SOME EFFECTS OF MECHANICAL EVAPORATION BARRIERS ON FISH GROWTH AND POND PRODUCTIVITY

by

Steven Alan Lewis

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SIGNED: Steven Alan Lewis

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Wm J McConnell
WILLIAM J. McCONNELL
Professor of Biological Sciences

28 April 1969
Date

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ABSTRACT

Four experiments were conducted to evaluate some of the effects of mechanical evaporation barriers on fish growth and pond productivity. Barrier coverages above 50% reduced fish growth, fish survival, aquatic insect yields, gross photosynthesis, dissolved oxygen concentrations, temperatures, and habitat areas. These reductions appeared to correlate with decreased amounts of light entering each pond. Zooplankton numbers, phytoplankton chlorophyll concentrations, pH, and turbidity measurements were not significantly affected at any coverage level.

INTRODUCTION

The purpose of this study was to evaluate some of the effects of mechanical evaporation barriers on fish growth, fish survival, pond productivity, and the physical habitat by comparative experiments on partially covered and uncovered ponds. Mechanical evaporation barriers that reduce the amount of sunlight entering small impoundments and reduce the degree of atmospheric contact may cause reductions in fish growth and pond productivity. Since the use of mechanical evaporation barriers to conserve water probably will increase in the arid parts of the world, it is important that their effects on the aquatic environment be known.

Prior studies of the biological effects of evaporation barriers have been conducted using hexadecanol, a long chain alcohol (Committee of Collaborators 1957, Hayes 1959, Timblin 1957, and Wiltzius 1967). There has been no published evaluation of mechanical evaporation barriers.

The experiments were designed to detect significant differences at selected points in the assumed food chain. Gross photosynthesis, phytoplankton chlorophyll concentrations, zooplankton numbers, aquatic insect yields, fish growth, fish survival, dissolved oxygen concentrations, pH, turbidity, photic depths, air temperatures, and water temperatures were measured and evaluated.

MATERIALS AND METHODS

Mechanical Evaporation Barriers

Evaporation suppression was caused by rigid, free-floating styrofoam rafts and floating layers of expanded volcanic rock granules (perlite). Numerous individual rafts were used to create the 18%, 32%, 50%, and 75% styrofoam coverages. These rafts moved randomly over the water surface allowing sunlight to pass between them and reach all of the bottom at some time during most days. A single large raft comprised the 80% styrofoam coverage. The continuous surface of this raft and its limited drifting prevented any sunlight from reaching most of the bottom at anytime during the day. Painted styrofoam as used transmitted less than 1% of the incident light to a depth of 10 centimeters. A monolayer of perlite granules 2 to 3 millimeters in diameter transmitted 10% of the incident light to a depth of 10 centimeters.

The percentage of water surface covered by rigid rafts (18%, 32%, 50%, 75%, and 80%) was constant and complete. Perlite coverage (100%) was apparent (nominal) coverage, but due to windrowing and compaction caused by wind, coverage averaged only about 80% of the surface area. Even when the entire pond was apparently covered by perlite, the actual occluded water surface was about 95% because of the open spaces between granules.

Study Area and Experiments

Three rectangular evaporation ponds (16.2 meters by 23.8 meters) were used at the Water Resources Research Center's Field Laboratory. The surface area of each varied between 102 and 115 square meters with a volume of 283.2 to 311.5 cubic meters. The water depth varied from 2.14 to 2.28 meters at the middle where the sloping sides meet. The sides and bottom were covered with horned pondweed, *Zannichellia palustris*. The measurements and coverages of the three experiments conducted in these ponds are in Table 1.

Six plastic-lined swimming pools were used at the off-campus research facility of the Arizona Cooperative Fishery Unit. Each pool was 5.5 meters in diameter with a surface area of 23.65 square meters. The volume was 23.65 cubic meters at a depth of 1 meter. The sides and bottoms did not support rooted aquatic plants. Each pool was cleaned, filled, and inoculated with a 24-liter mixture of water taken from several local ponds. Where possible, plants from these sources were rinsed in the inoculum to increase the number and kinds of invertebrates added. Half the pools (3) were then treated with 75% styrofoam coverage. The measurements made during this swimming pool experiment are contained in Table 1.

Fish Growth and Survival

Rainbow trout, *Salmo gairdnerii* (Richardson), were used to assess fish growth and survival during the spring trout experiment and the winter-spring trout experiment. The Malacca *Tilapia* hybrid

Table 1. Measurements and coverages in each experiment.

	Measurements[a]											
	Gross Photosynthesis	Phytoplankton Chlorophyll Concentrations	Air and Water Temp.	pH	Turbidity	Fish Growth	Fish Survival	Insect Yields	Zooplankton Numbers	Photic Depth	Oxygen Stratification	Food Habits
Evaporation Pond Experiments												
Spring trout experiment (100% perlite, control, and 18% styrofoam) February 12, 1967, to May 25, 1967	+	+	+	+	+	+	+	-	-	+	+	-
Summer *Tilapia* experiment (100% perlite, control, and 32% styrofoam) July 13, 1967, to November 11, 1967	+	+	+	+	+	+	+	-	-	+	+	-
Winter-spring trout experiment (80% and 50% styrofoam and control) November 30, 1967, to April 24, 1968	-	-	+	-	-	-	+	-	-	+	+	+
Swimming Pool Experiment												
Summer insect-zooplankton experiment (75% styrofoam and control) July 15, 1967, to October 30, 1967	+	+	+	+	+	-	-	+	+	-	-	-

[a] + indicates measurement made and - indicates measurement not made.

(Hickling 1960) was used to assess fish growth and survival during the summer Tilapia experiment.

Fish growth was assessed as the difference in mean lengths and weights at the start and end of each experiment. Rainbow trout and Tilapia stocks were selected for uniform lengths. The trout were individually measured at the start of each experiment. The Tilapia were subsampled because of their smaller size and the higher numbers used. The fish were held 48 hours after being sorted and measured before being planted to insure that there was no handling mortality.

At the end of the first trout experiment, rotenone was used to remove the fish. Because of the dense tangled growth of horned pondweed, the fish became entangled and did not float to the surface. Therefore gill nets were used for fish removal in the remaining experiments. Dead fish that remained in the water over two days by entanglement in aquatic plants or by remaining in gill nets were measured but not weighed.

Rainbow trout were obtained from the Arizona Game and Fish Department. The Tilapia came from stocks of the Arizona Cooperative Fishery Unit.

Trout Food Habits

The stomachs of trout from the winter-spring trout experiment were removed and preserved in 10% formalin. Later, relative visual estimates were made of the volume of the dominant organisms to determine what the trout were eating.

Insect Yields and Zooplankton Numbers

The insect yields were obtained by first removing the pool water with a screened pump and then collecting the pool residue. The residue was then rinsed and placed in half-gallon jars with 10% formalin. Later all insects over 1 millimeter were removed and counted. The insects were then dried for 42 hours at 60 C before weighing.

Zooplankton samples were taken by plunging a closable 4-inch diameter plastic tube into each pool almost to the bottom in at least four different locations. Individual samples were pooled until a total of 25 liters was obtained. The pooled sample was then filtered through a number 20 Wisconsin plankton net and the residue placed in a 130-milliliter reagent bottle. The samples were preserved in 10% formalin and allowed to settle. The major portion of the water was removed and the residue subsampled and counted.

Gross Photosynthesis and Dissolved Oxygen Concentrations

Gross photosynthesis was determined from diel oxygen concentration changes following the method described by McConnell (1962, 1963). Determinations were made at least two times per month. Gross photosynthesis is a measurement of primary productivity.

The Alsterberg (Azide) modification of the Winkler method was used to measure dissolved oxygen. Water samples were collected with a 500-milliliter self-filling syringe described by Kemmerer (1965). The syringe collects an integrated vertical water sample with minimum atmospheric contact. The water samples were collected from the water surface down to the photic depth (1% incident light level). The reagents were added to the samples in the field. The samples were then stored under refrigeration up to 24 hours. Phenylarsene oxide was used in the titration. The oxygen content of the photic column was determined at sunset, and at sunrise and sunset of the following day. Additional dissolved oxygen concentrations were determined periodically at sunset at depths of about 0.2, 1.1, and 2.1 meters.

