make the decision as to whether or not conditions are satisfactory for a safe dive. A non-diver should never make this decision.

DANGERS AND DIVING DISEASES

Contrary to popular belief, poor swimming ability and exhaustion are the principal causes of death while diving.

Air embolism is probably the most serious diving disease because it can occur in shallow water and is often fatal. This disease is a result of a person breathing compressed air underwater and ascending without properly exhaling.

Decompression sickness (Bends) is also a serious disease but does not affect divers working less than 40 feet deep. Deeper dives can be made with little danger of decompression sickness if U. S. Navy decompression tables are followed.

DISCUSSION

The usefulness of SCUBA as a fisheries tool in freshwater is yet to be fully realized. Biologists are beginning to see the advantages of being able to observe and study fish without permanently disturbing the aquatic environment. New underwater techniques are now needed. As developments occur in SCUBA methods, they should be reported as soon as possible to reduce duplication of effort and therefore improve fishery research and management methods, which is the ultimate goal.

REFERENCES

INSTRUCTION AND TECHNICAL INFORMATION ON SCUBA

National Co-operation in Aquatics, 1959. "The Science of Skin and SCUBA Diving," Association Press, New York, N. Y.

Navy Department, 1958 "U. S. Navy Diving Manual," NAVSHIPS 250-538, Superintendent of Documents, Washington 25, D. C.

A STUDY ON STRIPED BASS EGG PRODUCTION IN THE CONGAREE AND WATEREE RIVERS

By OTHO D. MAY, JR. and JEFFERSON C. FULLER, JR.

South Carolina Wildlife Resources Department

INTRODUCTION

For several years the Santee-Cooper Reservoir has enjoyed a fabulous reputation due to the presence of a freshwater population of striped bass. Current studies, during the 1961 and 1962 spawning seasons, indicate that approximately 95 percent of the total annual production of striped bass eggs occurs in the Congaree River and five percent in the Wateree River. Recruitment of the striped bass fishery in the reservoir is entirely dependent on the number of eggs spawned in these two rivers; therefore, it is apparent that any changes in the physical characteristics of the rivers, especially the Congaree River, will directly influence the fishery. The striped bass of the Santee-Cooper Reservoir is a warm water fishery; however, it represents the only, the term only is used advisedly, established, self-sustaining, totally freshwater population of this species in the world.

The major problem in sustaining a successful spawn from year to year is directly related to the spawning habits of the striped bass, the physiology of the egg and the physical characteristics of the spawning habitat. Striped bass, like most anadromus fish, are free spawners. The eggs, which have a specific gravity slightly greater than fresh water and a comparatively high metabolic rate, must remain suspended in water until they hatch. Being slightly heavier than fresh water, it is necessary that a certain amount of current be present to keep the egg suspended. In the absence of current, the eggs would slowly settle to the lower layers of water where there might exist a deficiency of dissolved oxygen and thus die or settle to the bottom when they would silt-over and die. Since the eggs require 36 to 75 hours, depending on the water temperature, to hatch a relatively long reach of moving water is necessary for a successful spawn.

The same techniques were used in sampling the 1961 and 1962 striped bass egg production; however, the collected data were handled differently each year. The 1961 data were analyzed to obtain the following information: demarcation of spawning areas in each river, percentage of nonviable eggs, quantitative estimate of total egg production in each river and age of the eggs collected at sample station. The 1962 data were analyzed only to make an estimate of the total production in each river. Except where noted, this paper will be concerned with the results of the 1961 study.

MATERIALS AND METHODS

Since 1955 extensive biological investigations on the striped bass in the Roanoke River, North Carolina have been conducted. "These studies included the annual estimation of the number of eggs spawned by striped bass each season, the determination of the most efficient type of net, the most efficient duration of sampling, the relative position and depth of sampling, a determination of the number of samples to be taken daily and the location of sampling stations." These studies were conducted by Hassler and Brandt (1955-1961), McCoy (1958), Cheek (1959) and Brown (1960-1961).

The results of the Roanoke River studies were utilized as a guide to survey the 1961 and 1962 striped bass egg production in the Congaree and Wateree Rivers. The Roanoke River studies have shown that two simultaneous five minute samples, taken at three-hour intervals, gives one of the most feasible egg production estimates, providing the river stage in feet at the sample station is known and that the samples are taken from the mean cross-sectional current. The Roanoke River study indicated that where the cross-sectional bottom contour is uniform, the concentration of striped bass eggs in an instantaneous cross section will be homogenous. Therefore, the average number of eggs taken in a pair of nets set side by side in the mean cross-section current will give a representative sample of the egg concentration.

Prior to the start of the Congaree-Wateree studies, a sample station was selected near the mouth of each river. The width of each river was determined by stretching a rope across the river at the desired cross-section. Bottom contours and water velocity at given intervals were accurately measured using the stretched rope to hold the boat at the desired position. Soundings were made by a weighted sounding line and an electronic depth sounder. Water velocities were determined by a Price patterned current meter. When the mean cross-sectional current was determined, a floating buoy was anchored at that point, thus insuring that each sample would be made in the same cross-section.

The nets used for making the samples were 20 inches in diameter at the mouth—funneling six feet in length and made of nylon netting (25 meshes to the inch). A canvas cuff, two inches in width and three inches in diameter was sewn to the small end of the net. Two metal screw rings from standard one-quart Mason jars were soldered together (top-to-top) and were laced into the cuff. The collecting jar, a standard one-quart Mason jar, was screwed into this ring.

