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ASSESSING EFFECTS ON WATER QUALITY BY BOATING ACTIVITY

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ASSESSING EFFECTS ON WATER QUALITY BY BOATING ACTIVITY

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the bioshpere, and
- a search for ways to prevent contamination and to recycle valuable resources.

Research studies on possible detrimental effects to man's recreational sources from usage of engined boats will help interested regulatory agencies and local groups to implement the required program for the preservation of our water resources. Emphasis of prior investigations has been on exhaust emissions. However, this preliminary study investigates the effects of agitation and mixing by motor boats and assesses the water quality implications that result from this activity.

A. W. Breidenbach, Ph.D.
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ABSTRACT

This research endeavor was directed towards an assessment of effects on water quality in shallow water bodies due to mixing by boating activity. Definition of the problem, isolation of effects and conditions, and determination of areas for further research were stressed.

Eight sampling locations on four selected lakes in Orange County, Florida, were studied. Heavy boating activity exists on Lake Mizell, Lake Osceola, and Lake Maitland in the Winter Park chain of Lakes with an average horsepower almost twice that of the estimated national average and a total of 814 registered motorboats during 1972 in the City of Winter Park. The fourth, Lake Claire, is located on the Florida Technological University campus and boating activity is permitted only for research studies. Boats equipped with different horsepower motors were run for limited periods of time in the area of sampling locations which vary in depth between 1.2 and 10.7 meters. Changes in several water quality parameters before and after boating activity have been documentated. Also water quality parameters on weekends and during week days were studied to investigate the significance of heavy boating activity. Three major parameters namely dissolved oxygen, resuspension of sediments and nutrients, were emphasized.

The results from these studies suggested that agitation and mixing by motorboats could increase the turbidity and average particle size of suspended material through the water column. The increase in turbidity was generally dependent on water depth, motor power and availability and nature of sediment deposits. A decrease in turbidity was noticed one hour after cessation of boating. However, changes in collodial suspensions within the water columns have not been investigated. Increase in turbidity was accompanied by an increase in organic carbon and phosphorus concentrations. Dissolved and particulate phosphorus seemed to increase in water samples collected after boating activity, at least on a temporary basis.

Agitation and mixing by boating activity destratified the lake, and in some cases, increased oxygen concentration and the rate of oxygen uptake by suspended matter. Results from other parameters such as pH, specific conductance, temperature, and nitrogen were not conclusive. Long term research studies are recommended.

This report was submitted in fulfillment of EPA Contract No. 68-03-0290 by the Florida Institute of Technology under the sponsorship of the Environmental Research Agency. Work was completed as of June 1, 1974.

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ACKNOWLEDGMENTS

The author wishes to acknowledge with graditude the assistance of the many individuals who helped make this investigation possible.

Special acknowledgments are extended to all students at Florida Technological University who participated in this project. Special recognition must go to Mr. Lorran R. Mears, photographer, who freely and willingly took the underwater pictures.

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Funding for this project was provided by the Environmental Protection Agency, Industrial Waste Treatment Research Laboratory, Edison, New Jersey. The interest and assistance of Mr. Thomas H. Roush and Mr. Leo T. McCarthy is most gratefully appreciated.

SECTION I

CONCLUSIONS

1. Dissolved oxygen profiles and turbidity measurements generally indicate a mixing of the water column following boating activity. This was also supported by underwater photography.

2. Under test conditions, the mixing depth appears to vary directly with horsepower of the motor. The effective mixing depth reached up to 15 feet below the water surface for a 50 HP motor.

3. Resuspension of solids from the bottom and aquatic macrophytes was observed following boating activity. Changes in turbidity was dependent on water depth, motor power, operational time and type and nature of sediment deposits. In the shallow shore areas with water depth less than 5 feet, physical changes in turbidity and floating matter at the surface were observed within less than five minutes of boating activity.

4. One hour after cessation of boating activity, a decrease in turbidity measurements was observed.

5. The increase in turbidity was generally accompanied by an increase in organic carbon and phosphorus concentration. Most of the organic carbon was dissolved, and most of the phosphorus was particulate. The extent and significance of these changes in nutrients and their possible contribution to the eutrophication problem is not known.

6. Temperature, pH, conductivity and TKN were deemed poor indicators of mixing in the lakes tested.

7. Under certain conditions, increases in the total dissolved oxygen was noted following boating activity. The oxygen transfer to the water body depends primarily on the oxygen deficit in the water column. Also, there is evidence that resuspended particles throughout the water column may exert a higher oxygen uptake rate.

SECTION II

RECOMMENDATIONS

During the course of this study, as much information as possible was collected within the budget and time limitations. The mixing process and water quality changes after limited boating activity were documented. However, the nature and significance of these changes are not known. Therefore, long term studies within the following areas of research are recommended.

1. Increase in turbidity was attributed to boating activity. Release of nutrients from the resuspended solids, their availability to autotrophic organisms and their impact on the eutrophication problem is not known. In particular, the significance of increasing the phosphorus concentration in the water column through mixing the lower levels of water, which are rich in phosphorus content, throughout the entire column depth need to be investigated.

2. It is desirable to study the net oxygen balance due to mixing effects. For example, to determine if the oxygen added to water from aeration is adequate to replace the oxygen possibly consumed by increased sediment uptake. Factors and conditions that will tend to increase the oxygen uptake rate need to be identified.

3. Underwater photography could be helpful in development of a mathematical model to predict the size and nature of resuspended particles under a set of operational conditions. Also the mixing process itself needs to be defined.

4. The effect of water column mixing and resuspension of solids on redistribution and changes in autotrophic organisms and benthos deserves further investigation.

5. Work is needed to determine if the water column mixing and solid resuspension is detrimental to the ecology of a lake and if so under what conditions?

6. The effect of boating activity on the stability of a thermocline and the various conditions under which the two interact needs definition.

SECTION III

INTRODUCTION

Outboard engined boats are increasing in number and average horsepower. Their possible detrimental effects to water bodies has been of growing concern. Various studies on exhaust emission have been initiated; however, agitation and mixing due to boating activity have not been evaluated.

There has been a growing concern to those interested in the preservation of our natural resources over the possibility that outboard engined boats could be detrimental to our lakes and water bodies. The outboard motor sales are increasing in number and average size as shown in Table 1. Table 1 shows a summary of the major usable motor population and sales statistics between year 1950 and 1971 as reported by the Boating Industry Association (BIA). Over 98% of all outboard motors in use are of the two-stroke cycle type (7). The sales increased from 430,000 in 1970 to 495,000 in 1971 and the average size motor increased from 31 to 35.6 HP. Information on inboard powered boats is not included.

Table 1. SUMMARY OF OUTBOARD MOTOR POPULATION

YEAR	SALES, thousands	AVERAGE HP SOLD	OUTBOARD MOTORS IN USE, thousands
1950	367	6.9	2811
1955	515	12.9	4210
1960	468	27.4	5800
1965	393	28.2	6645
1970	430	31.0	7215
1971	495	35.6	7300

In the area of central Florida, there were 11,010 registered pleasure boats in Orange County, 7,950 in Seminole County, and 1,233 in Osceola County during 1971-72 (5). Data of the horsepower in these counties are difficult to obtain. However, the City of Winter Park, Orange County registered during 1972 a boat population of 814 with motors ranging between 1.25 and 260 HP. The distribution and power range of these motor boats are shown in Table 2. The average horsepower for boats used in the City of Winter Park is 67.05 HP (22).

Table 2. MOTOR BOATS REGISTERED DURING 1972
City of Winter Park

POWER RANGE, HP	NUMBER OF BOATS
1 - 10	39
11 - 30	62
33 - 50	238
51 - 100	353
101 - 150	93
151 - 200	13
201 - 260	16
TOTAL	814
Avg. Power	67.05 HP

In recent years, several investigations have been carried out to determine the environmental effects due to emission exhausts (7,12). A recent search of the Smighsonian Science Information Exchange's records, in December 1973, showed no relevant notices of research projects related to agitation by outboard engined boats to be registered with them. Current studies supported by the Environmental Protection Agency are related to the investigation of the effects of outboard motor emissions.

However, no work has been done to evaluate the effects of agitation by motor boats on water bodies. The extent of water quality degradation in shallow lakes due to resuspension of organic matter and nutrients from bottom sediments is unknown and cannot be ignored or underestimated. Research is, therefore, required to define the magnitude of the changes in water quality by mechanical mixing and the rationale for the control of boating activity if such control is deemed to be necessary.

OBJECTIVES AND SCOPE

The overall objective of this endeavor is to determine whether mechanical agitation as a result of outboard engined boating activity could induce possible detrimental effects on the water quality in shallow lakes (less than 30 feet). The results of such work will supplement and compliment the other research regarding outboard engines. Also, it will help interested regulatory agencies and local groups to implement the required program to provide guidelines on motor boat usage for state and local authorities.

Specifically, an assessment of the effects on water quality in shallow water bodies due to mixing by boating activity in order to define the problem, isolate effects and conditions and determine areas of further research will be accomplished during this phase of study. Studies of selected lakes in central Florida, mainly in the Winter Park Chain of Lakes and on the Florida Technological University campus, have been initiated. Boating for limited periods of time using boats equipped with different horsepower motors has been considered to determine changes in turbidity, suspended solids, total organic and inorganic carbon, biochemical oxygen demand, dissolved oxygen, temperature, pH, phosphorus, and nitrogen.

Due to geographical and budget limitations, only shallow Florida lakes were observed. Hence, if any implications concerning the effects of mechanical mixing found in this investigation are applied to other geographical areas, it must be considered as the responsibility of the reader.

SECTION IV

DESCRIPTION OF TEST LAKES

Lakes classed as oligotrophic, mesotrophic and various stages of eutrophication exist in the area of central Florida. Orange County along has approximately 218 lakes with a total surface area of 44,251 acres (17921.7 hectares) within the St. John's Basin (4). The surface area of the lakes varies between one (0.405 hectares) and 30,671 acres (12421.8 hectares) and the maximum water depth varies between less than 5 feet (1.52 meters) deep and more than 30 feet (9.14 meters) deep. Studies have indicated that cultural influences, such as population characteristics, fertilized cropland and urban areas in the lakes watershed, are the most influential factors in determining the trophic states of Florida lakes (18,19).

Four lakes in Orange County Florida, have been used during the course of this study. Three of them are in the Winter Park chain of lakes, namely Lakes Mizell, Osceola, and Maitland. The fourth, Lake Claire, is located on the Florida Technological University campus. The Winter Park chain of lakes are used for boating activities but motor boats are generally not permitted on Lake Claire. A survey made by the lake patrol in the City of Winter Park Police Department showed the estimated number of boats operating at any time of a given day during the week as presented in Table 3 (22). Boating activities during the winter months is approximately one half that of summer months.

Motor boats were used on Lake Claire for research activities after obtaining special permission from the FTU administration.

Morphometric characteristics of the lakes are presented in Table 4 (4). A map showing the Winter Park chain of lakes and the six sampling locations is presented in Figure 1. A topographic map for Lake Claire is shown in Figure 2. The water depth in Lake Claire varies between 4 and 12 feet with an average value of 7.5 feet (17).

The Winter Park chain of lakes are eutrophic and excessive growth of higher aquatic plants such as Hydrilla and Vallisneria extend through the entire depth in several areas of the lakes. Currently, the City of Winter Park is heavily involved in weed control programs through the use of chemicals on the lakes. On the other hand, Lake Claire is an oligotrophic lake and is used for experimentation during the course of this study.

Wekiva Springs in Orange County were used for underwater photography because of the clarity of its water. Pictures were taken to document the process of mixing of the entire water column and the subsequent

Table 3. BOATING ACTIVITIES ON WINTER PARK CHAIN OF LAKES DURING THE SUMMER

LAKE	RANGE IN NUMBER OF BOATS OPERATING ON						
	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Sun.
Mizell	0 - 2	1 - 2	1 - 2	1 - 2	1 - 3	2 - 6	1 - 4
Virginia	2 - 12	2 - 12	2 - 12	3 - 14	3 - 15	5 - 25	4 - 20
Osceola	2 - 12	2 - 12	2 - 12	2 - 12	3 - 15	5 - 18	4 - 16
Maitland	5 - 16	5 - 16	5 - 16	5 - 16	6 - 18	10 - 40	8 - 32

Table 4. MORPHOMETRIC FEATURES OF THE LAKES

LAKES	SURFACE AREA Hectares	DEPTH (Meters)		DRAINAGE AREA Sq. Km	ELEVATION (MSL) Meters	COUNTY	REMARKS
		Maximum	Average				
Mizell	25.1	6.1	4.0	--	20.12	Orange	Streams flowing out of the lake
Osceola	63.5	7.0	4.3	--	20.12	Orange	Streams flowing both in and out of the lake
Maitland	182.7	10.7	4.6	50.0	20.12	Orange and Seminole	Streams flowing both in and out of the lake
Claire	8.1	3.7	2.3	--	19.51	Orange	Landlocked lake