Phytoplankton Chlorophyll Concentrations

Chlorophyll concentrations were measured as an index of the phytoplankton standing crop. The evaporation pond water samples were taken with the previously described syringe down to the 1% light level. The samples were transferred to amber one-quart glass bottles. The swimming pool water samples were taken by immersing amber one-quart bottles in the pools, then moving them horizontally and vertically while they filled to insure a distributed sample.

The phytoplankton was immediately removed by filtering as much of each sample as possible through two 0.80 mu AA Millipore filters. The chlorophyll was extracted in 20 milliliters of 95% alkalized acetone over a 24-hour period. Optical density of the extract was measured with a Bausch and Lomb "Spectronic 20" at 663 mμ, with a light path of 25 millimeters.

Temperatures and Photic Depths

Temperatures were measured with a recording thermograph every hour in the evaporation pond experiments. Thermistors were permanently located 1.3 centimeters above the water surface, 1.3 centimeters below the water surface, and 91.5 centimeters below the water surface. During the summer insect-zooplankton experiment, temperatures were measured with a mercury hand thermometer about 30 centimeters above the water surface and about 3 centimeters below the surface at sunrise and sunset.

The photic depth, the 1.0% light level, was determined with a submersible light meter.

Turbidity and pH Measurements

Turbidity and pH measurements were made to monitor water quality and as an indirect measurement of productivity. A LaMotte Chemical Company color comparator was used to determine pH measurements to the nearest 0.1 pH unit. Turbidity and pH measurements were run on the same water samples taken for chlorophyll determinations.

Turbidity measurements were made with a Hellige turbidimeter using a B-964 bulb, no filter, and a 100-milliliter tube. Measurements were recorded as equivalent ppm SiO_2.

Statistical Methods

Dunnett's test (Steel and Torrie 1960), Yates' adjusted chi-square, and Student's t tests (Simpson, Roe, and Lewontin 1960) were used to test for significant differences among treatments at the 95% confidence level.

RESULTS

Fish Growth

A 100% nominal perlite coverage and 18% styrofoam coverage did not produce any significant differences in rainbow trout growth during the spring trout experiment (Table 2). During the summer *Tilapia* experiment, fish growth in the 32% styrofoam was significantly higher (13.8% higher by weight) than fish growth in the control pond. *Tilapia* growth in the 100% nominal perlite-covered pond was significantly lower (39.6% lower by weight) than fish growth in the control pond (Table 3). Rainbow trout growth during the winter-spring trout experiment (Table 4) was not tested for significant differences because of the high mortality which occurred at some unknown time in the treatment and control ponds.

Fish Survival

Fish survival was above 60% in the spring trout experiment (Table 5) and above 80% in the summer *Tilapia* experiment (Table 6). Trout survival in the 100% nominal perlite-covered pond during the spring trout experiment was significantly higher than in the control pond. During the winter-spring trout experiment, however, fish survival dropped to 5.0% in the 80% styrofoam-covered pond which was significantly lower than in the control ponds with a survival of 45.0% (Table 7).

Table 2. Range and mean of trout weights and lengths at the start and end of the spring trout experiment.

	Weights (gms)			Lengths (cm)		
	Perlite 100%	Styrofoam 18%	Control	Perlite 100%	Styrofoam 18%	Control
Feb. 12, 1967						
n	15	15	15	15	15	15
Range	8.0-14.5	9.0-14.5	9.5-14.0	9.5-11.5	10.0-11.5	10.0-11.0
Mean	11.2	11.2	11.3	10.4	10.6	10.5
May 25, 1967						
n	14	9	10[a]	14	9	11
Range	76.5-121.0	68.5-119.5	83.0-111.0	19.5-22.0	19.5-21.5	19.5-21.5
Mean	94.8	97.4	93.1	20.4	20.1	20.8
Mean growth	82.6	86.2	81.8	10.0	9.5	10.3
Mean difference from control	0.8	4.4		0.3	0.8	
Dunnett's minimum sig. dif. (95%)	16.2					

[a] Fish recovered 48 hours after death were not used for weight analysis.

Table 3. Range and mean of *Tilapia* weights and lengths at the start and end of the summer *Tilapia* experiment.

	Weights (gm)			Lengths (cm)		
	Perlite 100%	Styrofoam 32%	Control	Perlite 100%	Styrofoam 32%	Control
July 13, 1967	15 representatives of the 50 fish placed in each pond					
n		15			15	
Range		0.5-1.0			3.2-4.1	
Mean		0.7			3.6	
Nov. 11, 1967						
n	24[a]	40	36	38	40	36
Range	90.5-121.0	143.9-229.5	125.8-204.5	16.9-19.2	19.5-22.6	18.9-22.0
Mean	101.1	189.3	166.9	18.0	21.2	20.3
Mean growth	100.4	188.6	166.2	14.4	17.6	16.6
Mean difference from control	65.8	22.4		2.2	1.0	
Dunnett's minimum sig. dif. (95%)	12.3					

[a] Fish recovered 48 hours after death were not used for weight analysis.

Table 4. Range and mean of trout weights and lengths at the start and end of the winter-spring trout experiment.

	Weights (gms)			Lengths (cm)		
	Styrofoam 80%	Styrofoam 50%	Control	Styrofoam 80%	Styrofoam 50%	Control
Nov. 30, 1967						
n	20	20	20	20	20	20
Range	25.6-36.6	25.2-32.8	25.3-31.7	14.1-15.0	14.0-15.0	14.0-15.0
Mean	30.0	29.3	28.9	14.6	14.6	14.6
Apr. 23, 1967						
n	1	7	9	1	7	9
Range	-	189.8-286.6	151.8-212.3	-	26.6-28.9	23.5-27.9
Mean	193.1	246.8	180.1	27.0	27.5	25.0
Mean growth	163.1	217.5	131.2	12.4	12.9	10.4
Mean difference from control	31.9	86.3				

Table 5. Trout survival at end of spring trout experiment.

Treatment	Number Stocked	Number Surviving	Percent Survival	Yates' Adjusted Chi-square
100% Perlite	15	15	100.0	5.27[a]
18% Styrofoam	15	9	60.0	0.17
Control	15	11	73.0	

a. Significantly different at the 95% level.

Table 6. _Tilapia_ survival at end of summer _Tilapia_ experiment.

Treatment	Number Stocked	Number Surviving	Percent Survival
100% Perlite	50	40	80.0
32% Styrofoam	50	41	82.0
Control	50	41	82.0

Table 7. Trout survival at end of winter-spring trout experiment.

Treatment	Number Stocked	Number Surviving	Percent Survival	Yates' Adjusted Chi-square
80% Styrofoam	20	1	5.0	6.53[a]
50% Styrofoam	20	7	35.0	0.10
Control	20	9	45.0	

a. Significantly different at the 95% level.

Gross Photosynthesis and pH

Gross photosynthesis reduction in the 100% nominal perlite coverage approached significance during the summer *Tilapia* experiment, and it was significantly reduced in the summer insect-zooplankton experiment (Tables 8 and 9). As the percentage of styrofoam coverage increased, gross photosynthesis decreased (Tables 8, 9, and 10).

During the first two evaporation experiments, pH measurements were higher in the controls than in the covered ponds. During the summer insect-zooplankton experiment there was no difference in pH measurements between the controls and the covered pools (Table 11).

Phytoplankton Chlorophyll Concentrations, Photic Depths, and Turbidity Measurements

Phytoplankton chlorophyll concentrations were too varied to show any significant differences in the experiments, but the 75% styrofoam covered pools frequently had noticeably higher concentrations than the controls (Tables 12, 13, and 14).

