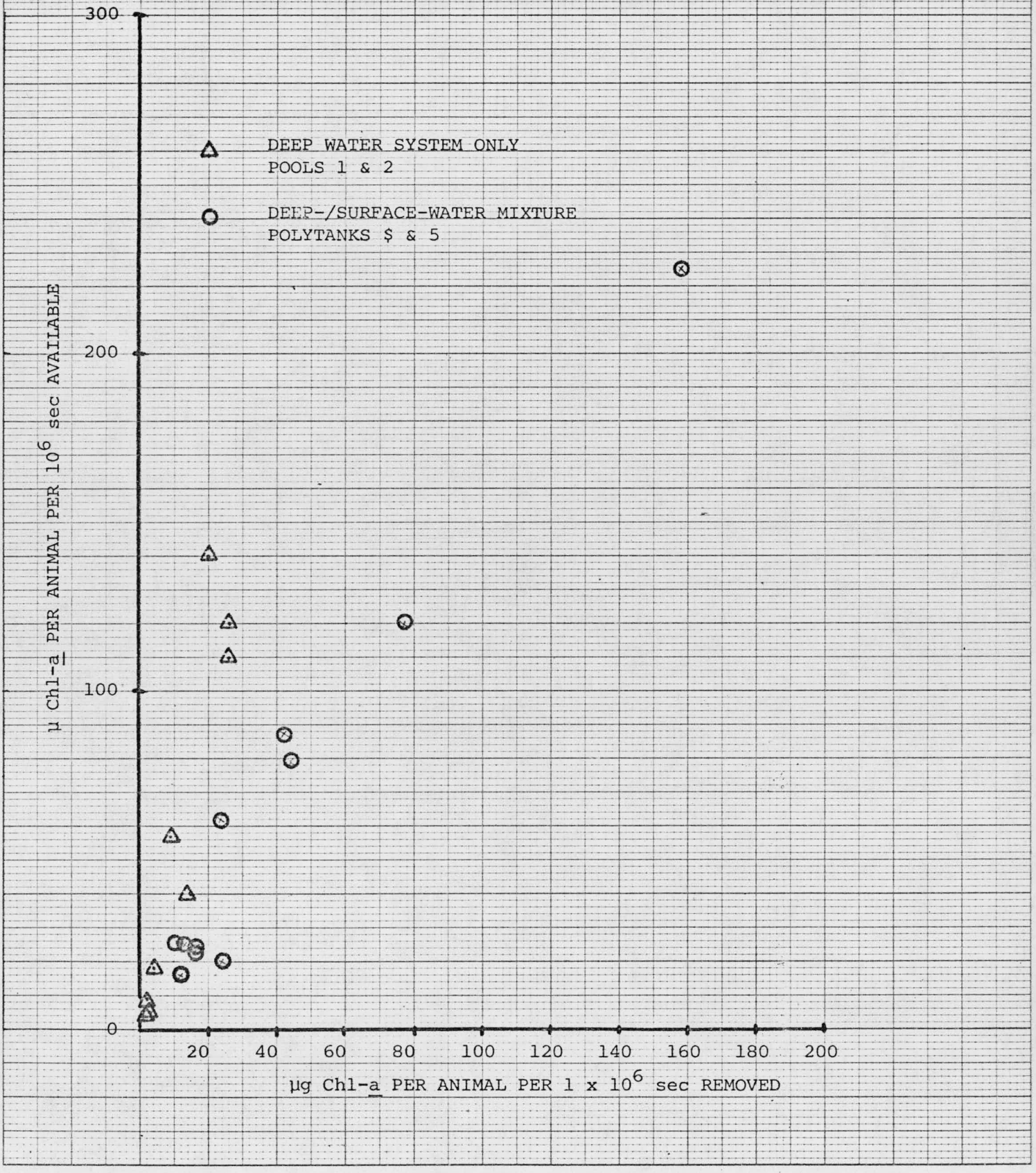
The total Cla available to each pool-fed tray was approximately 1.207×10^{-2} g, while the mixture-fed animals received approximately 1.692×10^{-2} g per tray. The pool-fed trays (which had a high proportion of the small (<5 μ in diameter) diatoms STX 114; 3H) received a total cell number of 1.726×10^{11}, while the mixture trays each

FIGURE 4



METRIC

FIGURE 5



received a total cell number of 9.622×10^{10}. Average stripping efficiencies, as measured by cell counts, were 46.21% and 46.46% for the pool- and mixture-fed trays, respectively; while stripping, based on Cla determinations, were 31.06% and 57.70%, respectively.