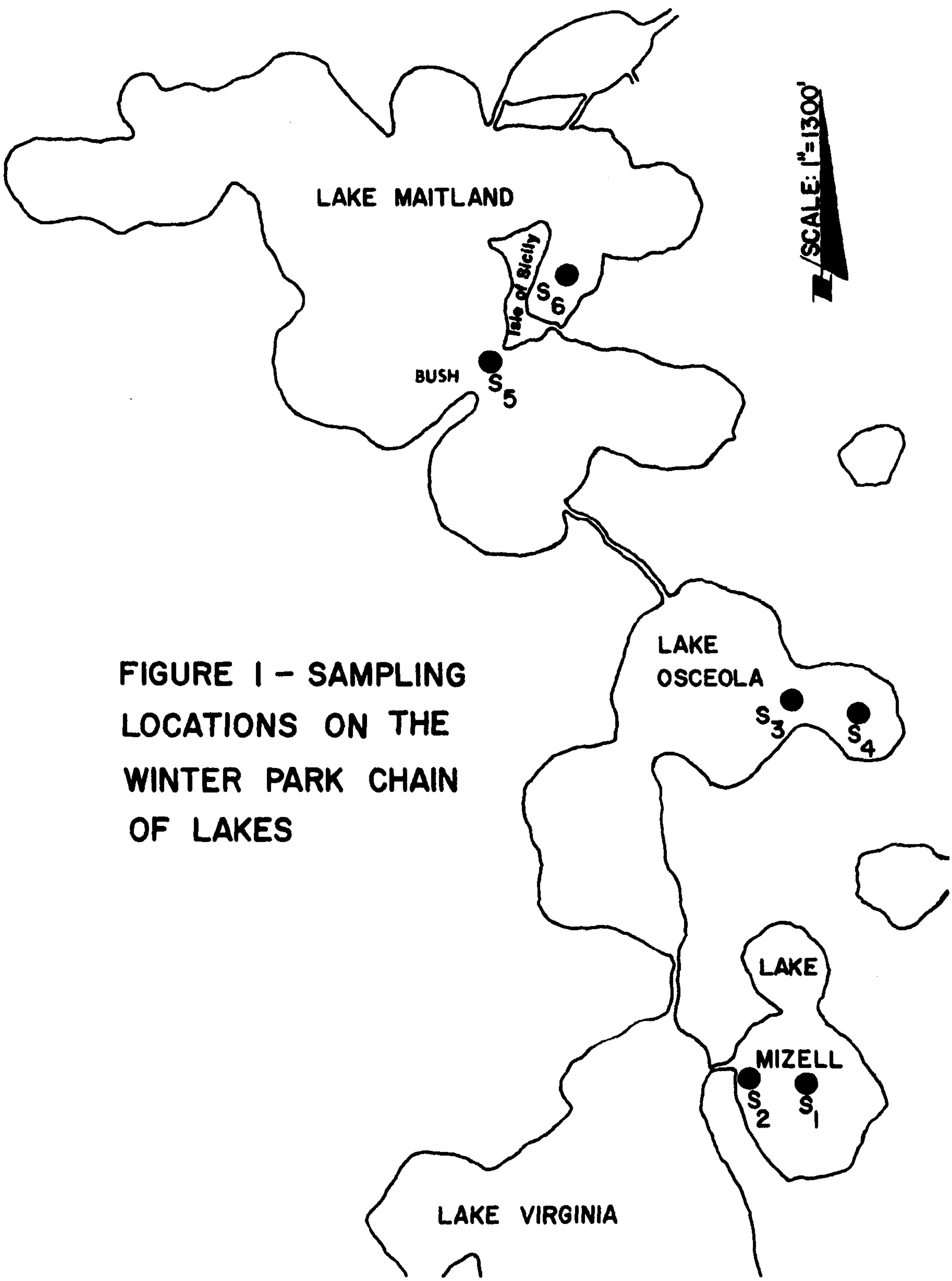


FIGURE 1 - SAMPLING LOCATIONS ON THE WINTER PARK CHAIN OF LAKES

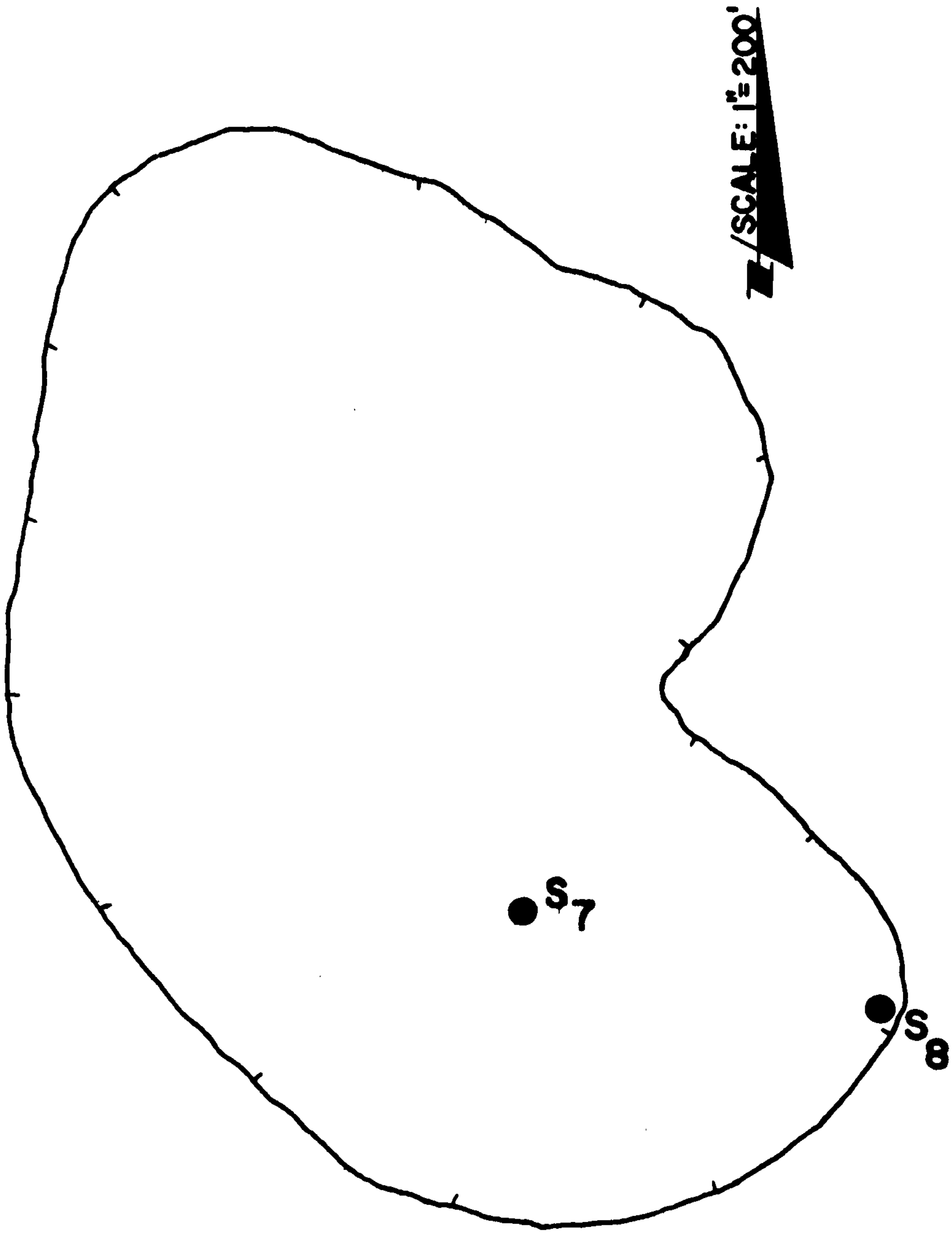


FIGURE 2— SAMPLING LOCATIONS ON LAKE CLAIRE

resuspension of aquatic sediments as a result of running an engined boat.

Description of the test location is presented in Table 5. The test sites are 4 to 35 feet deep (1.2 to 10.7 meters) as shown in Table 5.

Table 5. DESCRIPTION OF TEST LOCATIONS

LAKE	SAMPLING LOCATION	DEPTH	
		Feet	Meters
Mizell	S_1	16	4.9
	S_2	5	1.5
Osceola	S_3	8	2.4
	S_4	18	5.5
Maitland	S_5	8	2.4
	S_6	35	10.7
Claire	S_7	11	3.4
	S_8	4	1.2
Wekiva Springs	--	5-10	1.5-3.0

SECTION V

FIELD STUDIES

The water quality in shallow water bodies are usually affected by diurnal and seasonal variations, environmental conditions and turbulence of water. Probable changes in water quality caused by agitation from motor boats are complex and difficult to isolate from natural conditions. Agitation could influence the dispersion and floatation of plankton, could disturb the benthic organisms, resuspend settled solids, increase turbidity and affect the chemical interactions at the sediment-water interface. The long term effects from intermittent boating activities are not known, however, physicochemical water quality parameters before and after limited boating in shallow lakes (less than 30 feet deep) were evaluated.

EXPERIMENTAL AND ANALYTICAL PROCEDURES

Recreation boats equipped with different size motors were run across the sampling locations from one shore of the test lake to another. Boats were run for limited periods of time and at an estimated speed of 15 to 30 miles/hour (24.14 to 48.28 km/hour). Physico-chemical parameters of the water were monitored at sampling locations before and after boating activity. These parameters included dissolved oxygen (DO), temperature, pH, specific conductance, turbidity, carbon, nitrogen and phosphorus analysis.

The temperature and DO profiles were measured in the field using YSI 54 Oxygen Meter. The membrane electrode was usually calibrated in the laboratory and water samples were collected and fixed in the field to check the calibration of the DO meter. The azide modification of the iodometric method as described in the Standard Methods for the Examination of Water and Wastewater was used to check the calibration (20). A Corning Model 610 Expand Portable pH Meter was also used in the field to measure the hydrogen ion concentration. The Lab-Line Lectro Mho-Meter Model MC-1, Mark IV was used for measuring the specific conductance.

Water samples were collected from various levels in the water column by using a Wildco Water Sampler Model 1220. These samples were preserved and transported to the laboratory according to the EPA Methods for Chemical Analysis of Water and Wastes (16). The turbidity was measured by the Hach 2100 turbidimeter. The Beckman Model 915 Total Organic Carbon Analyzer was used for determination of OC and IC. Colorimetric Techniques as recommended by the Environmental Protection Agency (16) were used for determination of total Kjeldahl nitrogen (TKN), Orthophosphates (OP) and total phosphorus (TP). A Beckman DB-GT Spectrophotometer was used in the colorimetric analysis.

EXPLORATORY STUDIES

In late June and early July 1973, a 100 horsepower outboard engined boat was run for approximately 20 minutes at Lake Mizell, Osceola, and Maitland. The changes in temperature, dissolved oxygen concentrations, pH, turbidity, and nutrients were measured. The water quality analysis before and after boating are shown in Table 6 and Table 7. The results from Lake Mizell showed apparent changes in dissolved oxygen but no apparent changes in turbidity and nutrient concentrations. The location tested in this lake is 16 feet deep. The locations tested on Lake Osceola and Maitland are 6 to 8 feet deep and showed changes in turbidity and nutrient concentrations. Increases in nutrient concentrations were associated with increase in suspended solid concentrations. Changes in dissolved oxygen profiles are shown in Figure 3. It is interesting to notice that Lake Mizell has a very shallow photic zone, less than two feet, and a noticeable decline in dissolved oxygen concentration with depth. However, after agitation, mixing between layers did occur and the DO concentrations were homogenized.

This initial phase of studies was followed by extensive surveys of water quality parameters at various boating time intervals during July and August, 1973, at the Winter Park Chain of Lakes. These lakes are used for recreational activities as indicated in Table 3, and the surveys were planned in order to detect differences in water quality parameters during heavy boating activities. Studies before and after a national holiday (July 4), during week days and on weekends were performed. On these lakes, it was also possible to study the effects of limited boating activities using different power engines and locations on the lakes with different depths.

Boating activities on Lake Claire are not allowed and a special permission was granted to run boats for research purposes starting in September, 1973. Lake Claire is oligotrphic with low pH (about 5.0) and limited aquatic plants. Studies on the lake included changes in water quality parameters at a shore area and mid-width (S_7, S_8). Attempts were also made to evaluate the effect of depth, motor horsepower, elapsed time of operation, and characteristics of resuspended particles. The results and discussion are presented in the following sections.

Table 6. WATER QUALITY DETERMINATIONS BEFORE BOATING ACTIVITY
(100 HP Motor)

LAKE	DATE	TIME	LOCATION	DEPTH FT.	PARAMETER BEFORE BOATING								
					Temp °C	D.O. mg/l	pH	Turb JTU	Carbon mg/l		TKN mg/l N	P mg/l	
									IC	OC		OP	TP
Mizel	July 5	13:30	S_1	1	30.5	8.0	6.8	3.0	11.0	7.2	0.23	.06	0.2
				2		3.0							
				3									
				5	30.0	2.0							
				10	29.0	2.2	6.70	5.0	11.5	7.0		.10	.16
				15		2.0							
Osceola	July 5	14:30	S_3	1	31.0	8.0	7.00	1.8	15.8	3.2	0.25	.05	.14
				5	30.0	9.0	7.00	4.0	15.8	1.8		.08	.21
Osceola	June 26	10:30	S_3	1	28.0	6.5	7.60	1.6	18.9	2.5	0.25	.05	.07
				5	28.0	5.2							
				6	28.0	4.8	7.45						
Maitland	June 26	11:00	S_5	1	28.5	8.0	7.65	1.2	17.3	2.3	0.50	.04	.08
				5	28.5	6.6							
				6	28.5	6.0							
				7									

Table 7. WATER QUALITY DETERMINATIONS AFTER BOATING ACTIVITY

(100 HP Motor)

LAKE	DATE	TIME	LOCATION	DEPTH FT.	PARAMETER AFTER BOATING: Temp °C	D.O. mg/1	pH	Turb JTU	Carbon mg/1 IC	Carbon mg/1 OC	TKN mg/1 N	P mg/1 OP	P mg/1 TP
Mizel	July 5	13:30	S_1	1	30.5	5.5	6.7	2.8	11.0	6.5	0.3	.06	0.2
				2		4.5							
				3		4.5							
				5	30.0	4.0							
				10	29.0	3.5							
				15		2.0							
Osceola	July 5	14:30	S_3	1	31.0	8.1	6.95	7.0	15.0	5.5	0.30	0.2	0.32
				5	30.0	9.0	6.95	8.0	18.0	32		0.42	0.61
Osceola	June 26	10:30	S_3	1	28.5	7.2	7.45	2.1	18.9	2.9	1.0	.08	.10
				5	28	6.9							
				6	28	6.9							
Maitland	June 26	11:00	S_5	1	29	7.8	7.7	4.9	17.0	5.9	3.0	.06	.08
				5	28.5	7.8							
				6									
				7	28.5	8.0							

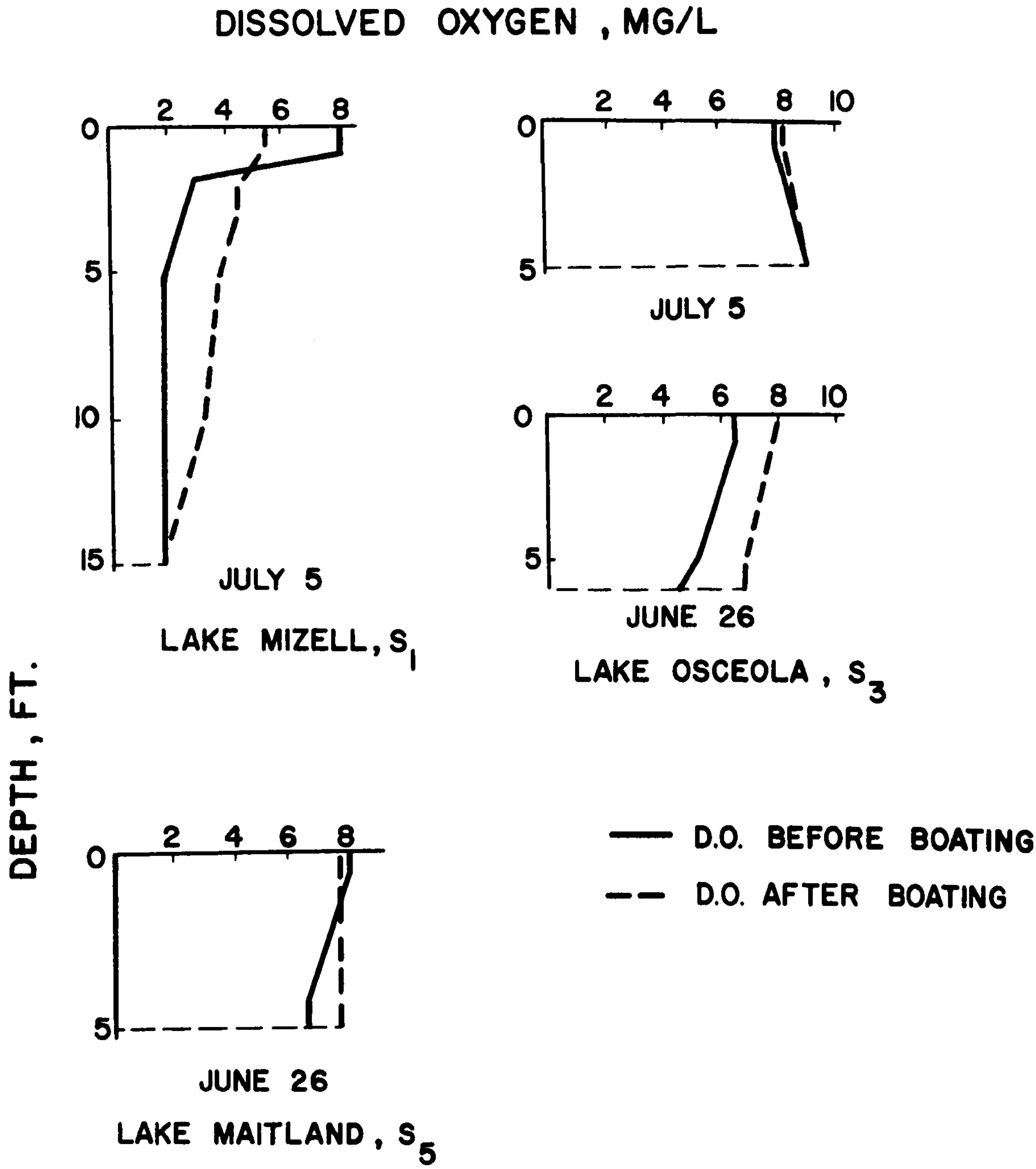


FIGURE 3 - TYPICAL CHANGES IN DISSOLVED OXYGEN PROFILES RESULTING FROM 20 MIN. BOATING ON THE WINTER PARK CHAIN OF LAKES

SECTION VI

DISSOLVED OXYGEN

Oxygen transfer in lakes from the atmosphere attributed to motor boats is influenced by turbulence, oxygen saturation deficit, and eutrophic stage of the lake. The turbulence created is a function of motor power, speed, and boat characteristics such as weight and position, depth, and dimensions of the propellor. In shallow, eutrophic lakes where stratification and hypolimnion dissolved oxygen depletion exist, mixing between layers occur and may result in considerable reduction of dissolved oxygen in the upper layers. The dissolved oxygen level changes will depend on the operation time of the boat and lake conditions. Also, in a non-stratified lake with oxygen levels close to saturation, relatively small amounts of oxygen would be transfered to the water. Changes in oxygen balance due to agitation in lakes are not defined.

THE WINTER PARK CHAIN OF LAKES

In the Winter Park Chain of Lakes, there was an increase in dissolved oxygen as noted in the profiles on days of heavy boat traffic as compared to days with less boating activity. This tendency was supported by oxygen profiles taken before and after July 4, on weekends, and during week days. However, natural variation could not be determined within the scope of this study.