Photic depth was always equal to the pond depth in the control ponds except on one occasion (Table 15). The photic depths of the 18%, 32%, and 50% styrofoam coverages were equal to or within 0.5 meters of the bottom. The 100% nominal perlite coverage seemed to cause a slight reduction with an average photic depth of 1.65 meters.

Turbidity values were not significantly affected by either of the two kinds of mechanical evaporation barriers at the coverage levels used (Table 16).

Table 8. Range and mean of gross photosynthesis as gms $O_2/m^3/24$ hours during the summer *Tilapia* experiment.

	Perlite 100%	Styrofoam 32%	Control
n	10	10	10
Range	0.36-5.44	0.63-7.72	2.92-8.58
Mean	3.48	4.23	5.46
Mean difference from control	1.98	1.23	
Dunnett's minimum sig. dif. (95%)	2.05		

Table 9. Range and mean of gross photosynthesis as gms $O_2/m^3/24$ hours during summer insect-zooplankton experiment.

	Styrofoam 75%	Control
n	30	30
Range	0.91-4.84	1.53-8.66
Mean	2.57	3.39
Student's t = 2.05 (sig. dif. at 95%)		

Table 10. Range and mean of gross photosynthesis as gms $O_2/m^3/24$ hours during spring trout experiment.

	Perlite 100%	Styrofoam 18%	Control
n	8	8	8
Range	1.03-5.60	2.19-7.70	1.73-5.70
Mean	3.78	4.87	4.02
Mean difference from control	0.24	0.85	
Dunnett's minimum sig. dif. (95%)	1.44		

Table 11. Measurements of pH for all experiments, in pH units.

Spring Trout Experiment

	Perlite 100%	Styrofoam 18%	Control
May 7, 1967	7.8	8.2	8.6

Summer *Tilapia* Experiment

	Perlite 100%	Styrofoam 32%	Control
July 25	8.0	8.6	8.2
August 1	8.5	8.5	8.6
August 24	8.0	8.4	8.7
September 6	8.5	8.5	8.8
September 21	8.6	8.6	9.0
October 5	8.5	8.4	8.8
October 19	8.5	8.0	9.0

Summer Insect-Zooplankton Experiment

	Styrofoam 75%			Control		
July 22	8.0	8.0	8.0	8.0	8.0	8.0
August 1	8.1	8.3	8.2	8.3	8.3	8.2
August 24	8.5	8.6	8.5	8.7	8.5	8.6
September 6	8.7	8.9	8.8	9.0	8.8	8.7
September 21	9.0	9.0	9.2	9.2	9.0	9.0
October 5	8.8	9.0	9.0	9.0	8.8	8.8
October 19	9.0	9.3	9.1	9.0	9.0	9.0

Table 12. Range and mean of phytoplankton chlorophyll concentrations as mg/m^3 during the spring trout experiment.

	Perlite 100%	Styrofoam 18%	Control
n	8	8	8
Range	0.7-16.3	0.5-5.9	0.5-21.5
Mean	4.7	2.2	8.0
Mean difference from control	3.3	5.8	
Dunnett's minimum sig. dif. (95%)	6.72		

Table 13. Range and mean of phytoplankton chlorophyll concentrations as mg/m^3 during summer _Tilapia_ experiment.

	Perlite 100%	Styrofoam 32%	Control
n	7	7	7
Range	0.7-14.5	0.7-11.4	0.4-11.7
Mean	5.5	3.3	3.1
Mean difference from control	2.4	0.1	
Dunnett's minimum sig. dif. (95%)	5.7		

Table 14. Range and mean of phytoplankton chlorophyll concentrations as mg/m^3 during summer insect-zooplankton experiment.

	Styrofoam 75%	Control
n	21	21
Range	1.0-21.0	0.5-13.5
Mean	5.6	3.4

Student's t = 1.59 (not sig. dif. at 95%)

Table 15. Photic depths in meters of all experiments taken in open water away from evaporation barriers.

	Perlite 100%	Styrofoam 50%	Styrofoam 32%	Styrofoam 18%	Control
Spring Trout Experiment					
May 22, 1967	2.4	-	-	2.4	2.4
Summer Tilapia Experiment					
July 3	1.8	-	2.4	-	2.4
August 17	-	-	2.4	-	1.5
August 22	-	-	2.4	-	2.4
September 5	1.5	-	2.4	-	2.4
Winter-Spring Trout Experiment					
February, 1968	-	2.1	-	-	2.4
March 26	-	2.4	-	-	2.4

Table 16. Turbidity measurements for each experiment as ppm SiO_2 equivalents.

Spring Trout Experiment

1967	Perlite 100%	Styrofoam 18%	Control
March 14	14.2	13.0	24.4
March 23	9.0	11.0	10.8
March 28	13.5	15.0	11.0
April 14	13.7	12.0	11.0
April 23	14.0	11.0	11.2
April 28	13.6	11.5	11.0
May 11	13.5	11.7	10.8
May 23	13.7	11.0	11.2

Summer Tilapia Experiment

1967	Perlite 100%	Styrofoam 32%	Control
August 24	7.0	7.0	10.5
September 6	11.5	11.0	11.8
Sepgember 21	10.0	9.5	11.5
October 5	10.0	9.5	11.0
October 19	10.0	7.5	9.0

Summer Insect-Zooplankton Experiment

1967	Styrofoam 75%			Control		
July 25	5.0	5.5	5.1	5.6	6.0	5.7
August 1	6.5	6.0	5.8	6.2	7.1	7.5
August 24	7.0	6.9	7.5	7.5	9.0	9.0
September 6	9.0	14.0	10.0	12.0	11.0	11.0
September 21	10.0	9.0	11.0	8.0	9.5	8.0
October 5	10.0	10.0	9.5	8.0	8.5	7.5
October 19	10.5	11.5	10.0	10.5	7.0	6.5

Insect Yields and Zooplankton Numbers

Table 17 shows that six aquatic insect families occurred in all of the swimming pools during the summer insect-zooplankton experiment. Only the hydrophilid beetle and dragonfly biomasses were not significantly higher in the control ponds. Most families also had a significantly higher number of organisms in the controls as compared to the covered ponds. The 75% covered ponds yielded 34.1% the total biomass and 28.2% the total number of insects per pool as compared to the controls. Other families that occurred in only some of the controls and treatments were Nepidae, Corixidae, Belostomatidae, Tipulidae, and members of the subfamily Chaoborinae.

The only zooplankton consistently present in appreciable numbers during the summer insect-zooplankton experiment were cladocerans. The 75% styrofoam coverage did not cause any obvious differences in the number of cladocerans per liter (Table 18). Other zooplankton occurring irregularly in all of the pools were copepods, ostracods, and *Eubranchipus*.

Trout Food Habits

Relative visual estimates of the volume of the dominant food items consumed by trout during the winter-spring trout experiment show that in the control pond dragonfly nymphs (Odonata) made up 85% of the diet (Table 19). In the 50% styrofoam-covered pond, damselfly nymphs (Zygoptera) made up 90% of the diet, but in the 80% styrofoam-covered pond, snails (Physidae) made up 40% of the diet, as did dragonfly nymphs.

Table 17. Range and mean of total insect yields in grams and number at the end of summer insect-zooplankton experiment.

Insects	Weights		Numbers	
	Styrofoam 75%	Controls	Styrofoam 75%	Controls
Order Odonata				
Family Libellulidae				
n	3	3	3	3
Range	1.580-5.560	5.308-11.966	52-155	196-1344
Mean	2.47	8.699	102	908
Student's t[a]	2.47		1.55	
Order Ephemeroptera				
Family Baetidae				
n	3	3	3	3
Range	0.021-0.170	0.427-0.490	61-425	857-2347
Mean	0.091	0.457	295	1541
Student's t	7.96		2.77	
Order Diptera				
Family Tendipedidae				
n	3	3	3	3
Range	0.097-0.180	0.107-0.408	408-850	811-1298
Mean	0.122	0.307	552	1012
Student's t	18.08		5.74	
Order Hemiptera				
Family Notonectidae				
n	3	3	3	3
Range	0.120-0.720	1.160-1.900	18-35	98-129
Mean	0.390	1.560	26	113
Student's t	4.19		8.58	

Table 17.--Continued.