SAMPLING PROCEDURE

Striped bass start their spawning run when the water temperature approaches 60° F.; therefore, it was decided that sampling would be started at twelve-hour intervals when the water temperature reached 58° F. Daily water temperature checks were started each year in mid-March. In 1961 the water temperature reached 58° F. on April 1. In 1962 the water temperature did not reach 58° F. until April 14.

The initial samples each year consisted of two simultaneous fifteen minute samples taken at 12-hour intervals—0600 and 1800 hours. The twelve-hour samples were continued until eggs began appearing in the nets. In 1961, the first eggs were picked up at 0600 hours, April 23. The water temperature at this time was 60° F. The water temperature from the initial 1961 sample until the first eggs were picked up ranged from 54° to 60° F.

In 1962, the initial sample was made at 1800 hours, April 14. The first eggs, three in number, of the 1962 spawning season were observed at 0600 hours, April 22. The water temperature at this time was 58° F. The range of water temperature from April 14 to April 22 was 56° F. to 58° F.

Four crews, two men each, were employed around the clock, seven days per week, to carry the 1961 egg study to completion. A work schedule was set up so that each crew was on duty for a period of twelve hours. The schedule also provided that the tour of duty of each crew alternated between day and night shifts. Shifts were changed at 0700 hours and 1900 hours with the crew on duty making and processing the 0700 hour or 1900 hour sample. Each crew was required to make four samples in each river at pre-set three-hour intervals during their tour of duty. The same general schedule was followed during the 1962 study. Five crews, two men each, were used during the 1962 study, with each crew remaining on duty for a period of 24 hours. Each crew was required to make eight samples in each river at pre-set three-hour intervals during their tour of duty.

A sampling schedule, pre-set at three-hour intervals, was set up before eggs began appearing in the nets. The hazards of running the river at night was taken into consideration, and a schedule was set up that would allow the least number of samples during darkness. The schedules were: 1961—0100, 0400 . . . 2200 hours; 1962—0300, 0600 . . . 2400 hours around the clock.

Each sample consisted of two simultaneous five-minute samples, one from each side of the boat and taken approximately two feet beneath the water surface. The step-by-step procedure followed in making a sample was as follows: At the scheduled sample time the boat was secured to the station buoy. The collecting jars were then attached to the nets, one man handling each net. The line securing the net to the boat was made ready for the set and the anchor at the end of the line was placed over the side of the boat. The trailing end of the net was put over the side of the boat and the collecting jar allowed to fill with water. The complete net was then held over the side of the boat, the mouth remaining clear of the water, and the current allowed to stretch the net to its full length. One man using a stop watch gave the signal for dropping the nets and started timing the set. Actual time of the set was determined by a regular watch and recorded. While the nets were fishing, the following information was recorded: date, sample number, time scheduled for the sample, actual time of the sample, water temperature, air temperature and weather conditions. The form used for recording the field data also included space for the number of eggs collected by each net, the river stage, total number of eggs collected and adjusted number of eggs—the adjusted number being the total in the event the nets were fished longer or less than five minutes. The nets were removed from the water at the end of five minutes and their contents washed into the collecting jar. The collecting jars were removed from the nets and the nets were washed and inspected for holes in preparation for the next sample. Each jar was labeled as to the side of the side of the boat and the river from which the sample was made. In the event the sample could not be "picked" immediately upon returning to camp, enough formalin was added to the sample to stop further development of the eggs. Eggs were picked from the sample and preserved in a 7.5 percent formalin solution for future analysis.

EXTENT OF SPAWNING

The 1961 striped bass spawning season in the Congaree and Wateree Rivers had a duration of 44 days—April 23 through June 5. The 1962 spawning season lasted only 33 days—April 23 through May 25. During the 1961 spawning season, three major peaks in number of eggs collected at the Congaree sample station occurred. The peaks in order of their magnitude occurred on the following dates: 0100 hours May 5 to 1900 hours May 10, 0400 hours April 30 to 0700 hours May 3 and 1800 hours April 23 to 1600 hours April 26 (Figure 1). Peaks exhibited by the 1962 study were almost identical with those of 1961. The 1962 peaks in order of their magnitude occurred at: 0900 hours April 29 to 0600 hours May 3, 0600 hours April 23 to 2400 hours April 26 and 0600 hours May 7 to 1800 hours May 9 (Figure 1A).

The same spawning pattern was noted in the Wateree River. Three major peaks occurred in this river each in 1961 and 1962. The Wateree River peaks