Figures 4 to 7 indicate dissolved oxygen and temperature profiles on Lakes Mizell, Osceola, and Maitland in the period from June 26 to July 31, 1973. All the profiles were measured in the afternoon hours between 13:00 and 16:00 pm. The shallowness of these lakes suggests that thermal stratification should be unimportant and indeed most of them do not exhibit the classical thermoclines with stagnant hypolimnia. Only the deep holes in the bay area of Lake Maitland are sufficiently deep to develop stable stratification and oxygen deficient bottom waters as observed in sampling location S_6, Figure 7.

Figure 4 shows that the dissolved oxygen profiles for Lake Mizell measured on July 5, 1973, exhibit lower dissolved oxygen concentrations as compared to profiles measured on June 26 or July 17. This phenomenon is specific for Lake Mizell and in contrast to profiles measured on Lake Osceola and Lake Maitland where the profiles were higher during the same period of time as indicated in Figures 5 and 6. Lake Mizell differs morphometrically from other lakes in the Winter Park Chain of Lakes. It is the smallest and is located upstream of the other lakes as indicated by the map in Figure 1. Also Lake Mizell has a very shallow photic zone and the dissolved oxygen concentration decline rapidly with depth as shown in Figure 3.

It must be realized that the dissolved oxygen profiles taken on July 5 across the water column of Lakes Mizell, Osceola and Maitland were measured after

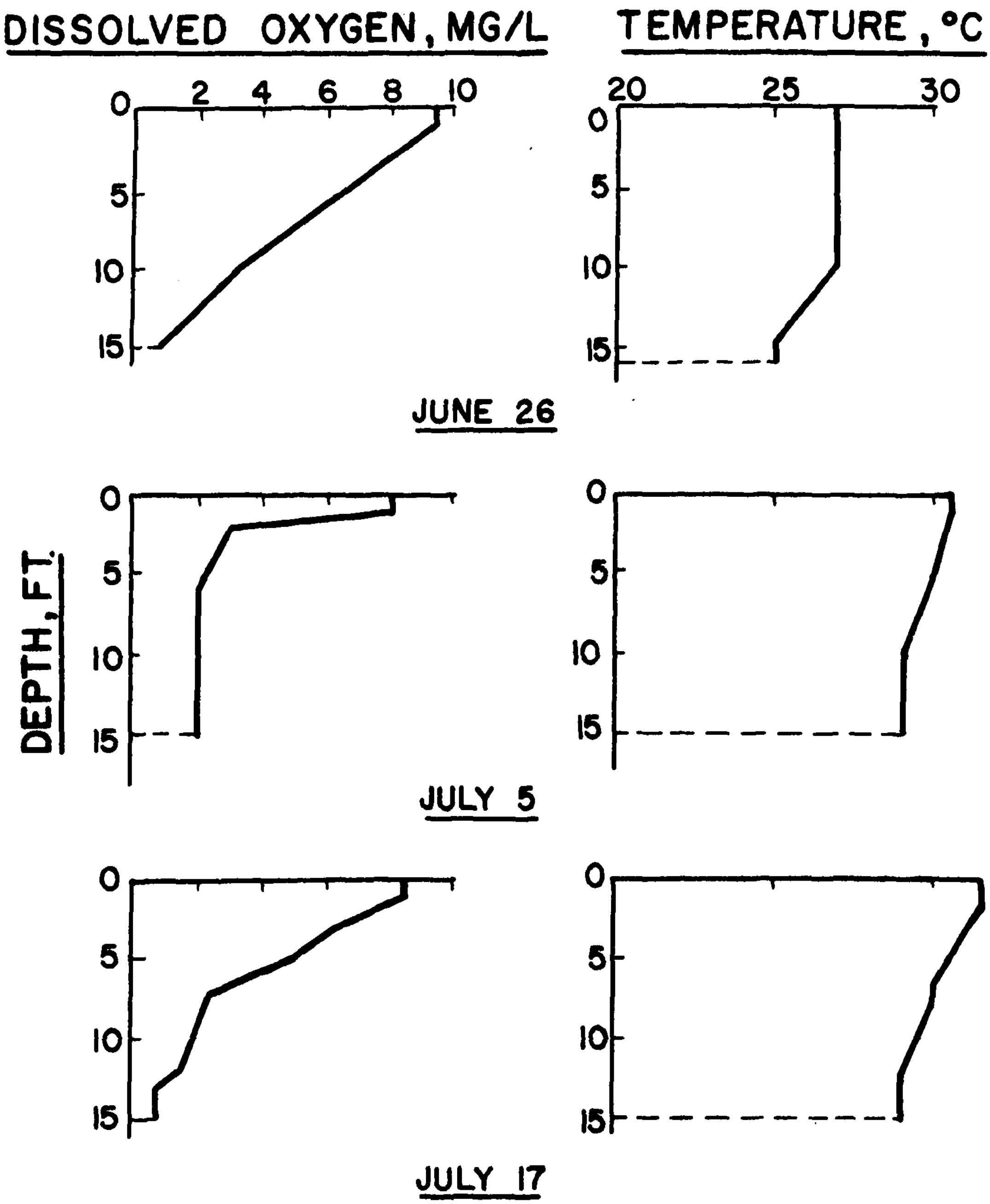


FIGURE 4. – DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE MIZELL AT S_1

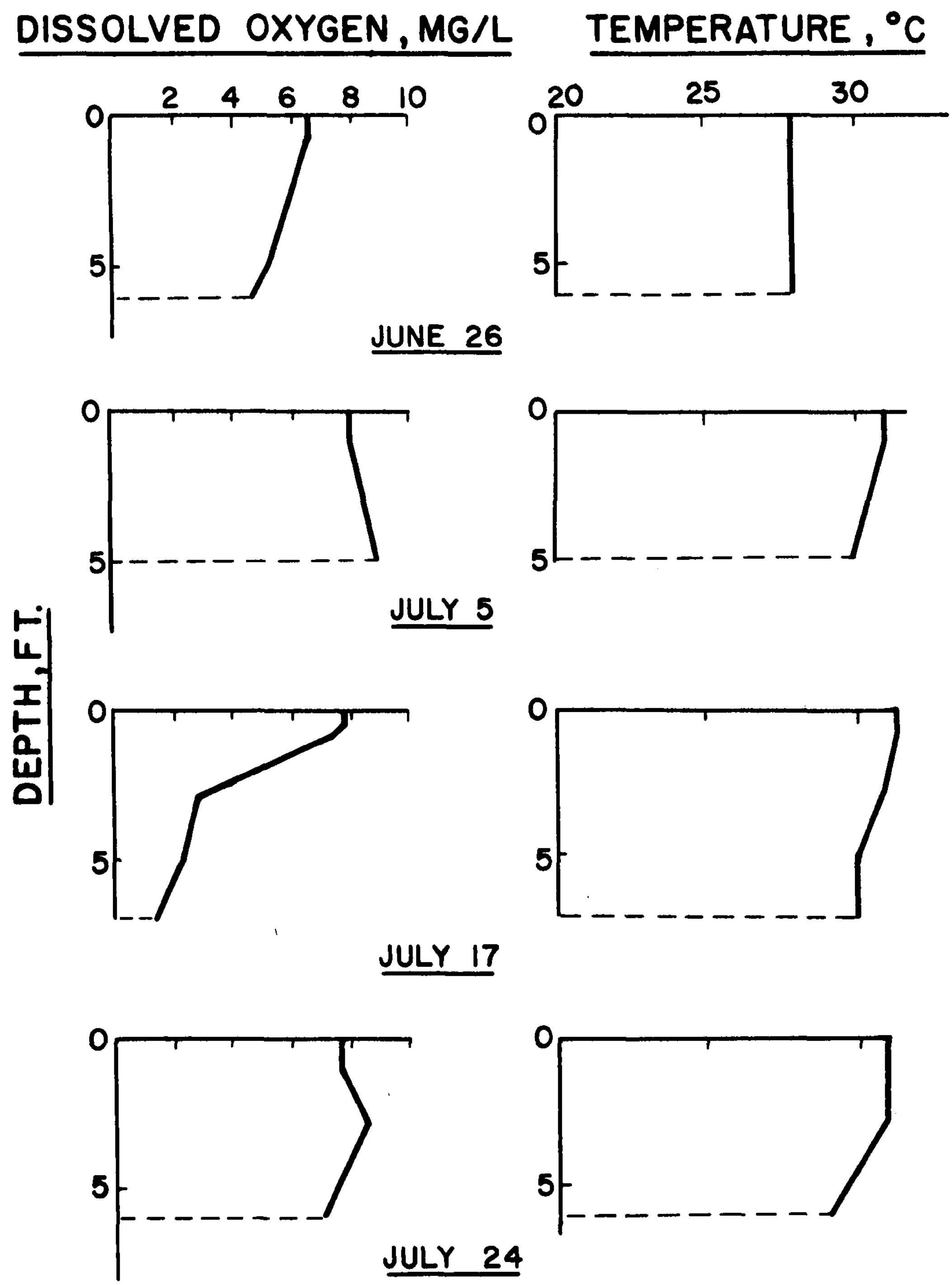


FIGURE 5. —DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE OSCEOLA AT S_3

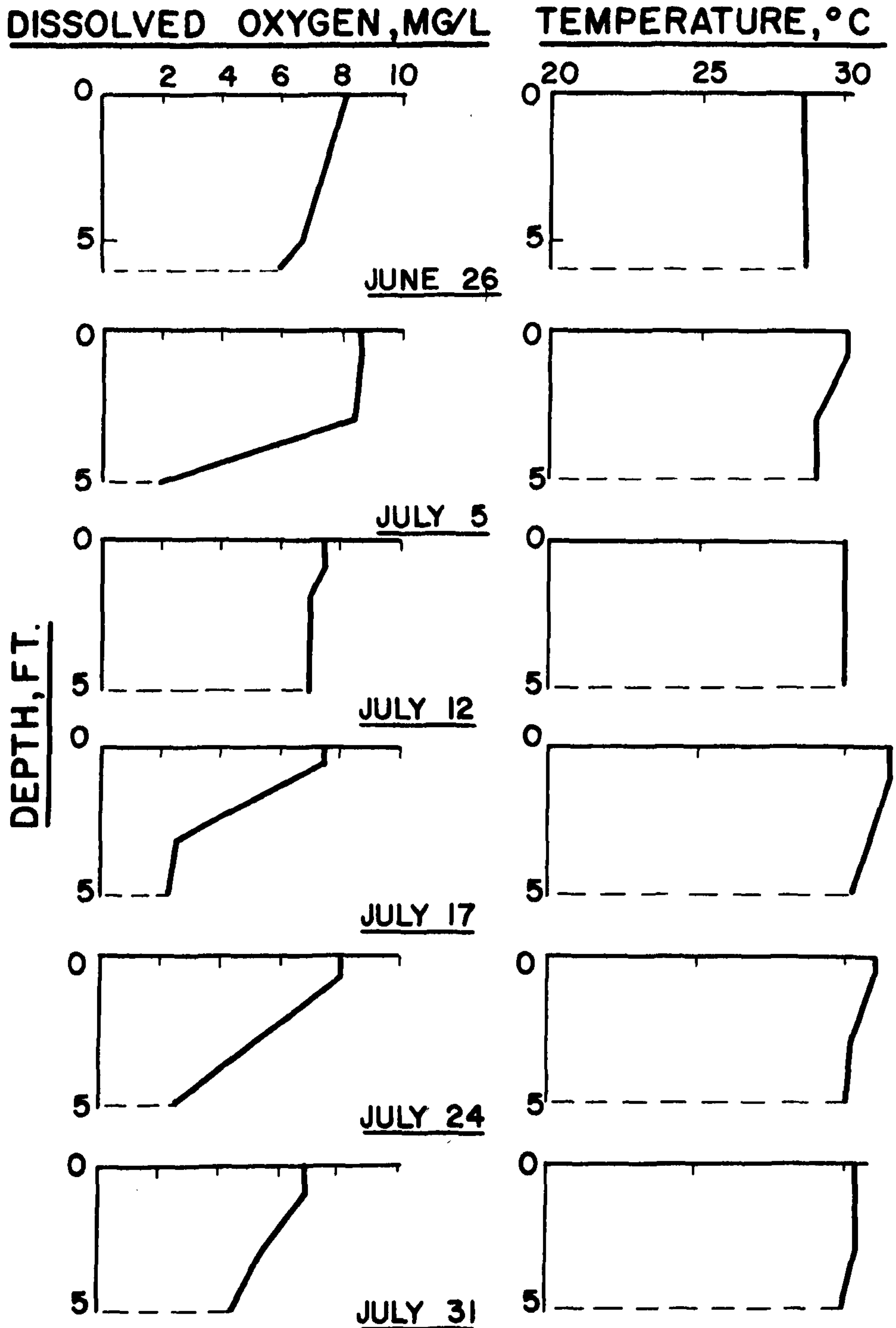


FIGURE 6. — DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE MAITLAND AT S_5

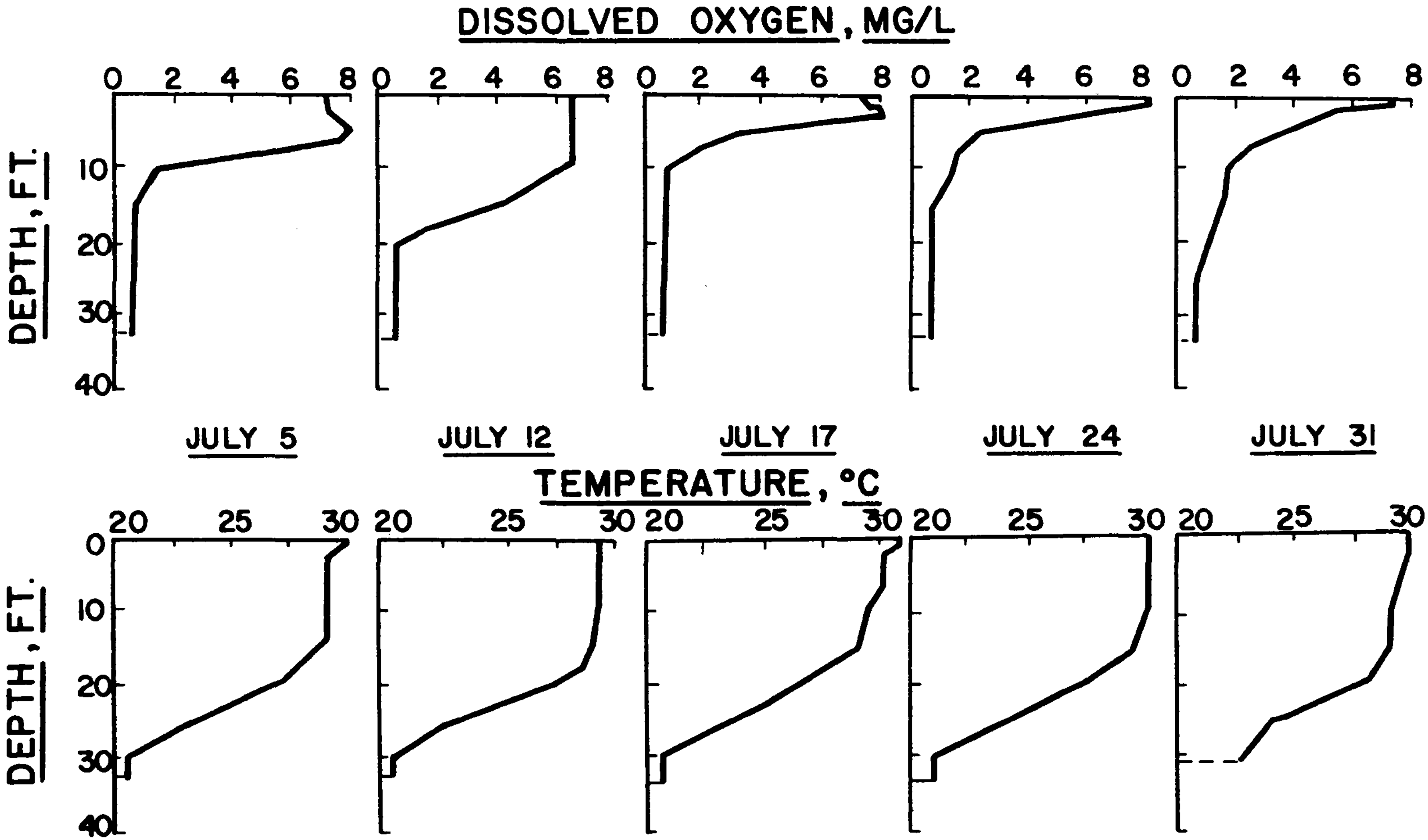


FIGURE 7. — DISSOLVED OXYGEN AND TEMPERATURE PROFILES ON LAKE MAITLAND AT S_6

heavy boating activities on July 4 which is a national holiday. It is also believed that the boating activity was responsible for the increase in dissolved oxygen concentrations on Lakes Osceola and Maitland. Boating activities can increase the dissolved oxygen concentration and tend to homogenize the dissolved oxygen between layers as indicated from Figures 3, 4, 5, 6. It is interesting to notice that changes in dissolved oxygen concentrations following motorboat activity can be noticed through an estimated depth of 15 feet (4.6 meters).