Insects	Weights		Numbers	
	Styrofoam 75%	Controls	Styrofoam 75%	Controls
Order Coleoptera				
Family Hydrophilidae				
n	3	3	3	3
Range	0.440-1.030	80-2.500	28-59	14-93
Mean	0.783	1.630	47	63
Student's t[a]	1.60		1.82	
Family Hydrophilidae (larvae)				
n	3	3	3	3
Range	0.002-0.007	0.026-0.088	1-8	27-65
Mean	0.004	0.047	4	43
Student's t	2.46		3.34	
Family Dystiscidae				
n	3	3	3	3
Range	0.150-0.500	0.807-1.580	16-45	16-75
Mean	0.367	1.406	95	50
Student's t	3.21		0.85	
Total of all insects in each pool				
n	3	3	3	3
Range	3.026-7.548	11.343-15.874	641-1486	2859-4841
Mean	4.840	14.351	1069	3797
Student's t	6.29		4.10	

[a] Student's t values above 2.78 are significant at the 95% level.

Table 18. Range and mean of numbers of cladoceran per liter at the end of the summer insect-zooplankton experiment.

	Styrofoam 75%	Control
October 5, 1967		
n	3	3
Range	11-17	8-23
Mean	13.7	17.0
October 20, 1967		
n	3	3
Range	38-48	14-59
Mean	42.3	36.0

Table 19. Visual relative volume estimates of rainbow trout stomach contents at end of winter-spring trout experiment.

Organism	Percent of Total Volume		
	Styrofoam 80%	Styrofoam 50%	Control
n	1	7	9
Order Pulmonata Family Physidae	40	4	0
Order Odonata Family Libellulidae	40	4	85
Family Coenagrionidae	10	90	9
Order Hemiptera Family Corixidae	0	1	1
Order Coleoptera Family Hydrophilidae	0	1	5
Order Diptera Family Tendipedidae	5	0	0
Family Culicidae Subfamily Chaoborinae	5	0	0

Dissolved Oxygen Concentrations

The ranges of the sunrise and sunset vertically integrated samples from the evaporation ponds (Tables 20, 21, and 22) show that higher coverage levels produced lower dissolved oxygen concentrations in the evaporation ponds. The 100% nominal perlite coverage caused the dissolved oxygen content to drop to 0.31 mg/l and the 80% styrofoam coverage caused the dissolved oxygen content to drop to 0.10 mg/l. The 75% styrofoam treatment did not cause a similar reduction in the dissolved oxygen concentrations in the covered pools during the summer insect-zooplankton experiment (Table 23). In fact, the dissolved oxygen concentrations were a little higher than in the controls.

Dissolved oxygen concentrations taken at about 0.2, 1.1, and 2.1 meters showed that at times the dissolved oxygen concentration dropped to zero in the 100% nominal perlite coverages and in the 80% styrofoam coverage (Table 24).

Temperature

Using the water temperatures measured at a depth of 91.5 centimeters in the evaporation ponds as the mean pond temperatures, the two perlite coverages reduced the water temperature 6.3 C and 4.6 C (Tables 25 and 26). There was no thermal stratification during the spring trout experiment, the summer Tilapia experiment, or the winter-spring trout experiment (Tables 25, 26, and 27). The automatically recorded temperatures at the 91.5 centimeter depth in the control pond taken during the winter-spring trout experiment were later shown to be in error, recording between 2.8 C and 5.6 C too low. This means that the

Table 20. Range and mean of sunrise and sunset vertically integrated dissolved oxygen concentrations through the photic zone during the spring trout experiment, in mg/l.

	Perlite 100%	Styrofoam 18%	Control
Sunrise			
n	8	8	8
Range	2.93-9.60	3.93-10.35	7.30-9.73
Mean	7.85	8.37	8.60
Sunset			
n	20	19	19
Range	2.78-12.84	4.32-12.50	8.01-12.50
Mean	9.74	10.60	10.57

Table 21. Range and mean of sunrise and sunset vertically integrated dissolved oxygen concentrations through the photic zone during the summer _Tilapia_ experiment, in mg/l.

	Perlite 100%	Styrofoam 32%	Control
Sunrise			
n	10	10	10
Range	0.31-10.00	4.40-8.63	4.87-7.78
Mean	4.06	6.48	6.08
Sunset			
n	21	21	21
Range	0.31-12.30	5.33-12.08	7.54-9.42
Mean	5.48	8.48	8.54

Table 22. Range and mean of sunrise and sunset vertically integrated dissolved oxygen concentrations through the photic zone during the winter-spring trout experiment, in mg/l.

	Styrofoam 80%	Styrofoam 50%	Control
Sunrise			
n	3	3	3
Range	2.80-4.00	4.70-5.95	5.50-7.55
Mean	3.58	5.28	6.43
Sunset			
n	9	9	9
Range	0.10-4.20	4.90-6.80	6.73-8.55
Mean	2.87	6.21	7.92

Table 23. Range and mean of sunrise and sunset vertically integrated dissolved oxygen concentrations through the photic zone during the summer insect-zooplankton experiment, in mg/l.

	Styrofoam 75%			Control		
Sunrise						
n	10	10	10	10	10	10
Range	7.85-12.71	7.69-12.59	7.69-14.11	7.85-11.30	7.54-11.30	7.85-10.04
Mean	10.61	11.26	11.14	9.58	9.30	9.10
Sunset						
n	20	20	20	20	20	20
Range	8.49-14.73	8.01-14.50	8.32-15.85	8.32-13.81	7.85-12.87	8.48-13.50
Mean	11.90	12.35	12.27	11.67	10.69	10.82

Table 24. Dissolved oxygen concentrations at 0.2, 1.1, and 2.1 meters at sunset, in mg/l.

	Perlite 100%			Styrofoam 80%			Styrofoam 32%			Control		
	0.2	1.1	2.1	0.2	1.1	2.1	0.2	1.1	2.1	0.2	1.1	2.1
1967												
May 13	10.67	8.48	0.31	-	-	-	-	-	-	-	-	-
Aug. 17	5.10	3.40	0.00	-	-	-	5.20	4.85	3.60	6.30	5.45	2.80
Aug. 22	2.80	2.35	0.00	-	-	-	4.15	3.50	3.60	6.90	6.80	6.65
Sept. 5	6.35	4.98	0.45	-	-	-	3.70	3.30	1.90	5.10	4.75	4.10
1968												
Mar. 26	-	-	-	9.20	0.50	0.00	-	-	-	-	-	-

Table 25. Air and water temperatures (C) on representative days taken every six hours during the spring trout experiment.

Date 1967	Time	Air	Perlite 100%		Styrofoam 32%		Control	
			1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below
	2400	3.9	10.0	10.0	14.4	14.4	13.3	13.3
March 13	600	1.1	8.9	9.4	12.8	12.8	12.2	12.2
	1200	21.1	4.4	8.3	15.6	13.3	15.6	12.2
	1800	17.8	11.1	9.4	15.6	14.4	15.0	13.9
	2400	9.4	9.4	8.9	13.9	13.9	13.2	13.2
(Mean)		10.7	10.8	9.2	14.4	13.8	13.9	12.4
	2400	10.6	12.8	11.7	18.9	18.3	18.4	17.8
April 7	600	4.4	11.1	11.1	16.7	16.7	16.7	16.7
	1200	24.4	21.1	11.1	21.1	17.2	21.7	17.2
	1800	25.6	20.0	11.1	22.2	18.3	22.2	21.7
	2400	10.6	12.2	11.1	18.3	18.3	18.9	18.3
(Mean)		15.1	15.5	11.2	19.4	17.8	19.6	17.7
	2400	10.6	13.9	10.6	20.0	18.3	20.0	17.2
May 6	600	8.3	11.1	10.6	17.8	17.8	17.2	17.2
	1200	22.8	16.1	10.6	18.3	17.2	18.3	16.7
	1800	28.3	21.1	11.1	23.9	19.4	19.4	18.3
	2400	17.2	14.4	11.1	20.6	19.4	20.6	18.3
(Mean)		18.0	15.4	11.3	20.1	18.1	20.1	17.7

Table 26. Air and water temperatures (C) on representative days taken every six hours during the summer *Tilapia* experiment.