Since the total amount of Cla and the stripping of that Cla was greater in the mixture-fed tanks, the total amount of Cla removed during the study was also much higher for these animals: 3.7×10^{-3} g for each pool-fed tray vs. 9.7×10^{-3} g for the mixture-fed cultures. Since the amount of Cla removed in these latter trays was so much greater, and the amount of weight gained was also greater, we may be interested in the average weight gained in each tray vs. the amount of Cla removed. For the pool-fed cultures, the total wet weight gain per tray was 13.965 g, while the gain per tray for the mixture-fed animals was 31.086 g. Weight gain divided by Cla removed is 3.774×10^{3} for pool-fed animals and 3.204×10^{3} for the mixture-fed animals. The conversion of removed Cla into total wet weight was therefore slightly more efficient in the pool-fed cultures.

Comparison of Extracted Chlorophyll a, In Vivo Fluorescence and Turbidity Readings

Since extracted Cla is a time-consuming technique, it was hoped that either in vivo fluorescence or turbidity measurements would display high correlation with Cla determinations. However, a linear correlation analysis revealed a correlation of .68 between turbidity and ex. Cla readings in the same sample, and a correlation of .33 between in vivo fluorescence and ex. Cla. We concluded that the lack of accuracy of these techniques did not compensate for their ease and speed in use.

Technical and Engineering Feasibility Study:

Open-Ocean Structures

(Scott Laurence)

SUMMARY

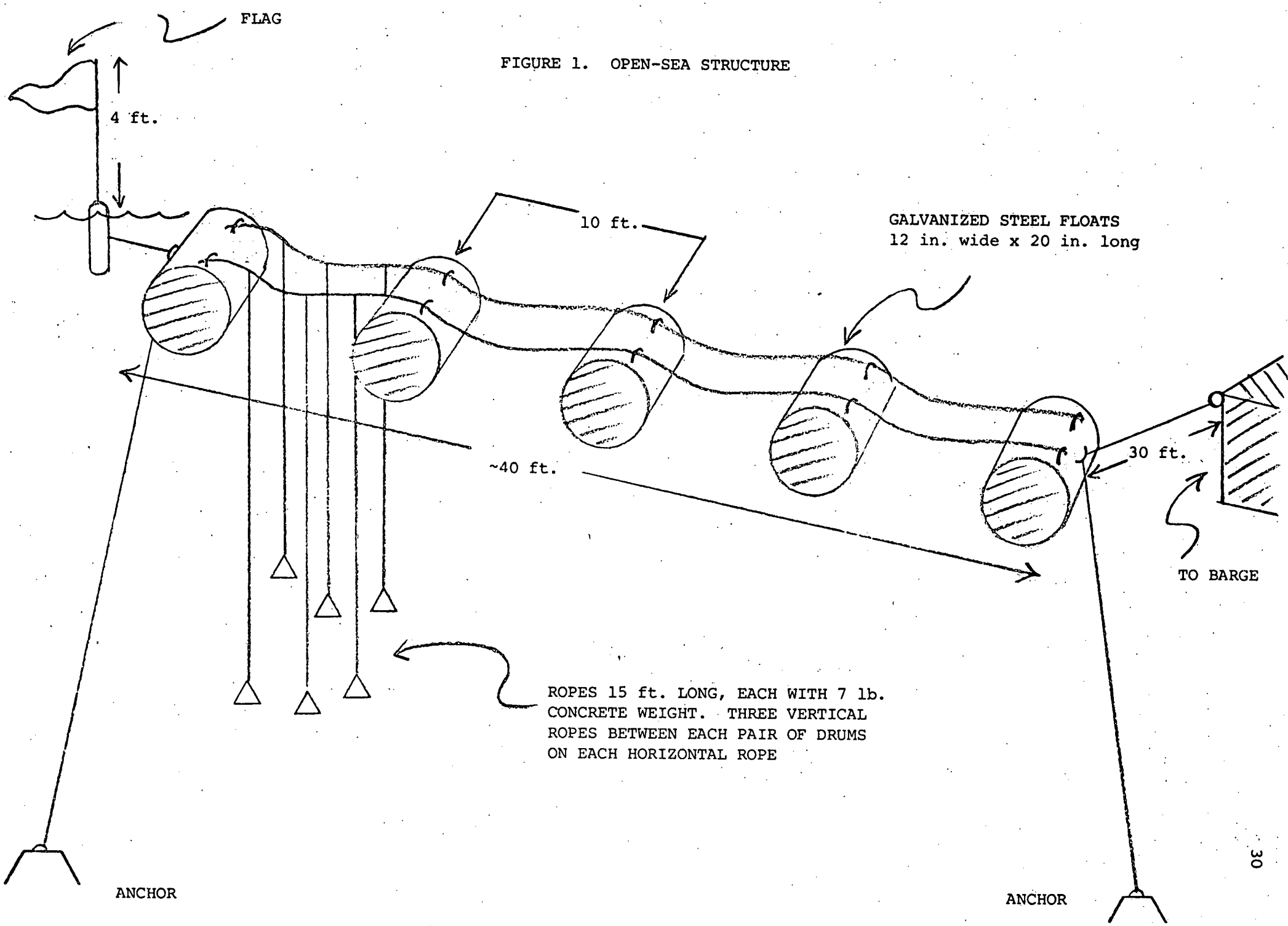
Our first attempt to design a suitable structure for growing bivalves in the open sea emphasizes flexibility and ease in use. The structure is comprised of five floats (galvanized steel) connected by parallel, horizontal nylon ropes. Three vertical strands of 3/4" diameter manilla rope, 13 ft. in length, hang from each horizontal rope between each pair of floats. The ropes are weighted with 7 lbs. of concrete to partially simulate the weight of growing mussels or oysters. The structure is designed to be used in the following way: manilla ropes will be placed in spawning trays in the hatchery under controlled density conditions. Once the optimum growth of larvae has been obtained (a point yet to be determined), the ropes will be hung from the floats. The ropes can be easily removed for measurement and/or collection of the bivalves.