Dissolved oxygen and temperature profiles for Lakes Mizell, Osceola, and Maitland during the month of August are presented in Tables 8 to 13. It is noteworthy that although the dissolved oxygen concentration at Lake Mizell on Sunday, August 5, at 15:00 had increased in the upper three feet, the lower layers had decreased as compared to readings taken at 11:30 am on the same day. This evidence indicates that mixing between the lower layers is responsible for the reduction in DO concentrations. The same phenomenon was repeated on Saturday, August 11, in the afternoon. On Sunday, August 19, the lake was stirred up for 90 minutes using a 260 inboard motor boat and the DO level showed an increase through the entire profile of the lake. The same general trend was observed at Lake Osceola, where dissolved oxygen concentrations in the lower layers were lower in the afternoon hours, unless heavy boating traffic would offset the difference.

The data presented in Tables 11, 12, and 13 suggest that boating activities in shallow lakes may have no noticeable effects on temperature profiles.

LAKE CLAIRE

Typical dissolved oxygen profiles at Lake Claire following limited boating activity is shown in Figure 8. The solid lines represent the DO profiles before boating while the dotted lines represent the DO profiles after boating. In general there was an increase in DO concentration across the entire section of the lake. It is also important to note that temperature changes due to boating were undetectable.

On September 18, 19, and 20 the temperature varied between 28 and 30^{o}C across the entire section of the lake. On November 24, the temperature varied between 22.5 and 20.5^{o}C while it was 13 to 13.5^{o}C on December 21. On November 24, it can be roughly estimated that 1.21 mg/1 O_2 was added to the deeper section of the lake, while 4.45 mg/1 was added to the shore area. In other words, an average of 2.83 mg/1 O_2 was added due to boating for 90 minutes using a 28 HP engined boat. Based on these calculations, an average increase in dissolved oxygen concentration of 1.9 mg/1/hour of operation was added to the lake. It is obvious that the oxygen deficit and depth are important parameters in the oxygen transfer.

Using the same approach, it is possible to calculate the DO increase at Lake Mizell following 20 minutes of boating by a 100 HP engined boat,

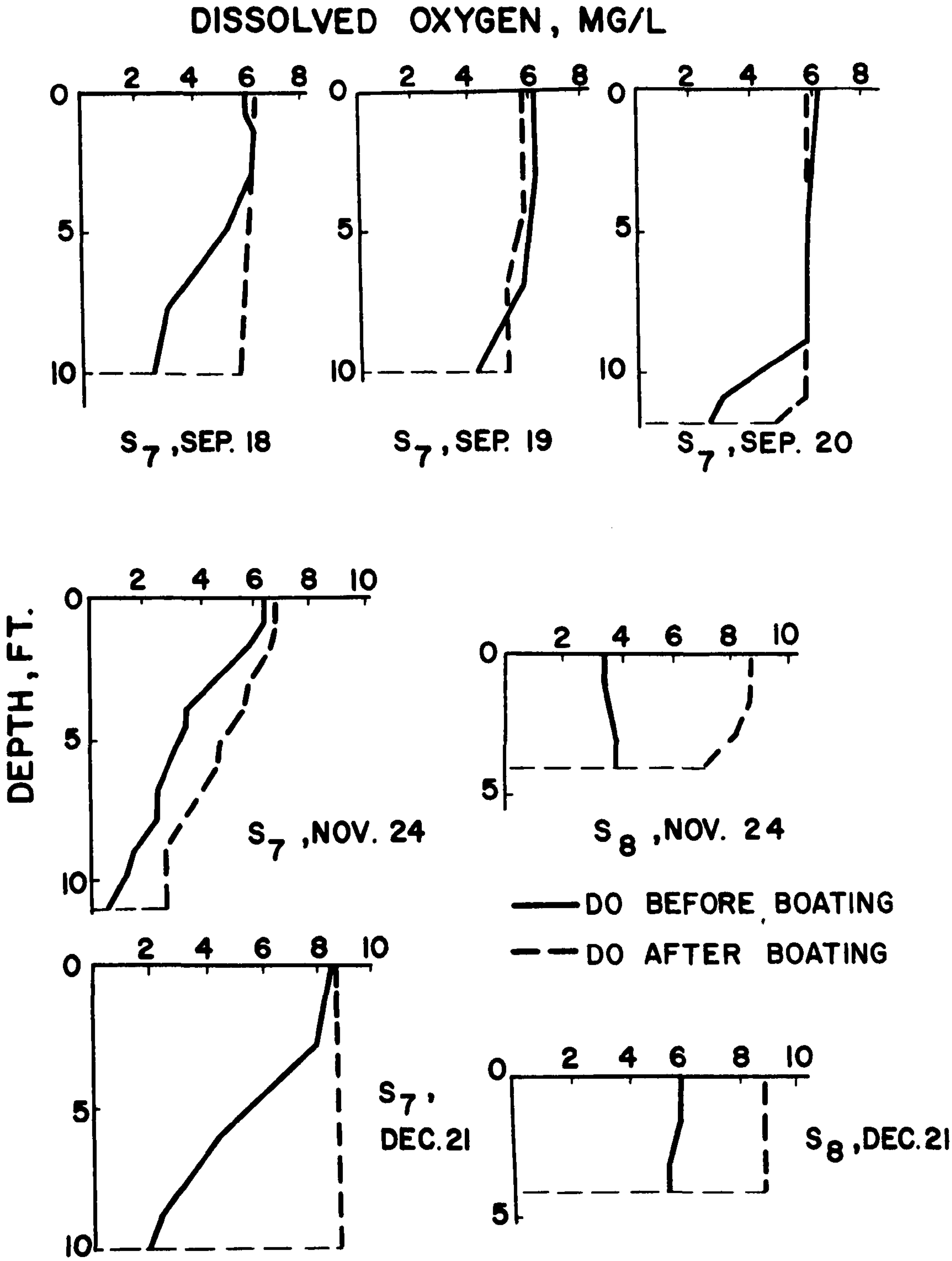


FIGURE 8 – CHANGES IN DISSOLVED OXYGEN PROFILES ATTRIBUTED TO LIMITED BOATING ON LAKE CLAIRE

Table 8. DISSOLVED OXYGEN PROFILES AT LAKE MIZELL DURING AUGUST 1973

LOCATION	DEPTH ft	DISSOLVED OXYGEN (mg/1)											
		8/05		8/06	8/07	8/11		8/14	8/16	8/19		8/20	8/21
		11:30 hrs	15:00 hrs	17:00 hrs	13:30 hrs	9:00 hrs	16:00 hrs	13:30 hrs	14:00 hrs	9:00 hrs	14:30* hrs	11:00 hrs	13:30 hrs
S_1	1	8.4	8.7	9.6	8.6	8.2	6.7	8.8	8.1	8.0	8.6	8.0	8.7
	2								7.9				
	3	8.3	8.0	9.8	7.2	8.0	4.5	8.2		7.9	8.6	8.1	8.7
	5	8.1	3.8	9.8	6.1	7.8	3.5	8.2	8.1	7.4	8.6	8.0	8.7
	7							7.7	8.0	6.9	8.6	6.9	8.3
	8	7.5	3.8	6.4	4.6	6.8	2.7	6.3	7.7				
	9								6.9			5.7	6.6
	10	5.4	3.3	3.6	3.7	6.0	2.3	3.8	4.3	5.1	6.7	4.7	5.4
	11	3.2	3.1			4.3	1.6		2.7	3.9		3.7	5.4
	12	2.4	2.8	0.6	2.3	1.4		1.5	0.5	0.7	3.7	2.1	1.9
	13	2.1	1.8		0.6	0.3		0.5		0.5	3.1	0.4	1.1
	14												
	15	0.2	0.9	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.5	0.3	0.2
	20		0.6										

* The lake was stirred up by a 260 H.P. motor engined boat for 1.5 hours.

Table 9. DISSOLVED OXYGEN PROFILES AT LAKE OSCEOLA DURING AUGUST 1973

LOCATION	DEPTH ft	DISSOLVED OXYGEN (mg/1)											
		8/05		8/06	8/07	8/09	8/11		8/14	8/19		8/20	
		10:30 hrs	16:30 hrs	15:00 hrs	15:00 hrs	15:00 hrs	10:00 hrs	16:30 hrs	14:00 hrs	10:00 hrs	15:00 hrs	11:00 hrs	14:00* hrs
S_3	1	8.4	8.6	8.5		9.0	8.1	8.6	8.6	7.8	9.0	8.7	9.6
	2												
	3	8.4	8.5	8.4		8.6	8.0	7.3	8.4	7.2	9.2	8.5	9.3
	4												
	5	8.1	6.0	8.2		8.7	7.5	6.4	8.2	7.6	9.3	8.7	9.7
	6					8.1		6.0					
	7		5.3	6.0			6.8	5.6		7.8	8.3	8.4	8.6
	8	8.0	4.9				6.6	4.7	7.1	7.8	8.3	8.3	8.2
	9									7.1			
	10	3.9								6.5			
S_4	1	7.7	8.5	8.5	7.8	8.5	8.4	8.9	8.3	8.3	9.2	9.8	9.7
	3	7.6	8.5	8.4	7.4	8.2	8.2	8.4	8.4	8.3	9.2	9.6	9.7
	5	7.6	8.5	9.1	6.7	8.0	7.8	7.3	8.0	8.2	9.2	9.0	9.7
	7							6.3		7.7	9.2	8.7	8.4
	8	7.1	8.1	8.5	5.7	7.1	7.2	5.5	7.1		8.2		8.3
	10	6.4	7.6	6.0	5.0	6.7	6.4	4.6	6.5	7.1	8.1	7.5	7.8
	12						4.6	2.9	5.0	5.7	7.1	4.9	6.8
	13	3.6	6.8	4.4	4.4	5.8	3.0				6.6	3.1	5.5
	14									4.1	0.8	1.0	4.1
	15	2.9	6.2	3.0	1.8	0.2	0.8	0.8	0.3	0.3	0.3	0.3	0.3
	16						0.2	0.2					
	17	2.3	3.6		1.2		0.2	0.2		0.3	0.3	0.3	
	18		2.6	1.7	0.2	0.2							
	20								0.2				

* Lake is stirred up for 45 minutes by a 260 H.P. motor engined boat.

Table 10. DISSOLVED OXYGEN PROFILES AT LAKE MAITLAND DURING AUGUST 1973

LOCATION	DEPTH ft	DISSOLVED OXYGEN (mg/l)											
		8/05		8/06	8/07	8/09	8/11		8/14	8/19		8/20	
		9:30 hrs	17:00 hrs	16:00 hrs	14:30 hrs	14:30 hrs	10:00 hrs	17:00 hrs	15:00 hrs	10:00 hrs	16:00 hrs	11:30 hrs	15:00* hrs
S_6	1	6.8	7.1	8.2	6.0	6.2	6.2	6.9	6.5	6.3	6.8	7.1	7.7
	3	6.6		6.9	5.8	5.7	6.0	6.3	6.2	6.3	6.7	7.0	7.6
	5	6.6	6.9	6.0	5.7	5.7	5.6	5.3	6.3	6.4	6.6	7.0	7.6
	7	6.8	6.7	5.0	5.3	5.6	5.0	4.5	6.1	6.4	6.1	6.7	7.7
	10	5.9	6.4	3.7	4.5	5.3	4.6	4.1	6.1	6.8	6.2	6.6	7.1
	12		5.4	2.2	4.0	4.5	4.0	3.3	5.3	5.4	5.4	6.0	6.5
	15	5.0	5.0	1.5	2.8	3.5	2.7	3.3	3.9	1.9	2.9	3.1	4.1
	18	3.8				2.2	1.4	2.7	1.2	0.7	0.7	0.3	0.6
	20	2.8	2.7	1.2	1.4	1.3	0.8	1.7	0.3	0.2	0.2	0.2	0.3
	22	0.3					0.3	0.8					
	25	0.1	0.2	0.7	0.3	0.2	0.2	0.6	0.2	0.2	0.2		
	28	0.1											
	30	0.1	0.2	0.5	0.2	0.3	0.2	0.3	0.1	0.2	0.2	0.2	0.2
S_5	1	7.2	8.2	8.5	7.6	8.2	7.2	8.4	8.0	7.4	8.8	8.8	9.5
	3	7.2	8.2	8.4	8.0	7.5	6.9	7.6	8.0	7.4	8.5	8.3	9.3
	5	6.6	8.1	8.2	8.5	7.5	6.4	7.1	8.1	7.3	8.5	8.2	9.3
	6				8.4		5.9	6.9		7.2	10.0	9.0	9.0
	7	7.0	7.7	6.0		7.7			7.6		9.5	9.0	7.9

* Lake is stirred up for 45 minutes by a 260 H.P. motor engined boat.

Table 11. TEMPERATURE PROFILES AT LAKE MIZELL DURING AUGUST 1973

LOCATION	DEPTH ft	TEMPERATURE °C											
		8/05		8/06	8/07	8/11		8/14	8/16	8/19		8/20	8/21
		11:30 hrs	15:00 hrs	13:30 hrs	17:00 hrs	9:00 hrs	16:00 hrs	13:30 hrs	14:00 hrs	9:00 hrs	14:30* hrs	11:00 hrs	13:30 hrs
S_1	1	29.0	31.0	30.0	30.5	29.2	30.5	31.0	31.0	29.5	30.5	30.0	30.4
	2												
	3	29.0	30.5		30.0	29.2	30.5	30.5	31.0	29.5	30.5	30.0	30.2
	5	29.0	29.5	30.0	29.0	29.2	30.5	30.0	30.2		30.0	30.0	29.8
	7										30.0		
	8			28.5				29.5	30.0		30.0		
	9	28.5	28.5			29.0	30.0	29.5	30.0			29.5	
	10			28.0	29.0			29.0	29.7				29.7
	11	28.5	28.5			29.0	29.5	29.0	29.3	29.5	29.5	29.0	
	12			28.0	28.5	29.0	29.0	29.0	29.0				
	13	28.5	28.5		28.0			28.5	29.0	29.0	29.0	29.0	
	14	28.0	28.0			28.5			29.0			28.5	
	15	28.0	28.0	27.5	27.5	28.0	28.5	28.0	28.5	28.5	28.5	28.0	
	20		28.0										

* The lake was stirred up by a 260 H.P. motor engined boat for 1.5 hours.

Table 12. TEMPERATURE PROFILES AT LAKE OSCEOLA DURING AUGUST 1973

LOCATION	DEPTH ft	TEMPERATURE °C											
		8/05		8/06	8/07	8/09	8/11		8/14	8/19		8/20	
		10:30 hrs	16:30 hrs	15:00 hrs	15:00 hrs	15:00 hrs	10:00 hrs	16:30 hrs	14:00 hrs	10:00 hrs	15:00 hrs	11:00 hrs	14:00* hrs
S_3	1	29.0	29.5	30.0		31.0	29.0	30.5	31.0	29.5	31.0	30.0	31.0
	2												
	3	28.5	29.5	30.0		30.5	29.0	30.0	30.5	29.5	31.0	30.0	31.0
	4												
	5	28.5	29.5	28.5		30.0	29.0	30.0	30.5	29.5	30.5	29.5	30.0
	6					29.5		30.0					
	7			28.5			29.0	29.5		29.5	29.5	29.5	29.5
	8	28.0	29.0				29.0	29.0	29.5				
	9												
	10								29.5				
S_4	1	29.0	30.5	30.0	30.5	31.0	29.0	30.5	20.5	29.5	31.0	30.0	30.0
	3	29.0	30.0	30.0	30.0	30.0		30.5	30.0	29.5	30.5	30.0	30.0
	5	28.5	29.5	29.5	29.5	29.5	29.0	30.0	29.5	29.5	30.5	30.0	30.0
	7									29.5	30.0	29.7	30.0
	8	28.5	29.0	29.0	29.0	29.2		30.0	29.0				
	10	28.5	29.0	28.5	29.0	29.0	29.0	29.5	29.0	29.0	29.5	29.2	29.5
	12												
	13	28.0	29.0	28.0	29.0	28.5	29.0	29.0	29.0	29.0	29.0	29.0	29.0
	14												
	15	28.0	29.0	28.0	28.5	28.3	28.5	28.5	29.0	29.0	29.0	29.0	29.0
	16												
	17	28.0	28.5	28.0	28.5		28.5	28.0					
	18		28.5	28.0	28.0	28.0							
	20								27.5				

* Lake is stirred up for 45 minutes by 260 H.P. motor engined boat.