Date 1967	Time	Air	Perlite 100%		Styrofoam 32%		Control	
			1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below
July 18	2400	22.8	24.4	23.9	28.3	27.8	27.8	27.8
	600	24.4	25.6	23.9	27.2	27.2	26.1	26.1
	1200	32.2	30.6	23.9	30.6	28.3	31.7	27.2
	1800	31.7	28.9	23.9	31.1	28.9	31.7	28.3
	2400	23.9	25.6	23.9	29.4	28.9	29.4	28.3
(Mean)		30.6	26.6	23.9	29.3	28.2	29.3	27.3
August 18	2400	22.6	24.4	23.9	27.8	27.8	27.2	27.2
	600	23.3	22.8	23.9	27.8	27.8	26.7	26.7
	1200	32.8	28.9	23.9	31.1	28.3	31.7	27.8
	1800	28.9	28.9	23.9	30.0	28.9	28.3	28.3
	2400	22.6	23.3	24.4	28.3	28.3	26.7	26.7
(Mean)		26.2	25.7	24.0	29.0	28.2	28.1	27.3
Sept. 18	2400	17.8	18.9	19.4	24.4	24.4	23.9	23.9
	600	20.0	17.2	19.4	23.9	23.9	22.6	22.6
	1200	31.1	22.6	18.9	25.6	24.4	26.7	23.9
	1800	26.1	21.0	19.4	26.1	25.0	25.6	24.4
	2400	20.6	18.3	19.4	24.4	24.4	23.9	23.9
(Mean)		23.2	19.2	19.2	24.9	24.4	24.5	23.8

Table 27. Air and water temperatures (C) on representative days taken every six hours during the winter-spring trout experiment.

Date 1968	Time	Air	Styrofoam 80%		Styrofoam 50%		Control	
			1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below	1.3 cm Below	91.5 cm Below
Jan. 13	2400	8.3	5.6	6.7	8.3	8.3	8.3	5.6
	600	7.7	3.9	6.1	7.7	7.7	7.7	3.9
	1200	11.7	4.4	6.1	7.8	7.7	7.8	4.4
	1800	22.2	7.7	6.7	10.0	9.4	10.6	7.7
	2400	0.6	5.0	6.7	8.3	8.3	8.3	6.1
(Mean)		9.5	5.2	6.5	8.3	8.1	8.4	5.5
Feb. 10	2400	6.1	7.7	7.8	11.1	11.1	11.1	7.7
	600	3.3	6.7	7.8	10.6	10.6	10.6	6.1
	1200	23.3	8.9	8.3	12.8	10.6	13.9	7.7
	1800	14.4	10.0	8.9	12.8	11.1	13.9	8.3
	2400	10.0	8.3	8.3	12.2	11.7	12.8	8.3
(Mean)		11.5	8.2	8.2	11.9	11.1	12.4	7.9
March 26	2400	5.0	11.1	11.7	15.6	15.6	16.1	13.3
	600	2.8	11.1	12.2	15.0	15.0	14.4	12.2
	1200	28.3	13.9	11.7	17.2	15.0	19.4	12.2
	1800	23.3	16.7	12.2	18.9	16.1	20.6	14.4
	2400	8.3	12.8	11.7	16.7	16.1	17.2	13.9
(Mean)		13.5	13.1	12.0	16.7	15.6	17.6	13.2

80% styrofoam coverage reduced the mean water temperature about 2.8 C. No major temperature changes occurred in the 18%, 32%, and 50% styrofoam treatments.

The 75% styrofoam coverage raised the average sunrise surface temperature 1.1 C, while not affecting the sunset temperatures during the summer insect-zooplankton experiment (Table 28). Mechanical evaporation barriers also reduced the rate and extent the pond water adjusted to the air temperature changes.

Table 28. Range and mean of sunrise and sunset temperatures (C) during the summer insect-zooplankton experiment.

	Air	Styrofoam 75%	Control
	30 cm Above	3 cm Below	3 cm Below
Sunrise Temperatures			
13 July 1967 - 19 October 1967			
Range	12.2-27.8	20.6-30.0	17.5-29.4
Mean	22.0	27.6	26.6
Sunset Temperatures			
12 July 1967 - 19 October 1967			
Range	27.6-36.7	24.4-31.7	21.1-32.2
Mean	30.8	29.5	29.4

DISCUSSION

The most important effect of the mechanical evaporation barriers was the reduction of the light quantities entering the ponds. Light limitations were associated with reductions in the trophic levels and fish survival. The total effective solar energy falling annually on a given ecosystem is the ultimate limit to the productivity of that ecosystem (Dice and Penford 1954). Odum (1957) showed the direct relationship between gross photosynthesis and dependent trophic levels. Therefore, any reductions in gross photosynthesis by light limitations should be reflected in all higher trophic levels.

Pond Productivity

Coverages of 50% and above reduced the light quantity sufficiently to inhibit gross photosynthesis and therefore the dependent trophic levels. Coverages below 50% probably increased photosynthesis during periods of high light intensity and reduced it during periods of low light intensity. Tucson has an average daily solar radiation of 475 gm cal per cm^2 (U. S. Dept. of Commerce, Weather Bureau), which is more than necessary for maximum photosynthesis. Therefore, light intensities presumably limited the photosynthesis in the control ponds during the middle of the day. Shade provided by the evaporation barriers probably permitted maximum photosynthesis in the covered ponds during these periods of high light intensity. However, during periods of low light intensity (early morning and late afternoon), this shading could have reduced the photosynthetic rate in the covered ponds. Therefore, gross photosynthesis was found to be similar in the ponds with less than 50% coverage and in the control ponds.

As the percentage of styrofoam coverage on the evaporation ponds increased, gross photosynthesis decreased. If primary productivity was dependent upon phytoplankton, there would have been reductions in phytoplankton chlorophyll concentrations in proportion to the gross photosynthetic reductions. The phytoplankton chlorophyll concentrations were not reduced, because the primary productivity was mainly dependent upon the rooted aquatic plants. The average chlorophyll concentrations for all of the evaporation pond experiments, 4.5 mg/l, could not have produced the average gross photosynthesis of 4.31 gm O_2 per 24 hrs. Stewart (1967) showed that an average of 16.7 mg of chlorophyll per liter for three Arizona lakes (Hawley Lake, Becker Lake, and Woods Canyon Lake) produced an average of only 0.50 gm O_2 per m^3 per 24 hrs. At the end of the study, there was a visible reduction in plant biomass in those ponds which had reduced gross photosynthesis.

Plants grown in shade develop more chlorophyll than those exposed to high light intensities (Ryther 1956). The higher chlorophyll concentrations in the covered swimming pools than in the controls were probably the result of such a physiological adaptation by the phytoplankton to lower light intensities. Similar adaptations could have occurred in the evaporation ponds causing the phytoplankton chlorophyll concentrations to remain relatively unchanged. This also showed that primary productivity of the swimming pools was largely dependent upon benthic algae.

The slightly higher pH in the control ponds of the spring trout experiment and the summer Tilapia experiment may indicate that the control ponds had higher productivity (Ruttner 1963). But pH in the control pools of the summer insect-zooplankton experiment was not higher than that for the covered pools, even though gross photosynthesis was significantly higher. Therefore, it appears that the increased pH during the first experiments may not be associated with higher gross photosynthesis. Turbidity measurements, as with pH measurements, showed no relationship to productivity rates.

Insect Yields and Fish Growth

Lower gross photosynthesis was associated with significantly lower aquatic insect yields in all covered pools during the summer insect-zooplankton experiment. These same insects were shown to be important trout food items during the winter-spring trout experiment. Cladoceran numbers apparently were not reduced by the 75% styrofoam coverage during the summer insect-zooplankton experiment. This could have been an artifact caused by the limited number of samples or the shorter life cycle and higher turnover rate of the cladocerans.