Initially, we intend to study the stability, durability and ease of handling these structures. Later, we hope to actually grow either mangrove oysters (Rhizophorae), the oyster Crassostrea gigas, and the mussel, Purna purna.

Our second structure, yet to be built, will be intended for the growth of non-attaching organisms such as Tapes semidecussata. We are also building an improved version of the first design (Fig. 1).

November 1975

FIGURE 1. OPEN-SEA STRUCTURE



APPENDIX A

Abstract of a Paper to be Presented at
1975 Annual Fall Meeting of American Geophysical Union

POTENTIAL MARICULTURE YIELD OF FLOATING SEA-THERMAL POWER PLANTS

O. A. Roels
S. Laurence
A. F. Amos (all at: Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964)
(Sponsor: D. Schink)

Floating sea-thermal power plants will utilize the temperature differential between warm surface water and cold deep water in tropical seas to produce energy. Large volumes of sea water from ~1000 m depth will be pumped up to provide the cold sink in the thermodynamic process. The concentration of nutrients (necessary for plant growth) in cold deep water is generally much higher than that of surface water. We have prepared a density model to predict the vertical movement of deep water after warming in a plant's heat exchangers and discharge at or near the surface. Where deep-water salinity is lower than that of surface water, condenser-discharge designs can ensure that surface-/deep-water mixtures remain in the euphotic zone. In batch experiments using surface water from the Caribbean Sea (17°47'N; 64°48'W) and Antarctic Intermediate Water pumped from 870-m depth in the same location, mixtures of 70% deep water and 30% surface water produced optimal blooms of phytoplankton. A subsequent continuous experiment using this 70:30 mixture produced algal blooms which sustained rapid growth of the Japanese clam, Tapes semidecussata, with <1% mortality. No attempt was made to optimize food utilization but the clams increased their weight 7-fold over a 29-day period at the same flow rate, achieving a 17% conversion of dissolved nitrate-nitrogen into animal-protein nitrogen. This means that a 100 megawatt plant, utilizing 4.5×10^7 l/min deep water could yield 25×10^7 lbs shellfish meat/yr with a potential value of $\$50 \times 10^7$/yr. The gross power sales of the plant (100% capacity at 4¢/kwh) would be $\$3.5 \times 10^7$/yr.

1. 014483SCHINK
2. 1975 Fall Annual Meeting
3. Oceanography (Session: "Environmental Effects of Ocean Thermal Plant Operation")
4. No
5. About 5% at OTEC Mtg., Houston, Tx., 5/8-10/75
6. Bill to: O.A. Roels, Lamont-Doherty Geological Observatory Palisades, N.Y. 10964
7. P.O. # to follow.