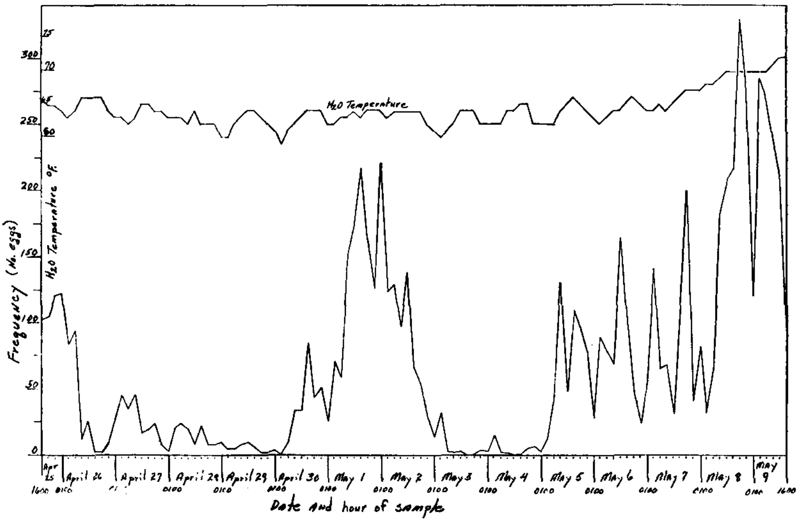

Figure 1 — Number of striped bass eggs taken per sample (two simultaneous 5-minute samples) in the Congaree River during the 1961 spawning season. Water temperature (°F.) at the time of sample is also given.

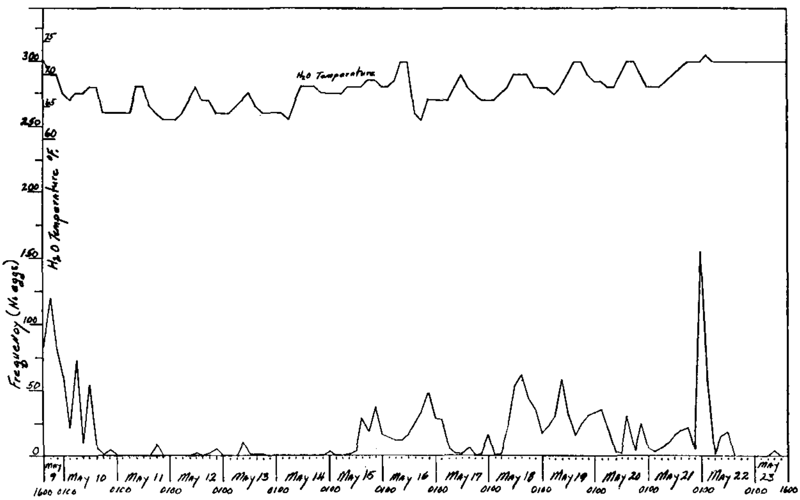

Figure 1 — Continued

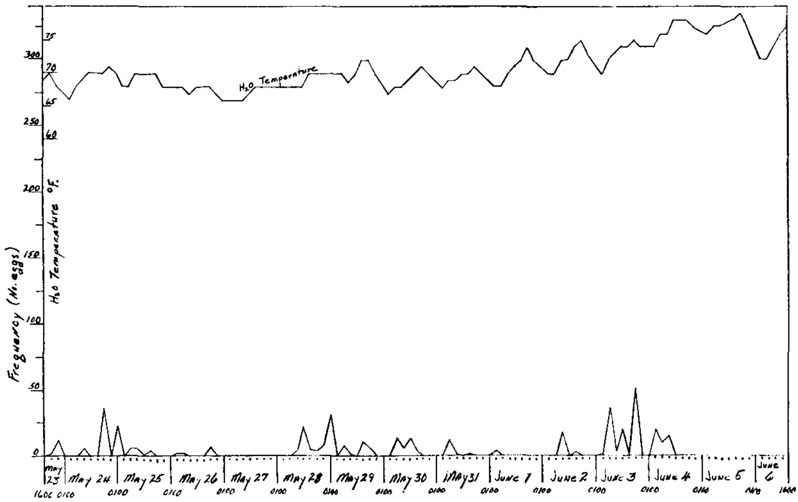

Figure 1 — Continued

in order of their magnitude were: 1961—0700 hours May 8 to 1900 hours May 10, 2200 hours May 22 to 2200 hours May 23 and 1600 hours May 29 to 2200 hours May 30 (Figure 2). 1962—2400 hours May 3 to 1500 hours May 9, 2100 hours May 13 to 0900 hours May 16 and 1800 hours April 30 to 1800 hours May 2 (Figure 1A).

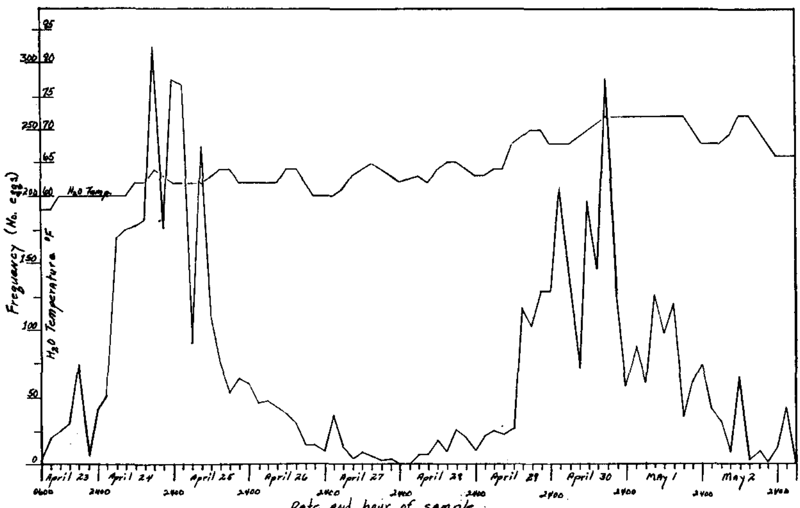

Figure 1A - Number of striped bass eggs taken per sample (two simultaneous 5-minute samples) in the Congaree River during the 1962 spawning season. Water temperature (°F.) at time of sample is also given.