Table 13. TEMPERATURE PROFILES AT LAKE MAITLAND DURING AUGUST 1973

LOCATION	DEPTH ft	TEMPERATURE °C											
		8/05		8/06	8/07	8/09	8/11		8/14	8/19		8/20	
		9:30 hrs	17:00 hrs	16:00 hrs	14:30 hrs	14:30 hrs	10:00 hrs	17:00 hrs	15:00 hrs	10:00 hrs	16:00 hrs	11:30 hrs	15:00* hrs
S_6	1	28.5	29.5	29.5	30.5	30.5	29.0	30.0	30.5	29.5	30.5	30.0	30.5
	3			29.0	29.5	30.0	29.0	30.0	30.0				
	5		29.0	29.0	29.0	29.5	29.0	29.8	29.8	29.5	30.5	30.0	30.5
	7		29.0	29.0	29.0	29.2	29.0	29.5	29.5	29.5	30.0	30.0	30.5
	10	28.5	28.5	28.5	29.0	29.0	29.0	29.2	29.2	29.5	29.5	29.5	30.5
	12		28.5	28.5	29.0	29.0	29.0	29.0	29.0	29.5	29.0	29.5	30.0
	15	28.0	28.0	28.0	28.5	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.2
	18					28.0	28.0	29.0	28.5	29.0	29.0	29.0	29.0
	20	28.0	28.0	26.5	28.0	27.5	27.8	28.2	28.0	28.0	27.5	28.0	28.0
	22	26.5					26.0	26.5					
	25	25.0	24.0	24.0	24.0	24.0	24.5	24.5	24.5	24.5	24.5	25.8	24.7
	28	22.0											
	30	21.5	21.5	23.0	21.0	20.5	22.0	22.5	21.5	23.0	23.0	25.1	24.5
S_5	1	29.0	29.5	29.5	30.0	30.5	29.0	30.0	31.0	29.5	31.0	30.0	31.0
	3	29.0	29.5	29.5	30.0	30.0			30.0	29.5	31.0	30.0	
	5	29.0	29.5	29.0	29.5	30.0				29.5	31.0	30.0	31.0
	6				29.5		29.0	30.0		29.5	30.5		
	7	29.0	29.0	29.0		29.5			30.0		30.0	30.0	30.2

* Lake is stirred up for 45 minutes by a 260 H.P. motor engined boat.

Figure 3. The average increase in DO through the entire depth is 1.07 mg/1 which is equivalent to 3.21 mg/1/hour of boating activity.

The dissolved oxygen emissions in the exhaust gas constituents and mass emissions retained in water phase for four outboard motors were measured in recent studies (7). These emissions are dependent on the mode of operation and the maximum values varied between 1560 grams of O_2 per hour of operation for a 4.0 HP motor and 17700 grams per hour for a 65 HP motor. Using the same approach, it is possible to predict the transfer efficiency of O_2 to the water phase. However, it is beyond the scope of this report.

In brief, dissolved oxygen is transferred to the water body from the atmosphere and the exhaust gas during the operation of engined boats on lakes. The rate of transfer is dependent on turbulence created by boat, motor power, water depth and oxygen deficit. It is also believed that boating activity tends to increase the rate of oxygen uptake by resuspended organic particles. This increase was responsible for the decrease in DO concentrations in the lower levels at Lake Mizell on weekends and following heavy boating activities as shown from Table 8.

SECTION VII

RESUSPENSION OF SEDIMENTS

Aquatic sediments are accumulated deposits of settleable and colloidal organic solids which are permanently water logged and continuously regenerated by deposition. In shallow, small lakes, the sediments are formed largely from material brought in from the shoreline, surrounding swamps, and drainage basins. However, in deeper and large lakes, the deposits are produced from dead planktonic organisms and organic material (9).

Sediments as a pollutant and as a transporting agent are found to play a predominant role in determining the quality of surface waters (15,21). Settled or suspended sediments may serve as a sink or source for nutrients and other contaminants. The exchange of elements and compounds at the water-sediment interface is affected by various physical, chemical, and biological factors. Investigators found that the influence of bottom sediments on overlying water quality becomes significant only when the dissolved oxygen concentration at the water sediment interface falls below 1 or 2 mg/l causing a corresponding decrease in electrode potential in the upper few millimeters of sediment (14). Substantial quantities of phosphate, silicate, and ammonia along with other elements such as manganese and iron are liberated at lower electrode potentials. Nutrient flux from the sediments of two lakes was investigated and concluded that 15 to 30 percent of the four major cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) in lake water resulted from the sediments (14). Also, the release of organic compounds and nutrients such as phosphates and ammonia could be retarded by maintaining a minimum dissolved oxygen concentration of 2 mg/l in the overlying water (2).

Aquatic sediments and detritus consume oxygen when stirred in aerated water. Oxygen uptake by thin layers of subsurface sediment show varying proportions of chemical and biological oxygen consumption. The oxygen consumption per unit weight is affected by particle size, nature and amount of organic material, size and metabolism of microorganisms associated with the sediments, and detritus particles (8). Studies in Denmark concluded that detritus consumed up to three orders of magnitude more oxygen per dry weight than sand, and uptake rates were inversely related to particle diameter and directly related to the particle organic content. The particulate oxygen uptake rate fell between 0.1 and 10 mg O_2/gm organic matter/hour (8). These effects of agitation from mixing by boating have not been investigated.

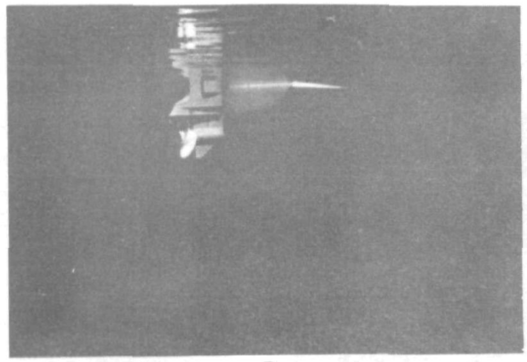
LAKE SEDIMENTS AFTER BOATING ACTIVITY

In shallow eutrophic lakes, outboard motor boats seem to resuspend those sediments previously deposited on aquatic plant leaves, stems, and on the lake bottom. Resuspension of these sediments is affected by water depth, particle size and composition, motor power, boat characteristics, and condition of the lake.

Areas close to shoreline, particularly those areas with less than 5 feet of water depth and loose detritus and sludge deposits, show rapid changes in turbidity due to boating activities.

Limited boating activities on Winter Park Chain of Lakes, Lake Claire, and Wekiva Springs were conducted. Changes in turbidity measurements, size of particles in suspension, and resuspension of bottom sediments have been investigated. However, the effect of agitation attributable to boating activity on relocation or changes in benthic organisms have not been studied. It is also interesting to note that motor boats will chop up aquatic plants which may result in their dispersion over the entire area of the lake and facilitate their transport from one lake to another if vegetative reproduction is a part of the species life history.

A series of underwater photographs were taken to demonstrate the process of resuspension of sediments by a 50 HP motor boat at Wekiva Springs, Figures 9, 10 and 11. Wekiva Springs was selected because the high clarity of its water made photography feasible. The pictures show a series of exposures before and during motor activity. It was visibly noticeable that sediments were resuspended from plant leaves, stems and bottom deposits. The water depth varied between 4 and 8 feet and aquatic plants extend from bottom to top in many areas of the springs. Preliminary studies showing changes in turbidity and particle size of suspended solids were performed. The turbidity increased from 2.3 to 4.5 and 6.5 JTU after operating a 50 HP motor boat in the springs for 15 minutes. Figure 9 presents various pictures showing the clarity of water at Wekiva Springs, the size of motor used and shape of the plumes produced by running the boat. The plume is shown by a conical shape with a narrow angle. The magnitude and extent of its influence on the water body is not known. Figure 10 shows a series of pictures demonstrating the resuspension of bottom sediments attributed to boating activity at Wekiva Springs. A cloud of bottom sediments tend to resuspend and then moves away or partially resettle as the boat leaves the area. Figure 11 shows a closer exposure to the propeller, plume and bubbles formed. It would have been interesting if these pictures were extended for a number of engine, propeller, hull and speed combinations to better understand the turbulence induced by motor boat activity. Figure 11 presents a series of photographs showing the shape of the plume produced from operation of the propeller attached of a 50 HP motor boat and the subsequent mixing process at the Wekiva Springs.



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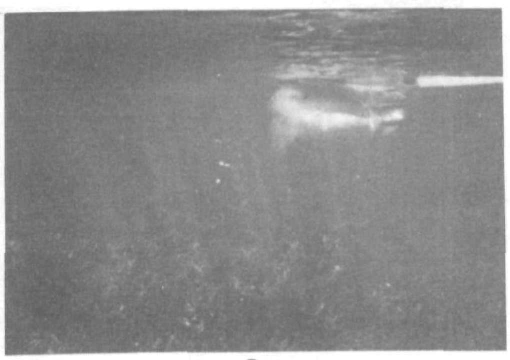

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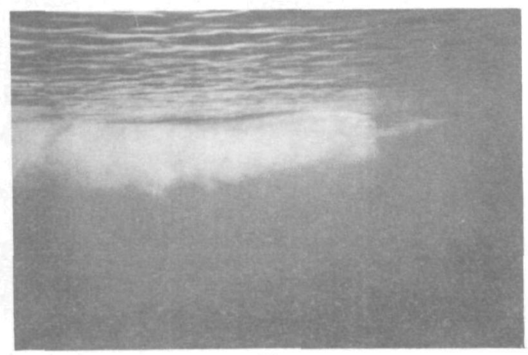

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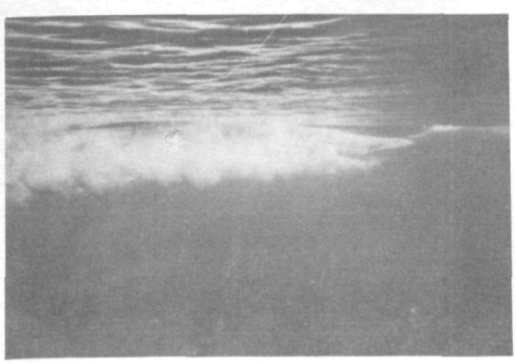

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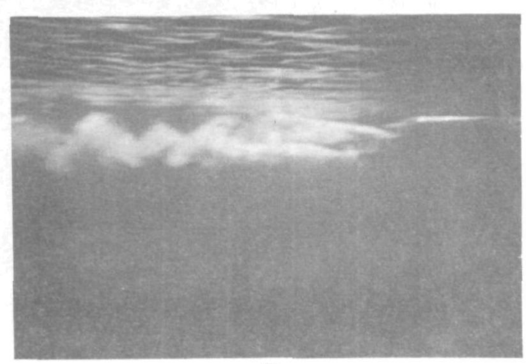


5

Figure 9. PHOTOGRAPHS BEFORE AND AFTER OPERATION OF A 50 H.P. MOTORBOAT ON WEKIVA SPRINGS.

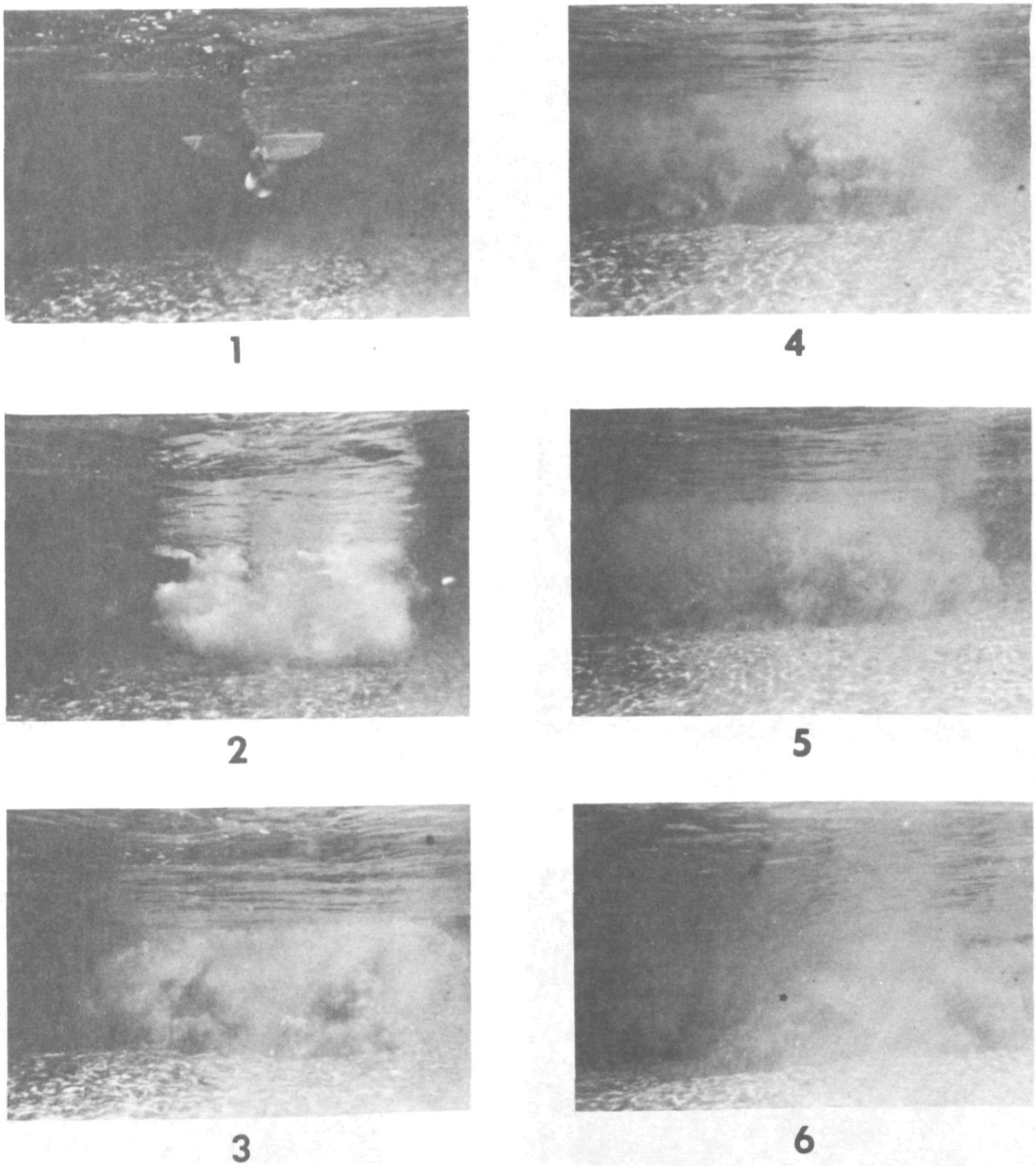


Figure 10. PHOTOGRAPHY DEMONSTRATING RESUSPENSION OF BOTTOM SEDIMENTS FROM OPERATION OF A 50 H.P. MOTORBOAT.