Fish growth in the evaporation pond experiments was probably more closely related to the original plant and animal communities than to primary and secondary productivity during the experiments. Differences in trout growth were not proportional to the large differences in surface coverage during the first trout experiment. Low stocking rates may also have been a factor by reducing food competition, thus moderating the effects that reduced photosynthesis might have had on trout growth.

The unexpected higher Tilapia growth in the pond with 32% styrofoam coverage probably resulted from visually undetected differences in the initial aquatic plant biomasses. This was important because Tilapia can be herbivorous. Because of concurrent evaporation experiments, benthic plants could not be removed or equalized at any time.

The lower fish growth in the 100% nominal perlite treatment during the summer Tilapia experiment was probably the direct result of reduced gross photosynthesis.

Hexadecanol, a long chain alcohol, used in earlier evaporation studies did not cause similar trophic reductions (Committee of Collaborators 1957, Hayes 1959, Timblin 1957, and Wiltzius 1967). Reduction of emergent insect numbers was the only trophic effect mentioned by these workers.

Fish Survival

Fish survival in the 100% nominal perlite coverages and the 80% styrofoam coverages was affected by low dissolved oxygen concentrations. The barriers reduced the dissolved oxygen concentrations in the same way that ice causes winterkills. When ice cover stops photosynthesis and limits diffusion, the oxygen supply is used up by plant decomposition and community respiration. The significantly lower trout survival in the 80% styrofoam coverage was associated with the low dissolved oxygen content of 0.10 mg/l recorded during one sunset sample. The dissolved oxygen content was probably lower than that of the preceding sunrise. Burdick *et al.* (1954) state that the lethal minimum oxygen concentrations for rainbow trout range from 1.05 mg/l at 11 C to 1.51 mg/l at 20 C. It is therefore highly probable that the low dissolved oxygen concentrations caused the mortality. During the summer *Tilapia* experiment, survival was not reduced by similar low dissolved oxygen concentrations (0.31 mg/l). *Tilapia* can tolerate lower oxygen tensions than trout. During the spring trout experiment survival was fair, and dissolved oxygen concentrations below 2.00 mg/l were never measured.

The low dissolved oxygen concentrations during the final two evaporation pond experiments were caused by higher plant decomposition rates. The increase in plant decomposition rates was cumulative, starting in the first experiment. It was not until after the second experiment was started that the barriers had caused enough aquatic plants to die such that the decomposition rate at times consumed the total available oxygen.

The 80% styrofoam coverage and the 100% perlite coverages used on the evaporation ponds and the 75% styrofoam coverage used on the swimming pools should have caused similar gas diffusion reductions. In the 75% styrofoam-covered pools the dissolved oxygen concentrations were higher than the dissolved oxygen concentrations in the controls. Therefore, reduced oxygen diffusion rates, while reducing the amount of dissolved oxygen entering the ponds, did not cause the lethal low oxygen concentrations observed in the evaporation ponds. Low dissolved oxygen concentrations did not occur in the 75% styrofoam-treated pools because of the lack of existing rooted plants to cause high decomposition rates.

The oxygen tension in the covered pools could have been higher than in the controls because the photosynthetic rate was slightly higher than the respiration rate in all ponds and the evaporation barriers reduced oxygen diffusion out of the pools, thus causing the supersaturation values. This indicates that, at higher coverages, mechanical evaporation barriers probably cause greater oxygen stresses when applied to existing eutrophic waters than when applied to existing oligotrophic waters or to newly created waters.

Temperature

Temperature reductions of about 2.8 C to 5.6 C by the higher coverages in the evaporation ponds extended the growing season of cold water fish in the spring and restricted the growing season of warm water fish. The benefits of these temperature reductions were counteracted by strong oxygen stratifications and oxygen depletions which restricted the habitat and lowered the survival rate. At lower coverages the barriers did not cause any major temperature changes. The 75% styrofoam coverage did not change the water temperature enough to override the heat exchange by the metal pool sides; thus, there was little temperature difference. Hayes (1959) showed that hexadecanol increased the surface temperature an average of 1.8 C by reducing the evaporation rate. Mechanical evaporation barriers reduced the surface temperature by reducing the amount of solar heating. Mechanical evaporation barriers also reduced the rate and extent that the pond water adjusted to the diel air temperature changes.

CONCLUSIONS

This study showed that coverages of over 50% by mechanical evaporation barriers caused significant reductions in fish growth, gross photosynthesis, and aquatic insect yields. These reductions seemed to be directly caused by the reductions of light quantities entering the ponds, and they occurred in both the existing ponds (eutrophic) and the new pools (oligotrophic). Because of the direct relationship, shown in this study and by other investigators, between the amount of light entering the ponds and gross photosynthesis, it can be assumed that any coverage by mechanical evaporation barriers will cause some reductions in gross photosynthesis and dependent trophic levels, but this study did not show any significant effects (adverse or beneficial) for coverages below 50%.

If the mechanical evaporation barriers are placed on existing ponds at the higher coverages (100% nominal perlite and 80% styrofoam) for a period of over 6 months, greater fish mortality could occur similar to winterkills under ice caused by oxygen depletions.

The future use of mechanical evaporation barriers on waters where fisheries are important should be avoided at coverages of 50% and higher. Where the use of these barriers prevents the seasonal drying up of a water body and thereby allows a permanent fishery to exist, the benefits may outweigh the productivity reductions.

APPENDIX

RAW TABULAR DATA - SPECIFIC MEASUREMENTS OF ALL EXPERIMENTS

Table A-1. Lengths and weights of fish at the start and end of spring trout experiment, February 12 and May 25, 1967, in cm and gm.

Date	100% Perlite		18% Styrofoam		Control	
	cm	gm	cm	gm	cm	gm
Feb. 12						
	10.0	10.0	10.5	11.0	10.0	10.0
	11.0	14.5	10.0	10.0	11.0	12.5
	11.0	13.0	10.5	10.5	10.5	11.5
	9.5	8.5	10.0	9.0	11.0	13.5
	10.0	10.0	10.5	10.0	11.0	12.0
	10.0	10.0	10.5	10.5	11.0	13.5
	10.5	11.0	10.0	10.0	11.0	12.0
	10.0	10.0	10.0	10.0	10.5	12.5
	9.5	8.0	10.5	11.5	10.0	10.0
	11.0	12.0	11.5	14.5	10.5	10.5
	10.0	10.0	11.0	14.5	10.0	9.5
	11.0	12.5	10.5	10.0	10.0	9.5
	11.0	13.0	11.0	12.0	10.0	9.5
	11.5	14.0	11.0	11.5	11.0	14.0
	10.5	12.0	11.0	12.5	10.0	9.5
	156.5	168.5	158.5	167.5	157.5	170.0
May 25						
	21.5	108.5	19.5	68.5	21.0	87.5
	20.5	90.0	21.5	89.5	19.5	75.5
	19.5	85.5	21.0	103.0	21.5	96.0
	19.5	80.5	21.5	119.5	21.0	84.0
	20.0	91.0	21.0	107.5	21.0	100.5
	21.5	116.0	20.0	99.5	19.5	83.0
	17.0[a]	47.0[a]	20.0	87.5	22.0	109.0
	22.0	121.0	21.5	104.5	19.5	87.0
	21.5	109.5	20.5	97.5	21.5	111.0
	20.0	84.0			20.5	97.0
	19.5	86.0			21.5	--[b]
	20.0	76.5				
	19.5	84.0				
	20.0	85.0				
	21.0	110.0				

a. Not used in growth analysis.

b. Fish taken 48 hours after death, so weight not taken.

Table A-2. *Tilapia* lengths and weights at the start and end of summer *Tilapia* experiment, July 13 and November 11, 1967, in cm and gm.