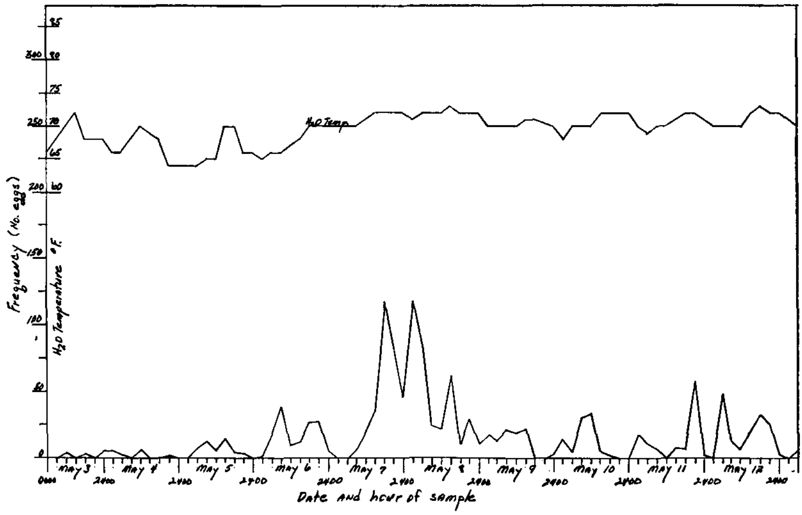

Figure 1A - Continued

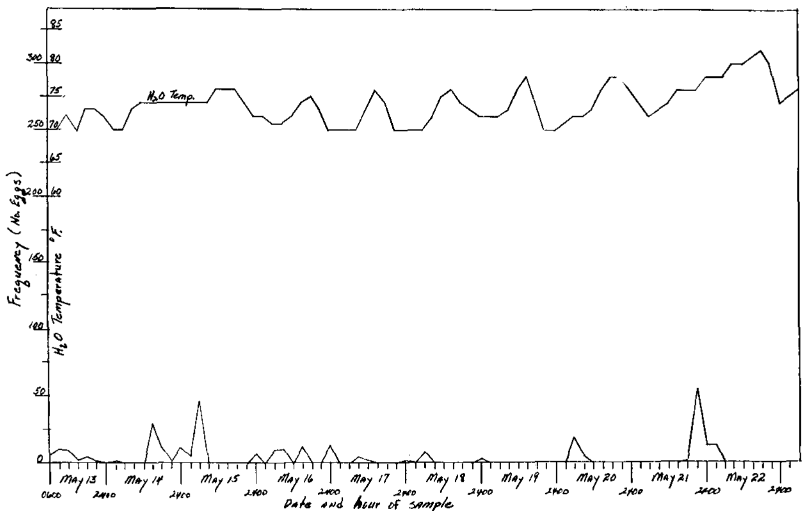

Figure 1A - Continued

An area ratio was used to estimate the number of eggs passing each station during each five-minute sample. The total number of eggs passing each station during the spawning season was estimated by expanding each five-minute sample to cover a three-hour period. For example, the 0700 hour period was expanded to cover the period from 0530 hours to 0830 hours. The average number of eggs collected from the two nets during the five-minute sample was used as the average for the three-hour period. Also, the water velocity at the time of the sample was considered as average for the expanded period. The estimates of the three-hour periods were then combined to give an estimate for the total annual spawn.

The ratio used to calculate the number of eggs passing each station in a three-hour period is expressed as:

$$\frac{\text{Area (sq. ft.) of river cross-section}}{\text{Area (sq. ft.) of mouth of net}} = \frac{\text{Number of eggs in cross-section of river}}{\text{Average number of eggs in nets X 36}} =$$

Since the area of the mouth of the net (2.18 sq. ft.) and the number of five-minute periods (36) in the expanded sample remain constant throughout the study, the ratio can be more simply stated as: Number of eggs passing the sample station in a three-hour period = (16.514) (average number of eggs in five-minute sample) (cross-sectional area of the river at the time of the sample).

There is no doubt that the water velocity affected the number of eggs picked up in each sample; however, since the current bringing the eggs to the nets was the mean velocity for the sample cross-section, the ratio of the number of eggs in the nets to the number of eggs passing the cross-section, in an equal period of time, will remain the same regardless of water velocity.

The estimated total number of striped bass eggs spawned in the Congaree River during the 1961 spawning season was calculated to be approximately 542,000,000. Confidence limits were calculated for approximately 75 percent of this total by the method of successive differences and these 95 percent limits were ± 34,000,000 eggs. The estimated total number of striped bass eggs spawned in the Congaree River during the 1962 spawning season was calculated to be approximately 307,000,000 eggs ± 33,000,000 eggs at the 95 percent confidence limits.

The estimated total number of eggs spawned in the Wateree River during the 1961 spawning season was approximately 22,000,000 eggs. The 95 percent confidence limits for this population estimate were ± 6,000,000 eggs. The 1962 total estimated spawn in the Wateree River was approximately 16,750,000 eggs. The 95 percent confidence limits for this estimate were ± 3,450,000 eggs.