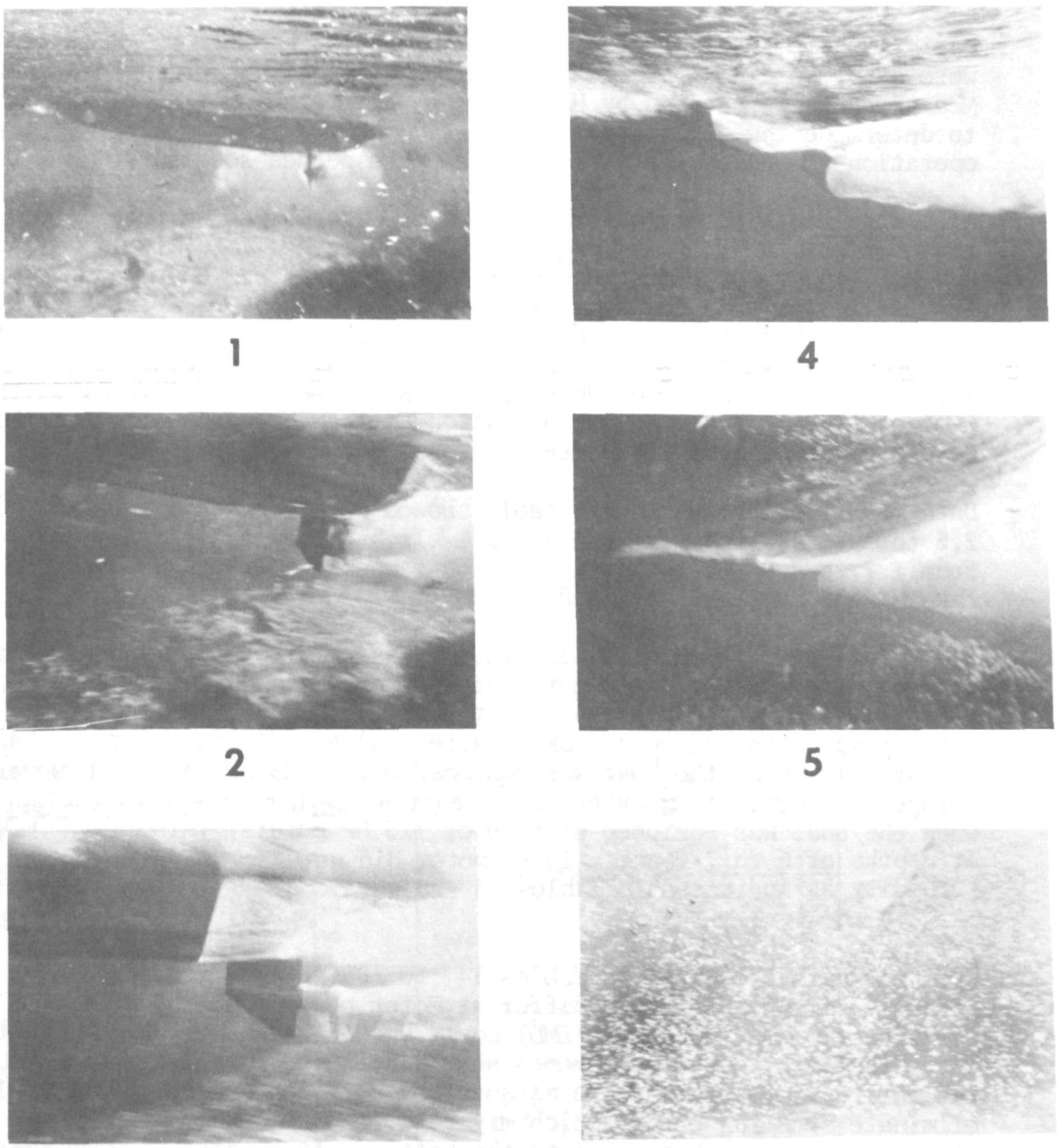


Figure II. PHOTOGRAPHS SHOWING THE PLUME FORMATION AND MIXING PROCESS FROM OPERATION OF A 50 H.P. MOTORBOAT.

TURBIDITY

Variations in turbidity caused by resuspension of settled sediments were determined under various operational conditions of engined boats. Measurements were taken by Hach 2100 Turbidimeter. Attempts were made to determine the effects of: A) water depth, B) motor power, C) time of operation and D) particle size of the resuspended sediments.

A) Water Depth: To study the effect of water depth on turbidity measurements, a 10 HP engined boat was run across Lake Mizell, Osceola, and Maitland for a short period of time (less than 1 hour) and samples were collected from the shallow shore areas and deeper areas at mid-width. The data collected are presented in Table 14 to Table 16. It is noteworthy that visible increase in turbidity was observed in shore areas of less than 5 feet deep after a short period of time (less than 5 minutes). However, longer operation time and more powerful engines may be required to stir up deeper areas in the lakes.

Data from Table 15 on Lake Osceola showed an increase in turbidity from 2.5 to 22.0 JTU in shore areas while slight increase at mid-width from 1.7 to 2.0 JTU was noticed. The same basic trend was observed at Lake Mizell and Lake Maitland.

B) Motor Power: Turbidity measurements associated with running boats engined with various power motor are presented in Tables 17 and 18. It appears from the data that the turbidity increases by increasing the motor power. For example, Lake Claire (S_7) showed little or no changes in turbidity when the boat was equipped with a 28 HP motor. However, changes in turbidity throughout the entire depth of the lake was noticed when the boat was equipped with 50 or 115 HP motors. Also, Lake Osceola, at depths of 6 to 7 feet, a 10 HP motor did not seem to change the turbidity as indicated in Tables 14 and 16.

From the data presented in Tables 14 to 18, an estimate for the effective mixing depth from different motor power could be predicted. The effective mixing depth (EMD) could be defined as the water depth where the turbidity measurements show a definite increase through out the entire depth of the lake as noted by surface changes. This would eliminate sampling errors which may reflect increases in turbidity of water samples taken close to the bottom. It is also assumed that the operation time is nearly constant.

The data in Table 19 suggests a direct relationship between the motor power and effective mixing depth as shown in Figure 12. Of course, this would depend on other factors such as bottom sediments and speed of the boat. Figure 12 suggests a strong correlation between EMD and motor powers provided all other variables are constant.

Table 14. WATER QUALITY DETERMINATION AFTER BOATING ACTIVITY ACROSS LAKE MIZEL
OCTOBER 26, 1974

(10 HP Motor)

LOCATION	DEPTH BELOW SURFACE Ft	PARAMETER: BEFORE BOATING Temp °C	D.O. mg/1	pH	Turb JTU	Cond. µmhos/cm	OP mg/1 P	AFTER BOATING Temp °C	D.O. mg/1	pH	Turb JTU	Cond. µmhos/cm	OP mg/1 P
West Shore S_2	1	25.0	8.8	8.1	3.9	308	.03	24.5	7.2	7.6	28.0	290	0.11
	2	----						24.5	6.7				
	3	25.0	8.5					24.5	6.0				
Mid-Width S_1	1	24.0	7.6	7.5	2.7	292	.025	24.0	7.4	7.2	1.5	290	.05
	2	24.0	7.5					24.0	6.8				
	3	24.0	7.5					24.0	6.6				
	5	23.5	7.5					23.8	6.3				
	7	23.5	7.2					23.5	5.7				
	9	23.2	6.7										
	10	23.0	6.4					23.0	4.7				
	12	23.0	5.2					23.0	4.5				
	14	23.0	4.3					23.0	4.2				
	16	23.0	3.6	7.4	4.5	287	.025	23.0	3.8	7.2	22	287	.075
East Shore	1	24.5	8.0	8.25	2.3	298	.035	23.8	7.0	7.1	5.5	290	.055
	2	24.0	7.2					23.8	6.6				
	3	24.0	6.1	8.25				23.8	6.3				

Table 15. WATER QUALITY DETERMINATION AFTER BOATING ACTIVITY ACROSS LAKE OSCEOLA OCTOBER 11, 1974

(10 HP Motor)

LOCATION	DEPTH BELOW SURFACE Ft	PARAMETER											
		BEFORE BOATING						AFTER BOATING					
		Temp °C	D.O. mg/l	pH	Turb JTU	Phosphorus mg/l		Temp °C	D.O. mg/l	pH	Turb JTU	Phosphorus mg/l	
						Ortho	Total					Ortho	Total
South Shore	1	27.0	4.7	6.1	2.5	.03	.04	27.0	8.0	7.6	22.0	.05	.05
	2	27.0	3.9					27.0	7.6				
	3	27.0	3.2					27.0	6.0				
	4	27.0	3.0					27.0	5.7				
Mid-Width S_3	1	27.5	6.9	7.3	1.7	.025	.03	27.0	8.0	7.6	2.0	.03	.05
	2	27.3	6.5					27.0	8.0				
	3	27.3	6.5					27.0	8.0				
	4	27.2	3.3					27.0	7.3				
	5	27.0	2.1					27.0	6.5				
	6	27.0	2.1					27.0	6.0				
	7	27.0	2.1					27.0	5.5				
North Side	1	27.0	6.9	7.6	2.3	.03	.04	27.0	7.7	7.6	23.0	.12	.37
	2	27.0	6.5					27.0	6.5				
	3	27.0	---					27.0	---				
	4	27.0	6.5					27.0	6.1				

Table 16. WATER QUALITY DETERMINATION AFTER BOATING ACTIVITY ACROSS LAKE MAITLAND
OCTOBER 26, 1974
(10 HP Motor)

		PARAMETER											
		BEFORE BOATING						AFTER BOATING					
LOCATION	DEPTH BELOW SURFACE Ft	Temp °C	D.O. mg/1	pH	Turb JTU	Cond. µmhos/cm	OP mg/1 P	Temp °C	D.O. mg/1	pH	Turb JTU	Cond. µmhos/cm	OP mg/1 P
Bush	1	24.5	7.8	7.6	0.7	216	.015	24.0	8.4	8.2	1.2	217	.01
	3	24.5	7.8					24.0	7.9				
	5	23.5	6.8					24.0	7.5				
	7	23.0	7.2					24.0	7.2				
Mid-Width S_5	1	24.0	7.6	8.2	1.5	215	.02	24.5	7.8	8.2	0.7	210	.01
	2	24.0	7.2					24.5	7.5				
	3	24.0	7.0					24.5	7.1				
	5	23.5	6.7					24.0	6.8				
	7	23.0	7.1		8.0		.05	23.5	7.7		30	225	.055
Isle of Sicily	1	24.0	7.3	7.95	0.5	210	.015	24.0	7.2	8.0	2.7	225	.02
	2	23.5	6.7					24.0	7.0				
	3	23.5	6.7					24.0	6.6				
	5	23.5	6.5										

Table 17. TURBIDITY MEASUREMENTS BEFORE AND AFTER BOATING ACTIVITY

LAKE & SAMPLING LOCATION	DATE	TIME	WATER DEPTH ft	MOTOR POWER HP	TURBIDITY, JTU	
					Before Boating	After Boating
Osceola[1]						
S_3	June 26	1030	1	100	1.6	2.1
Maitland[1]						
S_5	June 26	1100	1	100	1.2	3.2
Mizell[1]						
S_1	July 5	1400	1	100	3.0	2.8
Osceola[1]						
S_3	July 5	1430	1	100	1.8	7.0
			5	100	4.0	8.0
Claire[2]						
S_7	Sept 18	1630	1	28	1.7	1.8
			10		1.7	1.9
	Sept 20	1630	1		2.3	2.3
			10		2.8	2.7
Osceola[3]						
Shore	Oct 11	1100	1	10	2.5	22.0
S_2			1		1.7	2.0
Shore			1		2.3	23.0
Mizell						
S_2	Oct 26	1400	1	10	3.0	28.0
S_1			1		2.7	1.5
			15		4.5	22.0
Shore			1		2.3	5.5
Maitland						
S_5		1500	1	10	1.5	0.7
Shore			6		8.0	30.0
Shore			1		0.5	2.7
Claire[4]						
S_7	Nov 4	930	1	115	5.3	5.5
			10		6.6	8.0
S_8			1		5.5	14.0
			4		6.5	12.0

[1] 20-minute boating
[2] Boating for 20 hours at intervals
[3] Boating for 30 minutes across the lake
[4] One hour boating

Table 18. TURBIDITY MEASUREMENTS BEFORE AND AFTER CESSATION OF BOATING ACTIVITY

LAKE & SAMPLING LOCATION	DATE	TIME	WATER SAMPLE DEPTH ft	MOTOR POWER HP	TURBIDITY, JTU		
					Before Boating	After Boating	One Hour After Cessation of Boating
Claire[1]							
S_7	Nov 24	1400	1	28	6.5	6.5	
			3		5.0	6.0	
			6		4.7	6.5	
			9		6.7	11.5	
			10		13.0	15.0	
S_8			1		4.5	8.0	
			3		4.5	10.0	
S_7[2]	Dec 12		1		5.8	6.5	5.8
			3			6.5	
			6			6.5	6.2
			9			7.0	6.0
			10		6.0	6.5	
S_7[3]	Dec 21		1	50	6.8	7.5	
			3		6.8	7.8	
			6		6.1	8.0	
			9		6.4	8.0	
			11		6.5	9.5	
S_8			1		6.3	9.5	
			3		6.0	22.0	
Mizell[4]							
S_1	Dec 26		1	50	1.4	2.4	2.0
			3		1.6	2.4	
			6		1.3	2.4	
			9		1.6	2.0	
			12		1.9	2.0	
			15		---	2.4	1.7
S_2			1		2.3	3.4	1.9
			3		2.0	13.0	2.5

[1] Four hour boating
[2] Five hour boating
[3] Four hour boating
[4] Three hour boating

Table 19. CHANGES IN MIXING DEPTH AS RELATED TO CHANGES IN MOTOR POWER

LAKE	SAMPLING LOCATION	DATE	EMD Ft.	EMD M.	MOTOR POWER HP
Claire	S_7	Sept. 18	10	3.0	28
Osceola	S_3	Oct. 26	6	1.8	10
Claire	S_7	Nov. 4	10	3.0	28
Mizell	S_1	Dec. 26	15	4.6	50

It is also important to notice that the turbidity showed a noticeable decrease one hour after cessation of boating activities as shown in Table 18. It must be understood that colloidal particles and their relocation have not been studied.

C) Operational Time: The extent of the effects of motor boat activity on water quality parameters would be influenced by the time of running the boat. Naturally, the resuspended solids are limited by their availability at the bottom or on plant leaves and stems.

An interesting experiment was run at Lake Claire while the boat was stationary. A 50 HP motor equipped boat was tied to a tree and was held stationary in the lake at distances 10 to 100 feet from the shore. The motor was allowed to run and water samples were collected from boat side at different time intervals. The data collected are presented in Table 20.

The data shown in Table 20 shows that turbidity at S_8 increases in the vicinity of the boat area within the first five minutes of operation. However, by operating the motor boat for 30 minutes, the resuspended solids evidently were transported away from the area by prop wash currents. The same phenomenon was observed on February 28 and March 5th. The turbidity seems to increase in the vacinity of the boat to reach a maximum value which is followed by a decline as the operational time increases.