July 13	15 Representatives of the Stock Used	
	cm	gm
	4.1	0.9
	3.2	0.5
	3.8	0.8
	4.0	1.0
	3.7	0.7
	4.0	1.0
	3.1	0.5
	3.6	0.7
	3.9	0.8
	3.3	0.5
	3.5	0.6
	3.4	0.5
	3.4	0.5
	3.2	0.5
	3.5	0.6

Nov. 11	100% Perlite		32% Styrofoam		Control	
	cm	gm	cm	gm	cm	gm
	18.2	97.0	21.3	188.7	20.8	188.7
	17.7	100.8	22.0	198.4	20.3	180.0
	17.6	99.0	21.6	196.0	20.9	162.0
	18.7	108.5	21.5	187.7	20.1	158.4
	17.3	96.6	22.6	210.8	20.5	174.7
	18.8	114.1	21.6	206.4	20.1	152.5
	18.7	108.6	21.4	199.1	20.5	178.1
	18.2	108.8	19.9	149.0	19.4	135.1
	18.0	105.9	22.5	229.5	19.3	125.8
	17.6	97.5	21.6	206.9	18.9	126.8
	17.8	100.5	22.0	222.4	19.7	154.5
	17.2	94.1	20.7	196.7	20.2	164.3
	18.8	99.8	21.0	193.9	19.1	132.5
	17.2	96.3	21.2	195.0	22.0	204.5
	19.2	121.0	22.3	216.8	20.1	160.9
	17.1	90.5	21.0	183.2	21.6	198.7
	18.9	115.9	20.5	156.2	21.0	184.0
	18.0	105.9	21.9	217.4	19.6	147.4

Table A-2.--Continued

Nov. 11	100% Perlite		32% Styrofoam		Control	
	cm	gm	cm	gm	cm	gm
	17.2	90.5	19.9	166.5	21.1	181.1
	17.2	90.6	21.3	176.9	20.7	167.6
	16.7	85.4	21.2	170.0	20.6	171.1
	16.6	83.5	21.8	205.4	19.0	130.0
	18.0	106.6	21.9	193.0	20.1	157.9
	18.7	108.7	21.9	217.3	21.4	191.7
	18.5	———[a]	20.5	172.0	21.2	185.6
	17.6	--	21.2	184.3	20.8	186.6
	18.0	-- [b]	22.5	215.1	20.3	178.7
	18.3	--	20.8	149.8	21.0	192.4
	18.5	--	20.6	169.0	19.6	140.8
	18.5	--	20.6	184.4	20.4	178.3
	18.8	--	19.5	153.3	20.1	166.3
	17.9	--	19.8	166.6	21.0	197.3
	18.5	--	21.2	187.1	18.9	123.9
	18.4	--	21.1	194.1	20.8	178.5
	19.0	--	20.4	190.4	20.4	175.8
	19.3	--	19.6	143.9	20.8	178.5
	17.0	--	21.9	208.5	--	--
	17.5	--	21.3	173.7	--	--
	--	--	20.7	182.2	--	--
	--	--	20.8	214.1	--	--

a. Fish recovered 48 hours after death, so weights not taken.

b. Fish recovered 1-2 weeks after experiment ended - used only to determine survival numbers.

Table A-3. Lengths and weights of trout at the start and end of winter-spring trout experiment, November 30, 1967, and April 23, 1968, in cm and gm.

Date	80% Styrofoam		50% Styrofoam		Control	
	cm	gm	cm	gm	cm	gm
Nov. 30	15.0	34.1	14.5	32.8	14.7	31.6
	14.2	32.5	14.7	30.0	14.5	30.0
	14.1	26.8	14.6	28.8	14.5	30.0
	14.1	25.6	14.7	30.0	14.7	26.5
	14.3	30.0	14.8	31.5	14.0	25.9
	14.6	27.1	14.0	25.2	15.0	31.5
	14.5	28.1	15.0	29.9	14.4	26.3
	14.7	29.8	14.2	28.1	14.5	28.8
	14.3	27.8	14.3	27.8	14.1	26.0
	14.4	26.7	15.0	31.4	14.6	28.8
	15.0	32.6	14.5	30.2	14.9	30.6
	14.7	30.0	14.7	27.9	15.0	31.7
	14.7	31.3	15.0	30.9	14.9	28.7
	14.7	26.9	14.5	25.4	14.7	31.9
	14.9	32.9	14.6	29.4	14.5	26.3
	14.1	36.6	14.6	31.3	14.6	29.3
	14.9	33.3	14.3	27.8	14.4	29.3
	15.0	26.6	14.9	29.6	14.8	32.1
	15.0	30.6	14.5	30.2	14.2	25.3
	15.0	30.8	14.9	27.7	14.6	26.9
Apr. 23	27.0	193.1	27.6	271.5	25.3	152.3
			26.7	235.2	25.9	170.0
			28.1	251.8	27.9	212.3
			28.5	278.7	24.8	159.3
			28.8	286.6	24.3	151.8
			26.6	211.3	25.1	167.5
			26.6	189.8	24.1	142.3
					23.5	138.0
					24.2	147.4

Table A-4. Sunrise and sunset dissolved oxygen concentrations for spring trout experiment, in mg/l.

Date	Time	Perlite 100%	Styrofoam 18%	Control
Mar. 8	SS	12.84	12.50	11.73
Mar. 11	SS	9.86	11.71	12.50
Mar. 12	SR	7.76	10.03	9.70
Mar. 12	SS	9.64	11.37	10.96
Mar. 21	SS	9.80	10.00	11.10
Mar. 22	SS	10.00	10.50	11.50
Mar. 23	SR	8.20	8.00	8.60
Mar. 23	SS	10.40	11.20	11.40
Mar. 27	SS	11.30	12.20	10.60
Mar. 28	SR	9.60	9.50	8.60
Mar. 28	SS	11.50	12.20	10.90
Apr. 5	SS	10.70	11.00	10.30
Apr. 6	SR	8.32	8.55	7.78
Apr. 6	SS	9.88	10.83	10.60
Apr. 13	SS	9.51	10.21	9.57
Apr. 14	SR	7.40	7.08	7.75
Apr. 14	SS	10.68	11.60	11.30
Apr. 22	SS	10.28	11.60	9.65
Apr. 23	SR	9.25	9.65	9.34
Apr. 23	SS	11.22	14.21	11.78
Apr. 27	SS	11.46	12.70	10.43
Apr. 28	SR	9.36	10.35	9.73
Apr. 28	SS	12.16	12.45	10.82
May 12	SS	9.50	5.26	-
May 13	SS	7.17	-	8.56
May 22	SS	2.78	4.32	8.01
May 23	SR	2.93	3.93	7.30
May 23	SS	4.17	5.57	9.03

Table A-5. Sunrise and sunset dissolved oxygen concentrations for summer *Tilapia* experiment, in mg/l.

Date	Time	Perlite 100%	Styrofoam 32%	Control
Jul. 10	SS	0.31	11.68	8.64
Jul. 11	SR	0.31	8.63	5.26
Jul. 11	SS	1.96	12.08	9.11
Jul. 18	SS	2.75	11.13	8.08
Jul. 20	SS	4.08	11.52	9.03
Jul. 21	SR	1.88	7.93	5.57
Jul. 21	SS	4.24	10.50	7.79
Jul. 24	SS	4.55	9.88	8.01
Jul. 25	SR	2.36	7.22	5.88
Jul. 25	SS	4.72	10.04	8.64
Jul. 31	SS	3.53	7.53	8.48
Aug. 1	SR	1.88	6.28	5.65
Aug. 1	SS	3.69	8.16	9.03
Aug. 7	SS	4.08	6.91	7.69
Aug. 8	SR	2.20	5.81	4.87
Aug. 8	SS	3.69	6.75	7.54
Aug. 23	SS	5.72	7.38	8.24
Aug. 24	SR	4.72	6.28	6.75
Aug. 24	SS	7.46	8.95	9.66
Sept. 5	SS	9.50	7.21	9.05
Sept. 6	SR	6.60	4.63	6.20
Sept. 6	SS	6.83	6.44	8.95
Sept. 20	SS	11.30	5.88	8.08
Sept. 21	SR	10.00	5.49	5.81
Sept. 21	SS	12.30	5.57	7.54
Oct. 4	SS	2.98	9.58	8.95
Oct. 5	SR	1.98	8.16	7.75
Oct. 5	SS	3.48	9.26	8.56
Oct. 18	SS	9.78	5.88	9.42
Oct. 19	SR	8.72	4.40	7.23
Oct. 19	SS	8.08	5.33	8.87

Table A-6. Sunrise and sunset dissolved oxygen concentrations for summer insect-zooplankton experiment, in mg/1.