The total egg production during the 1962 spawning season decreased from that of the 1961 spawning season in each river. The 1962 Congaree River spawn decreased 43.4 percent from 1961 and the Wateree River spawn decreased 23.0 percent for the same period. In regard to total potential recruitment for the Santee-Cooper striped bass fishery, the 1962 potential was only 57.4 percent of that of 1961.

It is obvious from the 1961 and 1962 population estimates for striped bass eggs made on the Congaree and Wateree Rivers that the Congaree River is supporting the bulk of striped bass spawning for the Santee-Cooper Reservoir. Under existing conditions it is obvious that the Congaree River is the preferred spawning site. In 1961 the number of eggs spawned in the Congaree River made up approximately 96 percent of all eggs which are carried down to the upper reaches of the Santee-Cooper Reservoir. The same was true in 1962 when the eggs spawned in the Congaree River made up approximately 95 percent of all eggs going into the reservoir.

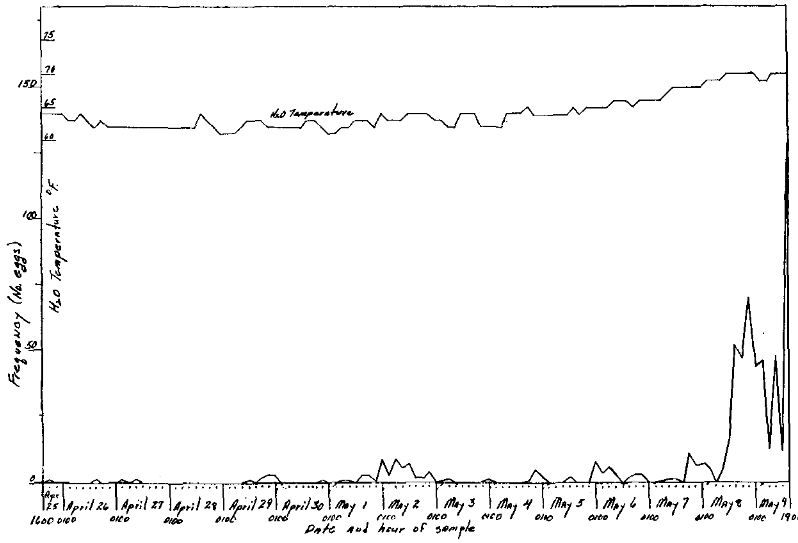

Figure 2 — Number of striped bass eggs taken per sample (two simultaneous 5-minute samples) in the Wateree River during the 1961 spawning season. Water temperature (°F) at the time of sample is also given.