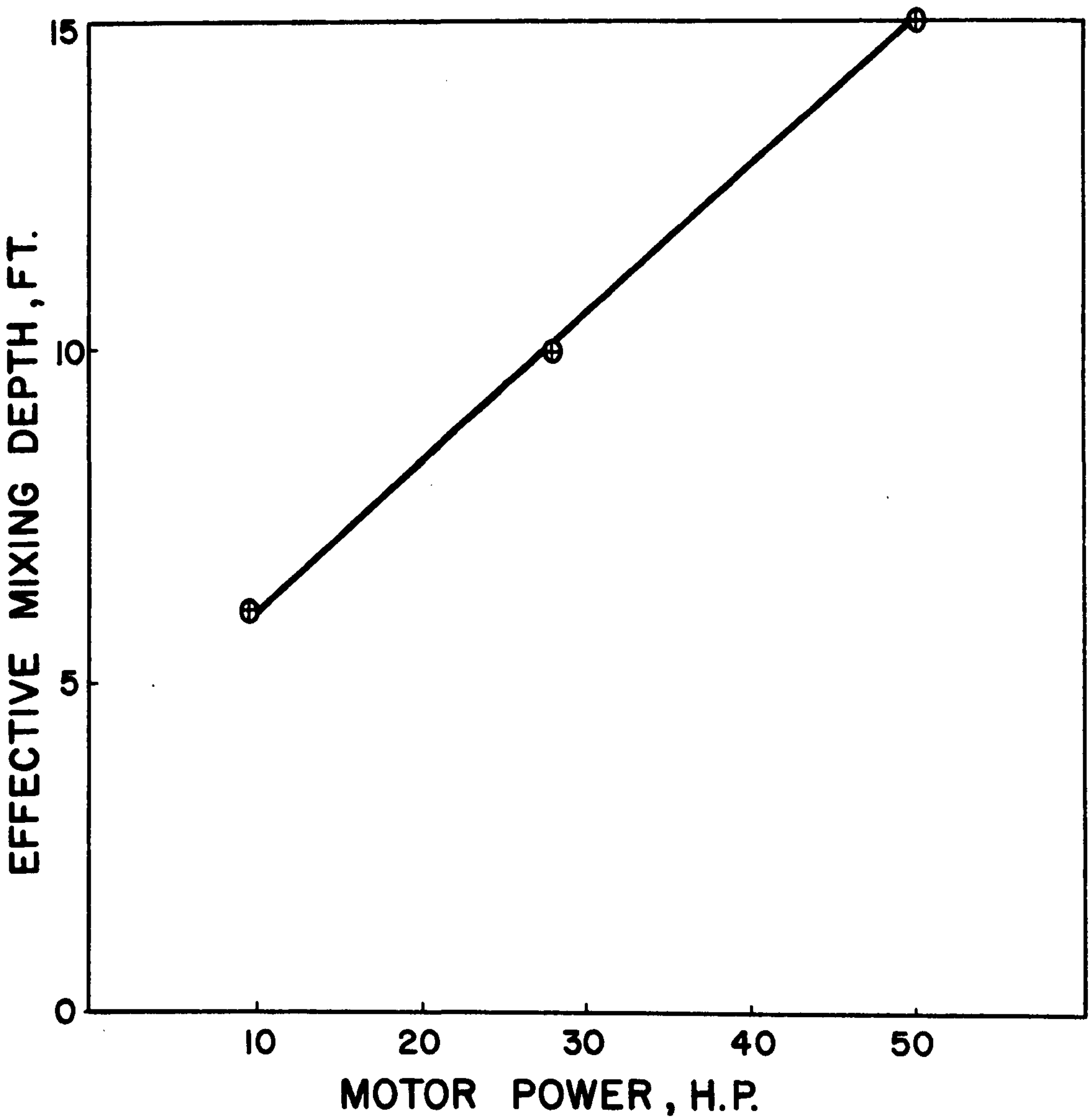


FIGURE 12 – RELATIONSHIP BETWEEN MOTOR POWER OF ENGINED BOATS AND MIXING DEPTH IN LAKES

Table 20. EFFECT OF OPERATIONAL TIME ON TURBIDITY

MOTOR POWER "HP"	LAKE	DATE	LOCATION	DEPTH Ft.	OPERA-TIONAL TIME Min.	TURBID-ITY JTU
50	Claire	Mar. 5, 1974	S_8	1.0	0	6.5
				1.0	5	8.3
				1.0	30	5.6
				1.0	60	5.5
50	Claire	Feb. 28, 1974	S_8	1.0	0	8.4
				1.0	30	6.5
			S_7	1.0	0	7.0
				1.0	30	5.5
				5.0	0	7.5
				5.0	30	8.0

D) Particle Size: Water samples collected before and after boating in Lake Claire, Mizell, and Wekiva Springs were microscopically examined using the Bausch and Lomb Dunazoom Research Laboratory Microscope and Integrated Camera Series. The microscope was calibrated using a stage micrometer with two millimeter range and each millimeter is divided into 100 deviations as shown in the picture on Figure 13. The mean and range of particle size diameter of sediments in five portions of each water sample were determined.

Figures 13 to 15 show the change in concentration and particle size of suspended particles on Lake Claire and Lake Mizell. Also, a picture of nonfilterable residue on a millipore filter paper from 50 ml water sample before and after boating activity at Lake Mizell is shown in Figure 15. This figure reflects the change in suspended solids at the shore area of Lake Mizell after running a 50 HP motor boat. The pictures show a definite increase in suspended solids concentration and particle size. It seems reasonable to assume that resuspended solids are generally larger in size or coagulation of particles may take place after mixing. Relocation of colloidal particles and mixing of plankton

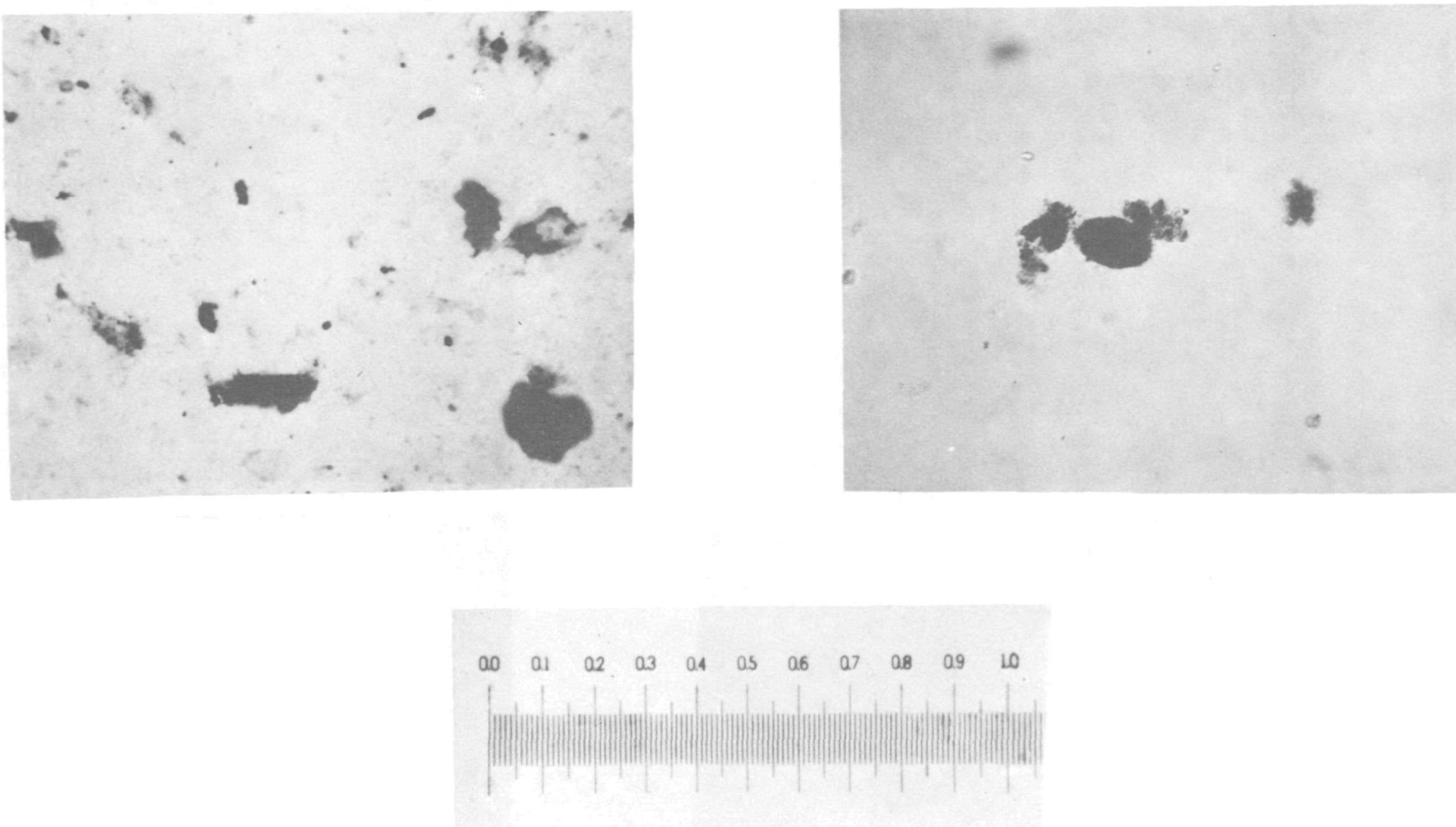
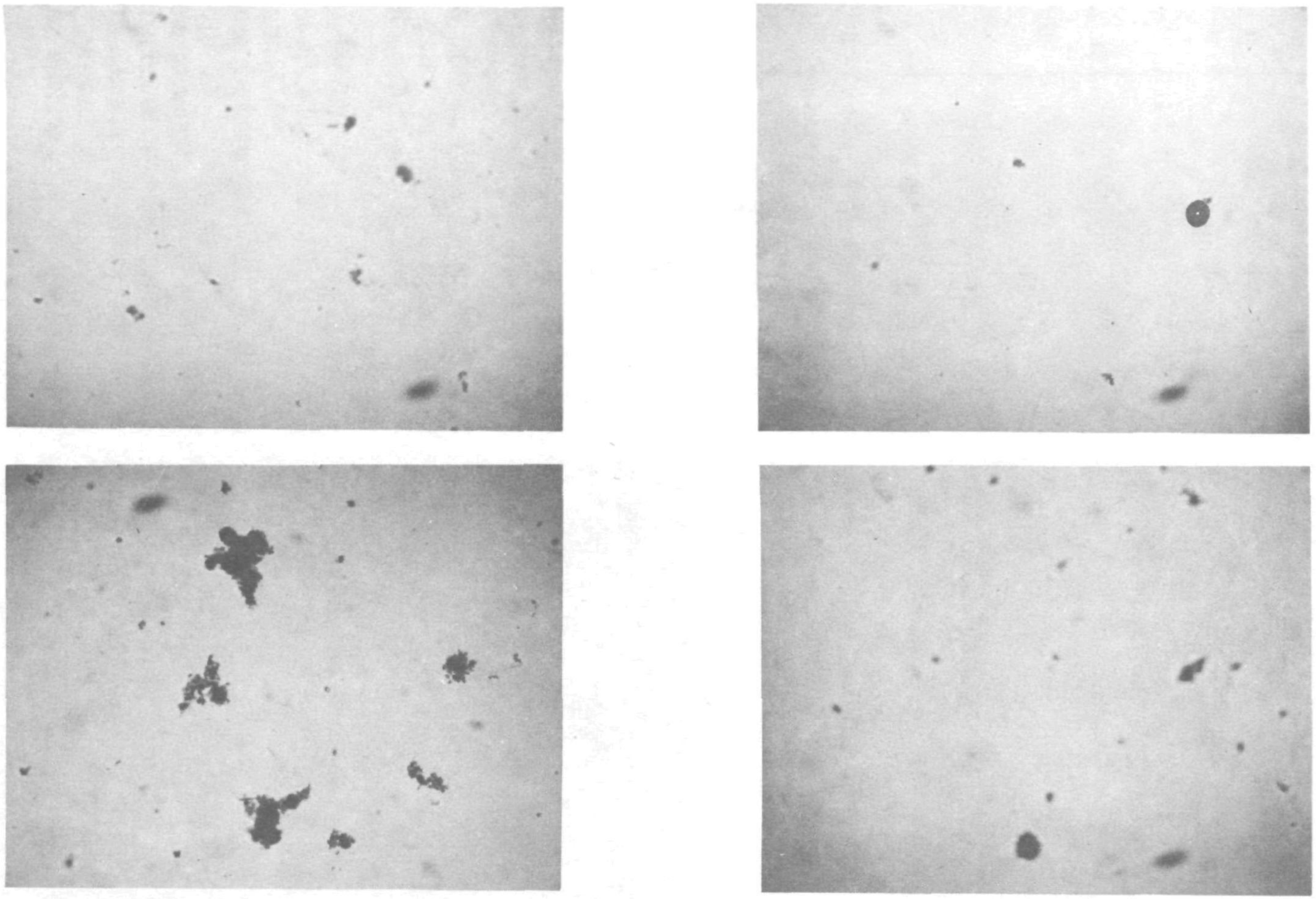


FIGURE 13. PARTICLE SIZE OF RESUSPENDED SEDIMENTS DUE TO BOATING ACTIVITIES.



(a) One Foot Below Surface Shore Area, S_8

(b) Five Feet Below Surface, S_6

FIGURE 14. RESUSPENSION OF SEDIMENTS BY 28 HP MOTORBOAT AT LAKE CLAIRE, ON JAN. 31, 1974.

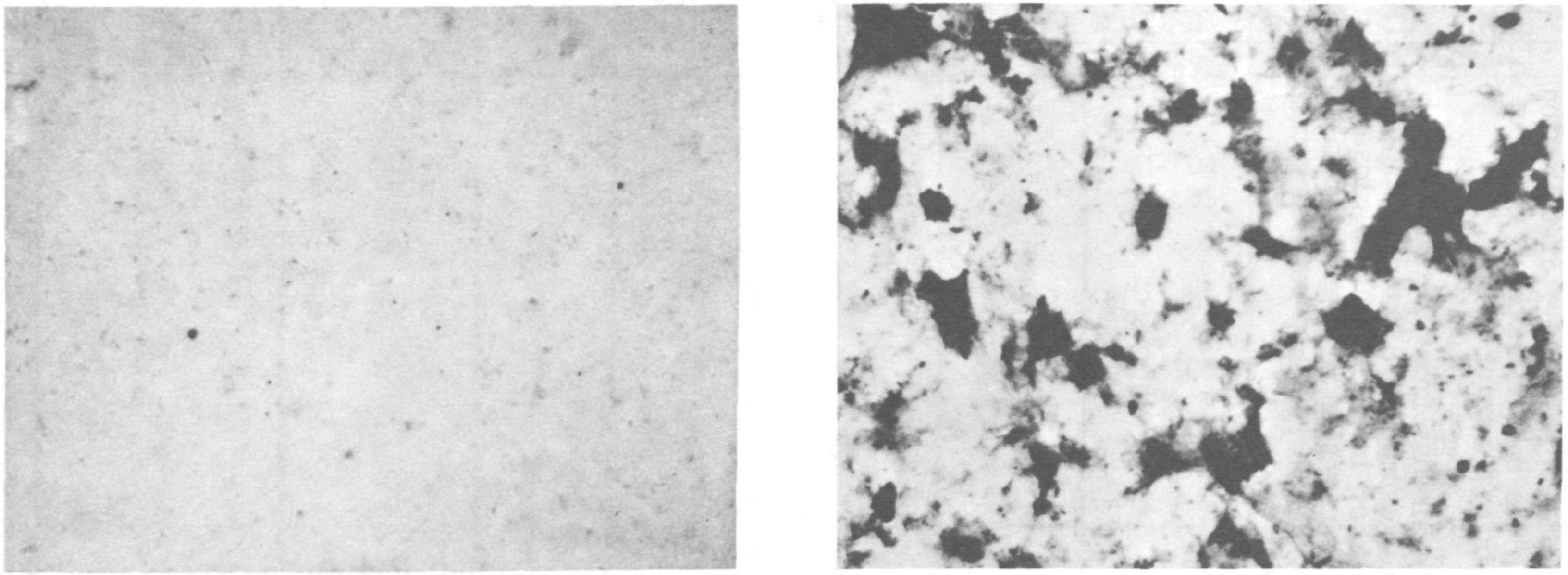


FIGURE 15. MILLIPORE FILTER RESIDUE FROM 50 ml LAKE MIZELL WATER BEFORE AND AFTER BOATING AT SHORE AREA.

within the water column and their impact on the ecological system in the lake have not been investigated. Assumably, distribution characteristics of biota within the entire depth of the lake will be influenced by agitation from mixing by motor boats.

Particle sizes of resuspended sediments from Lake Mizell and Lake Claire are presented in Table 21. The resuspended particles are generally less than 0.1 millimeter diameter except in shallow areas close to the shore where the resuspended particle size may reach a maximum of 0.3 mm. There appears to be a direct relationship between resuspended particle size and turbidity values.

Table 21. PARTICLE SIZE OF LAKE CLAIR AND LAKE MIZELL SUSPENDED SOLIDS

DATE	LOCATION	DEPTH Ft	MOTOR POWER HP	OPERATION TIME Min.	PARTICLE SIZE mm			
					BEFORE BOATING		AFTER BOATING	
					Mean	Range	Mean	Range
	CLAIR							
Jan 31, 1974	S_7	1	28	30	.02	.01-.04	.037	.02-.08
		5			.03	.01-.05	.045	.02-0.1
	S_8	1	28	5	.038	.01-.07	0.12	.05-.30
Feb 28, 1974	S_7	1	50	30	.02	.01-.05	.048	.02-0.15
		5			.038	.01-0.1	.062	.03-0.2
	S_8	1	50	30	.023	.01-.05	.062	.03-0.2
Mar 5, 1974	S_8	1	50	5	.085	.05-0.2	0.19	.05-0.5
				30			.03	.01-0.08
				60			.028	.01-0.1
	MIZELL							
Dec 26, 1974	S_1	1	50	180	UD**	UD**	.018	.01-.05
		3					.016	.01-.05
		6					.014	.01-.05
		9					.016	.01-.05
		12			UD**	UD**	.026	.01-.05
		15			0.1	.03-0.3	.028	.01-0.10
	S_2	1						
		3			.01	Very Few	.028	.01-.05
		4			.01	Very Few	.095	.05-.15

** UD is undetectable.

SECTION VIII

NUTRIENTS

Lake sediments concentrate nutrients from cyclical decay of planktonic material that sinks to the bottom and from runoff and wastewater effluents discharged into the water body. Nutrients may be released back to water and lake sediments may act as a reservoir supplying the overlying water with sufficient nutrients for autotrophic activity (3). Nutrients of particular concern are nitrogen and phosphorus. However, carbon, iron and other elements could be growth limiting in some cases. It is also realized that the substance in least abundance in the environment relative to the need of any organism will limit the total crop of the organism (10). Consequently, algal blooms, could occur in limited areas of the lake where nutrients, light, and temperature are adequate.