Date	Time	75% Styrofoam			Control		
Jul. 12	SS	8.49	8.01	8.32	8.32	7.85	8.48
Jul. 13	SR	7.85	7.69	7.69	7.85	7.54	7.85
Jul. 13	SS	8.95	8.63	8.95	8.95	8.63	9.11
Jul. 20	SS	11.15	13.33	11.62	10.68	9.73	10.20
Jul. 21	SR	10.37	11.92	10.36	8.76	8.32	8.79
Jul. 21	SS	11.13	11.14	10.99	10.82	9.26	9.26
Jul. 24	SS	12.09	13.02	12.08	10.04	9.26	9.86
Jul. 25	SR	10.83	11.92	10.82	9.10	8.63	9.11
Jul. 25	SS	12.55	13.20	12.00	10.37	9.57	9.73
Jul. 31	SS	10.82	12.08	11.13	11.14	10.36	11.14
Aug. 1	SR	9.73	11.30	10.68	10.04	9.10	9.42
Aug. 1	SS	11.77	12.87	11.78	11.45	10.68	10.51
Aug. 7	SS	12.88	12.48	12.37	11.30	10.51	11.45
Aug. 8	SR	10.83	11.62	10.68	10.04	9.26	9.73
Aug. 8	SS	12.23	12.56	12.87	11.45	10.99	11.45
Aug. 23	SS	13.02	14.50	15.00	11.30	11.14	10.68
Aug. 24	SR	11.77	12.59	14.11	9.18	8.79	9.26
Aug. 24	SS	12.88	15.21	15.85	11.14	10.68	9.73
Sept. 5	SS	12.63	13.63	12.65	10.83	10.99	11.14
Sept. 6	SR	11.61	12.00	11.70	8.95	9.18	8.87
Sept. 6	SS	13.32	13.65	12.94	11.14	10.59	10.91
Sept. 20	SS	14.73	12.55	14.29	13.81	12.15	12.23
Sept. 21	SR	12.71	11.14	13.01	11.30	11.30	9.34
Sept. 21	SS	14.11	12.08	13.97	11.62	12.22	11.62

Table A-6.--Continued

Date	Time	75% Styrofoam			Control		
Oct. 4	SS	10.67	11.92	12.55	12.71	12.87	13.50
Oct. 5	SR	10.04	10.68	11.30	10.35	10.50	8.63
Oct. 5	SS	11.15	11.78	12.40	12.24	12.40	12.56
Oct. 18	SS	11.92	12.87	11.78	11.23	12.00	11.62
Oct. 19	SR	10.67	11.78	11.00	10.20	10.35	10.04
Oct. 19	SS	11.53	11.52	11.92	11.85	11.85	11.30

Table A-7. Sunrise and sunset dissolved oxygen concentrations for winter-spring trout experiment, in mg/l.

Date	Time	Styrofoam 80%	Styrofoam 50%	Control
Feb. 19	SS	1.80	6.38	8.55
Feb. 20	SR	4.00	5.20	7.55
Feb. 20	SS	1.70	6.60	7.00
Mar. 8	SS	0.10	5.13	8.38
Mar. 9	SR	3.95	4.70	6.23
Mar. 9	SS	4.20	4.90	7.15
Mar. 25	SS	2.10	6.70	8.40
Apr. 3	SS	3.75	6.53	6.73
Apr. 4	SR	2.80	5.95	5.50
Apr. 4	SS	4.20	6.82	8.27
Apr. 24	SS	4.10	6.33	8.35
Apr. 29	SS	3.90	6.50	8.50

Table A-8. Phytoplankton chlorophyll concentrations for each experiment, in mg/m^3.

Spring Trout Experiment

	Perlite 100%	Styrofoam 18%	Control
March 14	2.4	1.5	15.0
March 23	3.2	5.9	5.2
March 28	16.3	3.2	21.5
April 14	8.0	2.4	15.0
April 23	3.2	1.7	2.4
April 28	0.7	0.8	2.1
May 11	1.3	1.3	1.9
May 23	2.4	0.5	0.5

Summer Tilapia Experiment

	Perlite 100%	Styrofoam 32%	Control
July 25	4.1	2.0	1.0
August 1	1.1	0.8	0.8
August 24	0.7	0.7	0.4
September 6	1.5	1.2	1.5
September 21	14.5	11.4	11.7
October 5	10.3	3.8	6.4
October 19	6.4	1.6	1.4

Summer Insect-Zooplankton Experiment

	Styrofoam 75%			Control		
July 25	1.3	1.1	1.1	0.5	0.5	0.7
August 1	1.5	2.8	1.0	1.2	2.4	2.5
August 24	2.1	1.6	2.0	1.8	1.8	1.8
September 6	2.4	1.0	1.6	0.8	0.9	0.9
September 21	14.2	20.3	21.0	13.5	13.2	6.8
October 5	9.2	5.6	8.6	4.1	6.1	3.1
October 19	9.5	4.7	5.1	4.1	2.0	2.2

Table A-9. Insect numbers and weights at end of summer insect experiment.

Insect	75% Styrofoam			Control		
	(gm) No.	(gm) No.	(gm) No.	(gm) No.	(gm) No.	(gm) No.
Order Odonata Suborder Anisoptera Family Libellulidae	5.560 (99)	1.580 (52)	1.651 (155)	5.308 (1183)	8.823 (196)	11.966 (1344)
Order Ephemeroptera Family Baetidae	0.021 (61)	0.170 (425)	0.083 (399)	0.454 (857)	0.490 (1419)	0.427 (2347)
Order Diptera Suborder Orthorrhapha Family Tendipedidae	0.097 (394)	0.180 (850)	0.090 (408)	0.406 (1298)	0.107 (811)	0.408 (926)
Order Coleoptera Family Hydrophilidae	0.440 (28)	1.030 (59)	0.800 (53)	1.510 (81)	2.500 (93)	0.880 (14)
Order Hemiptera Family Notonectidae	0.720 (35)	0.330 (24)	0.120 (18)	1.900 (113)	1.620 (129)	1.160 (98)
Order Coleoptera Family Dytiscidae	0.450 (16)	0.500 (45)	0.150 (34)	1.580 (75)	1.830 (60)	0.807 (16)
Order Hemiptera Family Nepidae	0.230 (4)	0.130 (2)	0.040 (1)	0.140 (2)	0.270 (4)	0.120 (2)
Order Hemiptera Family Corixidae	0.020 (2)	0.020 (1)	0.000 (0)	0.000 (0)	0.000 (0)	0.000 (0)

Table A-9.--Continued

Insect	75% Styrofoam			Control		
	(gm) No.	(gm) No.	(gm) No.	(gm) No.	(gm) No.	(gm) No.
Order Coleoptera Family Hydrophilidae (larvae)	0.002 (1)	0.004 (4)	0.007 (8)	0.026 (27)	0.088 (65)	0.028 (37)
Order Diptera Family Tipulidae	0.000 (0)	0.002 (6)	0.000 (0)	0.019 (54)	0.028 (81)	0.028 (56)
Order Diptera Family Culicidae Subfamily Chaoborinae	0.000 (0)	0.000 (0)	0.005 (23)	0.000 (0)	0.000 (0)	0.000 (0)
Order Hemiptera Family Belostomatidae	0.080 (1)	0.000 (0)	0.000 (0)	0.000 (0)	0.080 (1)	0.050 (1)

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