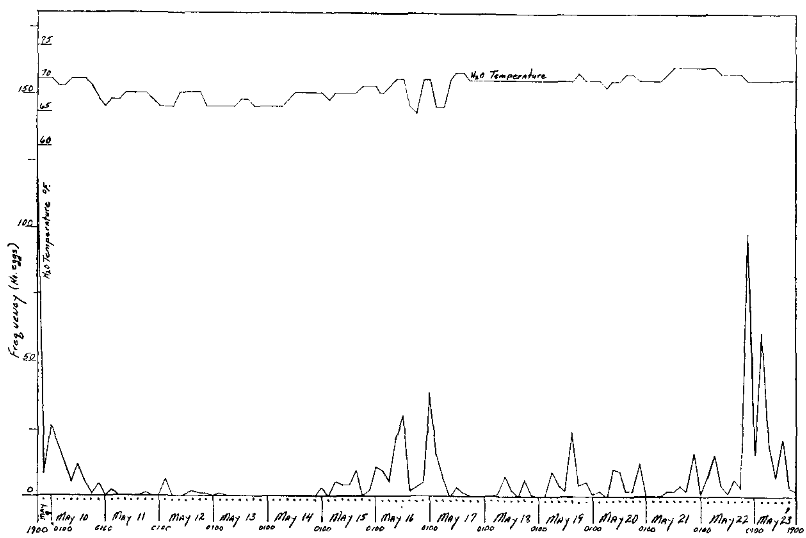

Figure 2 — Continued

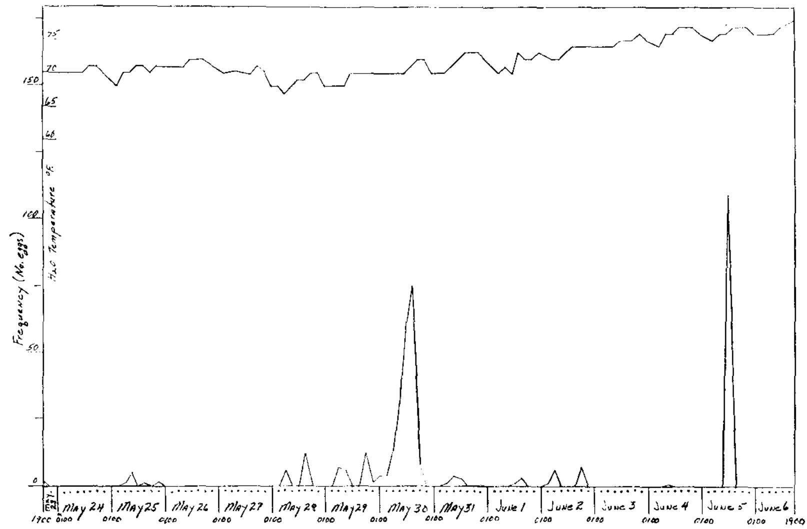

Figure 2 — Continued

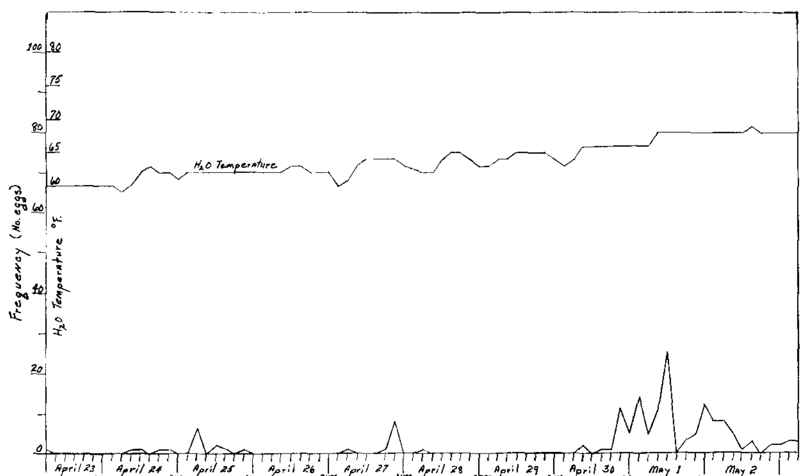

Figure 2A - Number of striped bass eggs taken per sample (two simultaneous 5-minute samples) in the Congaree River during the 1962 spawning season. Water temperature (°F.) at time of sample is also given.

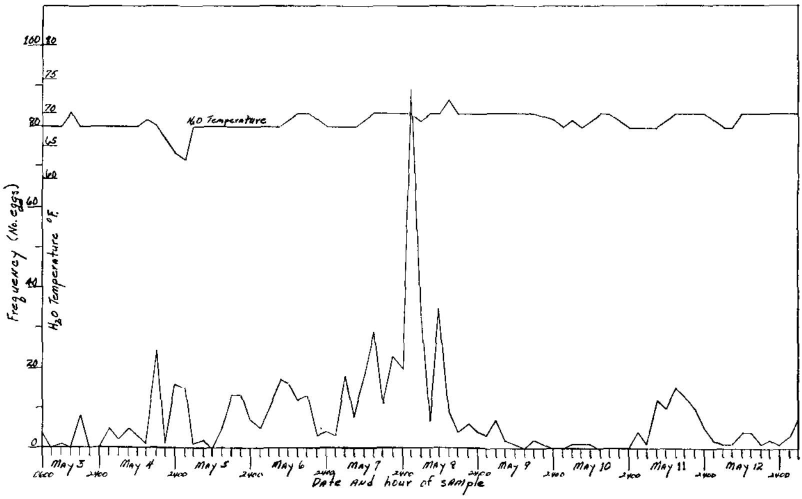

Figure 2A. Continued

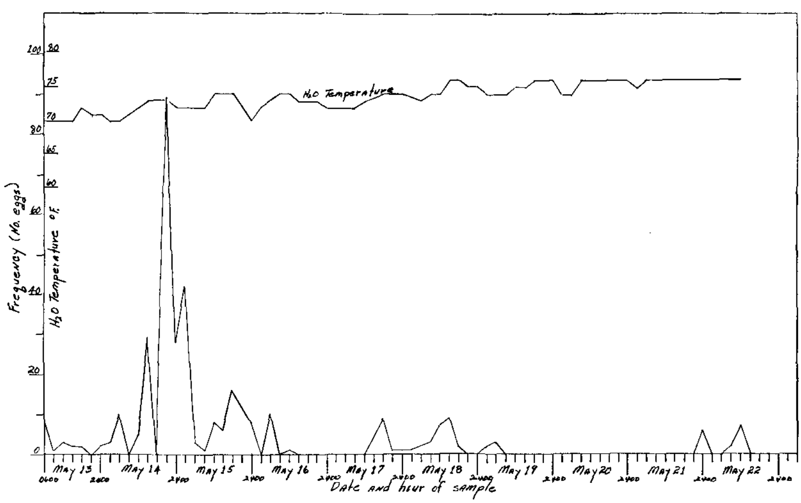

Figure 2A - Continued

STAGE OF DEVELOPMENT AND VIABILITY OF THE COLLECTED EGGS

During the course of the 1961 study, 383 samples were made in the Congaree River in which 10,525 striped bass eggs were collected. Since it was impractical to stage and age all of these eggs, a sub-sample of 94 samples comprising approximately 24 percent of the original samples was inspected. The eggs were examined by the techniques prepared by James T. Brown; however, the final age assessment was made by means of a nomograph also prepared by Brown. Altogether 4,553 striped bass eggs or 43 percent of the total number of eggs were examined by these techniques. The mean age for the 4,553 eggs examined from the Congaree River was approximately 20 hours. Standard deviation for this mean was approximately 8¼ hours and the range extended from 3 to 39 hours. Examination of the Congaree River eggs indicated that 17 percent of the eggs collected were non-viable.

A sub-sample of 86 samples was selected from the 383 egg samples available from the Wateree River. The number of sub-samples examined was approximately 22 percent of the total number of available samples. In all, 1,551 eggs were collected in the Wateree River and 678 of these eggs (44 percent) underwent analysis. The mean age of the Wateree River striped bass eggs was approximately 14 hours. The standard deviation was approximately 9¼ hours and the range of development extended from 2 to 44 hours. Thirty percent of the eggs collected from the Wateree River were non-viable.