MIXING OF LAKE WATER

The epilimnion and the underlying hypolimnion may exist as two separate zones with little or no mixing. This is largely due to the density gradient separating the two zones which imposes limitations on exchanges of heat and dissolved material (1). Agitation and mixing of these zones, especially in shallow lakes, will evenly distribute the nutrients through the water column and may sustain a more productive ecosystem. Numerous investigators have noted general increases in phytoplankton abundance during destratification. On the other hand, intermittent water column mixing and continuous destratification have been successful, in some cases, in decreasing phytoplankton abundance, at least on a temporary basis (13).

Most fresh-water phytoplankton have 1.01 to 1.03 specific gravity, thus are heavier than the medium in which they float (11). As a result, they will sink slowly when placed in undisturbed water and their growth is limited by the available nutrients in the immediate surroundings. However, turbulent water permits more rapid nutrient uptake and so faster division than would be possible for a stationary cell(11). The nature and significance of nutrient interchange between sediments and overlying water is not clearly defined. The rate of nutrient interchange is affected by the water movement and sediment transport which also affects benthos. Changes in abundance of several dominant species of benthos were observed in shallow waters during destratification (13).

EXPERIMENTATION AND RESULTS

During the course of this study, organic and inorganic carbon concentrations, Ortho and total phosphorus measurements and total Khjeldahl nitrogen were analyzed for samples of lake water at various levels before and after limited boating activity. Also, the fraction of nutrients associated with suspended solids and fractions in solution were determined.

Changes in nutrient concentrations on Lakes Mizell, Osceola, Maitland, and Claire are presented in Tables 22 to 25. The average nutrient concentrations are summarized in Table 26. The average values include samples taken before and after boating activity and also include samples taken one foot below the water surface and one foot above the bottom sediments. The high concentration of phosphorus presented in Table 26 is mainly attributed to the higher concentration in the water samples above the bottom sediments. The data indicates that the increase in trubidity after limited boating activity is generally associated with a similar increase in organic carbon and phosphorus concentrations.

The data presented in Tables 22 and 23 shows that the phosphorus content in most of the water samples taken one foot above the bottom of the lake is several times higher than the phosphorus content in samples taken one foot below water surface. This is particularly true in deep sampling locations on the lakes, S_1 and S_4, where the DO content is minimal. It is known that the distribution of phosphorus in a water column of a lake is generally not homogeneous (6). The dissolved phosphates tend to reach uniform concentration throughout the column; however, particulate phosphate compounds counteract this tendency. This seems to agree with the data presented in Table 27. Filtered water samples taken from Lake Mizell and Lake Claire throughout the water column exhibited fairly uniform concentration of phosphorus after filtration through 0.45 μm millipore filter. It is also obvious that most of the phosphorus concentration is associated with the suspended solids in the water samples. Before boating an average orthophosphate in the filtrate was 0.006 mg/l "P" as compared to 0.029 mg/l in the non-filtered samples. After boating activity the average has increased to .01 mg/l in the filtrate and 0.034 mg/l in the non-filtered samples as shown in Table 27. It is believed that boating activity tends to increase the dissolved and particulate phosphates in the water column in shallow lakes at least on a temporary basis. The dissolved orthophosphate averaged 21 to 29% of that present in water samples.

Twenty-four samples were taken from Lake Claire on December 11 to December 14 showed that the dissolved organic carbon averaged 5.2 mg/l as compared to 0.6 mg/l associated with suspended solids. Most of the organic carbon is found in solution and amounts to 90% of the total organic carbon.

Table 22. NUTRIENTS IN WATER SAMPLES FROM LAKE MIZELL

DATE	TIME	LOCATION	DEPTH Ft	CARBON mg/1 "C"		TKN mg/1 "N"	PHOSPHORUS mg/1 "P"		REMARKS
				IC	OC		OP	TP	
6/26	9:30	S_1	1	13.2	7.5	--	0.12	--	
7/5	14:00	S_1	1	11.0	7.2		0.06	0.2	
			10	11.5	7.0	0.3	0.10	0.16	
			1	11.0	6.5	--	0.06	0.2	After 20 min boating-100 HP motor
7/17	14:00	S_1	1	10.8	8.4	0.2	.04	.05	
8/5	11:30	S_1	1	10.7	6.7	0.4	.025	--	
	15:30		1	10.1	6.7	0.56	.03	--	
8/11	9:15	S_1	1	10.8	7.4	0.5	.03	--	
	16:00		1	11.8	6.2	1.5	0.8	--	
8/14	13:30	S_1	1	10.4	7.4	.45	.025	--	
8/16	13:45	S_1	1	11.0	7.8	.30	.031	--	
	14:45		1	11.2	7.2	.30	.01	--	After 1 hour boating-35 HP motor
8/19	9:15	S_1	1	10.4	8.6	.44	0.02	0.1	
			15	12.8	25.2	.56	0.03	.32*	
	14:35	S_1	1	10.4	7.1	.42	0.02	.06	
			15	10.0	22.5	.44	0.53	.75*	After 45 min boating-260 HP motor
8/22			1	11.1	8.9	1.2	0.03	.12	
			15	13.8	10.9	1.3	0.06	.12	
12/26	13:00	S_1	1			.86	.015	.025	
			3			.78	.02	.028	
			6			.76	.01	.025	
			9			.86	.005	.022	
			12			.82	.005	0.03	
			15			2.62	0.15	0.35*	
		S_2	1			0.75	.01		
			3			0.82	.01		
1/3	12:15	S_1	1			0.86	.01	.015	After boating-50 HP motor
			3			0.73	.01	.03	
			6			0.8	.01	.02	
			9			1.16	.01	.01	
			12			0.82	.015	.02	
			15			0.82	.015	.03	
		S_2	1			1.16	.01	.02	
			3			1.76	.02	.03	
1/4		S_1	1			0.82	.005	.02	
			15			0.73	.007	.02	
		S_2	1			0.92	.005	.015	
			3			0.75	.007	.02	

* High phosphorus content in samples taken one foot above the bottom.

Table 23. NUTRIENTS IN WATER SAMPLES FROM LAKE OSCEOLA

DATE	TIME	LOCATION	DEPTH Ft	CARBON mg/1 "C" IC	CARBON mg/1 "C" OC	TKN mg/1 "N"	PHOSPHORUS mg/1 "P" OP	PHOSPHORUS mg/1 "P" TP	REMARKS
7/26	10:30	S_3	1	18.8	2.7	1.0	.05	.07	
			1	18.9	2.6		0.08	0.10	After 20 min boating-120 HP motor
7/5	14:30	S_3	1	15.8	1.8	0.25	.08	0.14	
			5	15.8	3.2		0.14*	0.21	
			1	15.0	5.5	0.30	0.25	0.34	
			5	18.0	3.2		0.56*	0.61	After 20 min boating-100 HP motor
7/17	13:30	S_3	1	15.0	7.6	0.05	0.05	0.11	
			8	15.7	7.3		0.03	.05	
7/24	15:00	S_4	1	14.6	6.2	0.03	0.02	0.05	
			10	14.5	5.5		0.02	0.06	
7/31	14:30	S_4	1	14.1	3.9	0.18	0.02	0.04	Exceptionally high "P" in filtered samples
			16	14.1	4.7		3.3*	3.5	
8/5	11:00	S_3	1	15.1	3.8	0.3	0.02	--	
		S_4	1	14.4	4.2	0.42	.025	--	
	16:00	S_3	1	14	5.0	0.5	.02	--	
		S_4	1	13.9	4.3	0.4	0.02	--	
8/7	14:30	S_4	1	13.4	3.5	--	.015	--	
8/9	15:00	S_4	1	12.6	3.6	0.18	.015	--	
8/11	10:00	S_4	1	14.3	5.3	0.4	.015	--	
	16:30		1	13.0	8.3	0.5	0.01	--	
8/14	14:00	S_4	1	14.5	6.5	0.5	0.03	--	
8/19	9:45	S_4	1	18.2	5.6	0.32	0.03	0.06	
			16	13.6	7.0	0.4	1.0*	1.13	
8/20	13:45	S_4	1	16.0	2.0	0.42	0.03	0.06	After 45 min boating-260 HP motor
			16	17.1	4.9	0.4	.38*	0.75	
8/22	15:00	S_3	1	14.0	6.0	1.50	.02	0.12	
			8	15.4	5.0	1.60	.03	0.12	
			1	14.2	6.5	1.6	.02	0.13	
			16	14.0	6.0	1.6	.02	0.13	
10/11	11:00	S_3	1				.025	.03	
		Shore Area	1				.03	.05	
		S_3	1				.03	.05	After 30 min boating-10 HP motor
		Shore Area	1				0.12	0.37	

* High phosphorus content in samples taken one foot above the bottom.

Table 24. NUTRIENTS IN WATER SAMPLES FROM LAKE MAITLAND

DATE	TIME	LOCATION	DEPTH ft	CARBON, mg/1		TKN, mg/1 "N"	PHOSPHORUS, mg/1 "P"		REMARKS
				IC	OC		OP	TP	
6/26	1100	S_5	1	17.3	2.3		0.04	0.08	
			1	17.0	3.9		0.06	0.08	After 20 min. boating - 100 HP motor
7/05	1500	S_5	1	15.0	5.0	0.45	0.04	0.13	
			5	15.0	20		0.26	0.57*	
7/12	1400	S_5	1	15.8	6.6	0.25	0.02	0.05	
			6	15.4	7.0		0.05	0.06	
7/17	1600	S_5	1	15.1	6.5	0.25	0.03	0.10	
			7	15.0	9.8		0.06	0.11*	
7/31	1330	S_5	1	14.0	5.0	0.20	0.01		
			7	13.6	4.6		0.01		
		S_6	1	12.0	4.5	0.30	.005		
			10	12.2	5.1		0.01		
8/05	1000	S_5	1	14.3	4.4	0.40	.015		
	1630		1	13.3	4.4	0.42	0.02		
	930	S_6	1	13.6	5.2	0.42	.015		
	1700		10	12.7	4.7	1.60	.025		
8/07	1415	S_6	1	13.1	2.9	0.25	0.01		
		S_5	1	13.0	1.8	0.30	.015		
8/09	1415	S_6	1	12.4	3.7	0.15	.015		
8/11	1015	S_6	1	15.6	5.8	0.20	.015		
	1645		1	11.3	7.9	0.20	0.03		
8/14	1430	S_6	1	13.6	7.0	0.08	0.01		
8/19	1015	S_6	1	12.6	6.6	0.40	0.01	0.09	
8/20	1630	S_6	1	12.0	5.5	0.22	0.01	0.06	After boating 45 min. - 260 HP motor
8/22	1600	S_5	1	14.5	4.8	1.80	0.03	0.14	
		S_6	1	14.7	4.3	0.20	0.01	0.14	

* High phosphorus content in samples taken at one foot above the bottom.

Table 25. NUTRIENTS IN WATER SAMPLES FROM LAKE CLAIRE

DATE AND LOCATION	DEPTH ft	BEFORE BOATING: CARBON, mg/1 C		TKN, mg/1 N	PHOSPHORUS, mg/1 P		AFTER BOATING: CARBON, mg/1 C		TKN, mg/1 N	PHOSPHORUS, mg/1 P		REMARKS
		IC	OC		OP	TP	IC	OC		OP	TP	
9/18, S_7	1	0.8	3.3		.005	.03	0.8	2.8		.008	.015	Boating - 25 HP motor
	10	0.9	5.2		.02	.06	0.8	3.6		.03	.07	
9/20, S_7	1	0.9	3.7		.005	.03	0.7	3.0		.012	.07	
	10	0.7	3.1		.012	.03	0.8	4.3		.018	.04	
11/04, S_7	1			0.24	.03	.035			0.22	.065	.085	
	10			0.22	.035	.04			0.28	.01	.01	
S_8	1			0.24	.03	.035			0.32	.065	.075	
	4			0.22	.035	.06			0.32	.10	.13	
12/11, S_7	1	0.5	4.5	0.07	.01		0.6	6.9	0.33	.02	.05	Boating - 50 HP motor
	3						0.6	5.7	0.35	.023	.055	
	6			0.31			0.6	5.9				
	9						0.6	7.4		.04	.08	
	10	0.5	5.1	1.24	.015		0.6	5.7		.02	.04	
S_8	1	0.5	4.6		.015		0.6	7.7	0.12	.02	.06	
	3	0.5	4.4		.01		0.6	6.0	0.22	.06	.12	
12/11, S_7	6	0.5	5.4	0.31	.05	.16						One hour after cessation of boating
	9	0.5	5.1	0.22	.04	.075						
S_8	1	0.5	6.5	0.24	.045	.075						
	3	0.6	7.1	0.54	.04	.045						
12/12, S_7	1	0.6	4.9		.035	.065						19 hours after cessation of boating
	6	0.5	4.8		.025	.037						
	9	0.5	5.3		.035	.065						
S_8	1	0.5	5.2		.04	.05						
	3	0.5	4.5		.03	.04						

Generally, organic carbon and phosphorus seemed to increase in water samples taken after boating activity. However, total Khjeldahl nitrogen data did not reflect any specific pattern. It must also be realized that this study is limited in scope and budget and more research is needed to investigate the significance and nature of the changes in nutrient concentrations due to agitation from motor boats.

Table 26. SUMMARY OF NUTRIENT CONCENTRATIONS IN LAKE WATER SAMPLES

LAKE	CARBON, mg/1 C		TKN mg/1 N	PHOSPHORUS mg/1 P	
	IC	OC		OP	TP
Mizell	11.2	9.4	0.8	0.07	0.10
Osceola	15.9	4.9	0.6	0.20	0.35
Maitland	14.0	5.7	0.4	0.03	0.13
Claire	0.6	4.9	0.35	0.03	0.05

Table 27. DISSOLVED AND PARTICULATE PHOSPHORUS

LAKE AND LOCATION	DATE	DEPTH ft	PHOSPHORUS CONCENTRATION, mg/l P							
			Before Boating				After Boating			
			Filtered		Non-Filtered		Filtered		Non-Filtered	
			OP	TP	OP	TP	OP	TP	OP	TP
Mizell, S_1	12/26	1	.003		.008	.01	.005	.015	.015	
		3	.005		.01	.02	.01	.025	.01	
		6	.005		.01	.02	.005	.015	.01	
		9	.005		.008	.01	.005	.01	.01	
		12	.003		.015	.02	.003	.02	.015	
		15	.003			.01	.005	.025	.013	
S_2		1	.008		.01	.015	.005	.02	.01	.02
		3	.003		.008	.014	.005	.01	.02	.03
S_1	1/04	1					.005	.02	.018	
		15					.003	.015	.015	
S_2		1					.005	.015	.01	
		3					.007	.018	.01	
Claire, S_7	11/24	1	.02		.04		.015		.055	
		3	.005		.04		.02		.05	
		6			.04		.065		.095	
		9	.01		.045		.005		.08	
		11	.005		.085		.01		.1	
S_8		1	.005		.03		.005		.06	
		3	.005		.05		.02		.055	
Average Concentration, mg/l "P"			.006		.029		.01		.034	

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16. ABSTRACT

This research study was directed towards an assessment of effects on water quality in shallow water bodies (less than 30 feet deep) due to mixing by boating activity. Definition of the problem, isolation of effects and conditions and determination of areas for further research were stressed.

Four shallow lakes in Orange County, Florida, namely Lake Mizell, Lake Osceola, Lake Maitland, and Lake Claire were studied. Changes in several water quality parameters before and after limited boating activity were monitored.

Agitation and mixing by boating activity destratified the lake and in some cases, increased oxygen concentration and the rate of oxygen uptake by suspended matter. An increase in turbidity was observed and was generally dependent on water depth, motor power, and nature of bottom deposits. Increase in turbidity was accompanied by an increase in organic carbon and phosphorus concentration. A decrease in turbidity was also noticed after cessation of boating activity. Results from other parameters such as pH, specific conductance, temperature, and nitrogen were not conclusive.

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