PERCENTAGE OF EGGS SPAWNED IN EACH RIVER THAT COULD HATCH

There are four factors involved in the determination of the percentage of eggs spawned in each river that might successfully hatch. These factors are:

1. The average current velocity of the river above sampling point and 10 miles below the sampling point.
2. The water temperature prevailing during the developmental stages of the egg.
3. The upstream distance at which the egg originated.
4. The number of viable eggs reaching sample point.

The data collected during the 1961 study were utilized to make an estimate of the number of striped bass eggs spawned in each river which would hatch.

CONGAREE RIVER

Age of Eggs at Station	*Time Required to Hatch*	*Temperature of Water*
20 hours	41 hours	66.5° F.

Current Velocity 4 Miles Below Station	*Transport Time*	*Current Velocity 4-10 Miles Below Station*	*Transport Time*
1.6 mph	2.5 hours	0.33 mph	18.5 hours

At these rates 50 percent of the eggs (minus one-half of the non-viable eggs) could be expected to hatch. Approximately 41.5 percent of the striped bass eggs which originated in the Congaree River could be expected to hatch. This figure would be approximately 225,000,000 eggs.

WATEREE RIVER

Age of Eggs at Station	*Time Required to Hatch*	*Temperature of Water*
14.1 hours	36 hours	69.5° F.

Current Velocity 4 Miles Below Station	*Transport Time*	*Current Velocity 4-10 Miles Below Station*	*Transport Time*
1.6 mph	2.5 hours	0.33 mph	18.5 hours

Under these conditions, 46 percent of the Wateree River striped bass eggs (minus one-half the non-viable eggs or 15.0 percent) could be expected to hatch. This would be approximately 6,820,000 eggs.

In terms of total number of eggs which could be expected to hatch from each river, approximately 97 percent of the total number of striped bass eggs reaching the Santee-Cooper Reservoir originated in the Congaree River. It is doubtful if the loss of the eggs spawned in the Wateree River would appreciably affect the striped bass population in the reservoir; however, the loss of the Congaree River spawn would, in all probability, mean its extinction or at best reduce its status to one of insignificance.

PROBABLE SPAWNING AREAS

The 1961 data indicate that spawning occurred throughout most of each river. Examination of the field data and age analysis of the striped bass eggs in the Congaree River indicated that approximately one-third of all eggs originated below river mile 27. Approximately one-third of the striped bass eggs spawned in Congaree River during the 1961 spawning season originated between river mile 26 and river mile 42, while the remaining one-third was spawned above river mile 42 (Figure 3). The area which could be classified as the mean spawning point for striped bass in the Congaree River would be located at approximately river mile 37. The standard deviation would extend considerably above and below this point since the value for this statistic was approximately 41 miles. Striped bass eggs were spawned over a considerable distance of the Congaree River and the estimates indicate that this spawning occurred from river mile 5 to river mile 53.

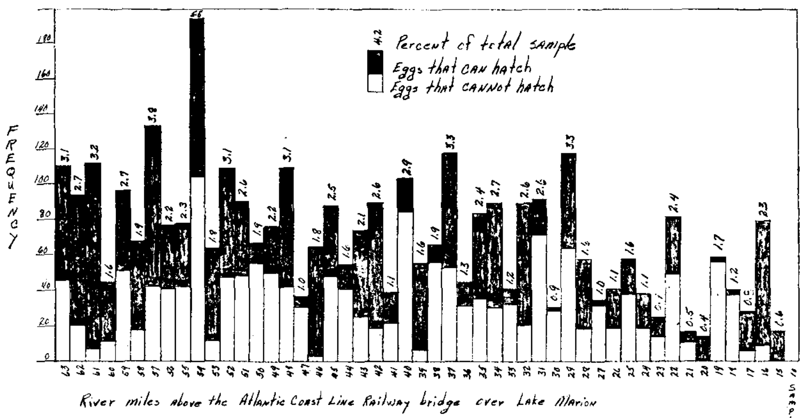

Figure 3 — Relative locations of striped bass egg production in the Congaree River during the 1961 spawning season.

Analysis of the 1961 Wateree River data indicate that approximately one-third of the 1961 striped bass eggs originated below river mile 9. Approximately one-third of the 1961 spawn occurred between river mile 9 and river mile 18 while remaining one-third originated above river mile 18. Approximately 92 percent of all the striped bass eggs, as indicated by the data collected at the sampling station, originated at or below river mile 32.

In addition to the age of the egg and the transport rate method of delimiting the spawning areas in each river, a movable station was set up on each river. The purpose of these stations was to keep sampling upstream, at five-mile intervals, until "green" eggs, eggs which had not yet become water hardened, were picked up. Inasmuch as spawning occurred, indicated by Figures 3 and 4, in practically each river mile, "green" eggs could have been picked up at any sample point. Eggs were collected by the movable station on the Congaree River as far upstream as river mile 45 and on the Wateree River as far upstream as river mile 58.

It is quite possible that striped bass spawning occurred in each river which was not detected at the sampling stations. Determination of the points of origin

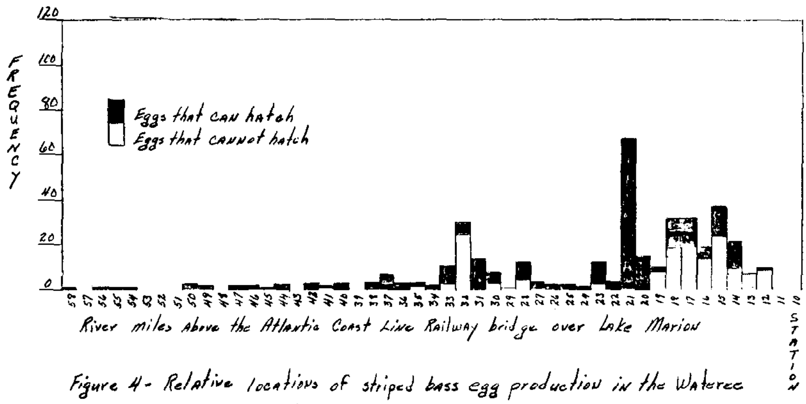

Figure 4- Relative locations of striped bass egg production in the Wateree River during the 1961 spawning season.

of the eggs were based on two assumptions: (1) that the eggs traveled at a velocity equal to the calculated average velocity of the river at the stage observed when the sample was taken and (2) that the eggs were spawned at the same water temperature as was observed in the river at the time of the sample. It is realized that both of these assumptions are possibly incorrect; they were made because more accurate data were not available. Water velocities for each river were supplied by the U. S. Army Corps of Engineers, Charleston District.

Since no egg was collected at the sampling station at the mouth of the Wateree River in 1961 from further upstream than river mile 58, the apparent presence of eggs in the river above this point, ascertained by the movable station, indicates that spawning occurred in the upper reaches of the river which was not detected at the main station. In 1962 the movable station again picked up eggs as far upstream as river mile 60. The eggs collected in 1962 at river mile 60 were collected on May 10-11 when the water temperature was 70° F. and the river stage was 10.0 feet.

Tables I and II were set up for each river to show the theoretical maximum distance, under various development rates for the egg and various water velocities, that an egg could originate upstream from the station and be picked up in the sample before hatching.

The eggs collected by the movable station on the Wateree River in 1962 had a development rate of 36 hours. The theoretical values from Table II indicate that these eggs could not have possibly reached the sampling station at the mouth of the river before hatching. Theoretically, even though they had been spawned at river mile 60 where they were collected, they would have hatched approximately 30 miles upstream from the station. Several times during the course of the 1961-1962 study, conditions existed on one or both rivers which would have prevented, due to hatching, the eggs that were spawned in the extreme accessible portions of the rivers from being detected at the sampling stations.

NIGHT VS. DAY SPAWNING

During the 1961 striped bass egg study 4,553 eggs from the Congaree River were aged and 678 eggs were aged from the Wateree River. The hour of the day at which the eggs were spawned was determined and plotted as a graph to determine if any particular time of the day or night was more conducive to spawning than another (Figures 5 and 6). Data on which Figures 5 and 6 are based are: Congaree River 1,896 eggs and Wateree River 327 eggs. These figures do not consider that on a given day, due to different environmental conditions, spawning activity might be concentrated at a certain time of day. They indicate only the average daily spawning activity for the entire spawning season. When considering the spawning season as a whole it is apparent that daylight or the absence of daylight had little or no influence on the time at which spawning will occur. The Congaree River spawning was equally divided

Table I

Maximum Upstream Distance from Sampling Station Which Eggs Can Originate and be Picked Up at the Station before Hatching
Maximum Distance Accessible to Spawning Population is 62 Miles

CONGAREE RIVER

Miles Upstream from Sampling Station

Hours Required for Eggs to Hatch	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
76									
74									
72	62								
70	61								
68	60								
66	58	62							
64	56	61							
62	54	59							
60	53	57							
58	51	56							
56	49	54							
54	47	52	62						
52	46	50	61						
50	44	48	58						
48	42	46	55	62					
46	40	44	52	61					
44	39	42	50	58	62				
42	37	40	48	55	60				
40	35	38	46	53	58	62			
38	34	37	43	50	55	61			
36	32	35	41	48	52	58			

River Stage (Feet)

Table II

Maximum Upstream Distance from Sampling Station Which Eggs Can Originate and be Picked Up at the Station before Hatching
Maximum Upstream Distance Accessible to Spawning Population is 78 Miles

WATEREE RIVER

Miles Upstream from Sampling Station

Hours Required for Eggs to Hatch	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
76	36	43	50	57	63	70	78		
74	35	42	48	55	61	69	76		
72	34	41	47	54	60	67	74		
70	33	40	46	52	58	65	72	78	
68	32	39	45	51	56	63	70	77	
66	31	37	43	49	55	61	68	75	78
64	30	36	42	48	53	59	66	72	77
62	29	35	41	46	51	58	64	70	74
60	28	34	39	45	50	56	62	68	72
58	27	33	38	43	48	54	60	65	69
56	26	32	37	42	47	52	58	63	67
54	25	31	36	40	45	50	56	61	65
52	24	30	34	39	43	48	53	59	62
50	23	29	33	37	41	46	51	56	60
48	23	27	32	36	40	45	49	54	58
46	22	26	30	34	38	43	47	52	55
44	21	25	29	33	37	41	45	50	53
42	20	24	28	32	35	39	43	47	50
40	19	23	26	30	33	37	41	45	48
38	18	22	25	29	32	35	39	43	46
36	17	21	24	27	30	34	37	41	43

River Stage (Feet)

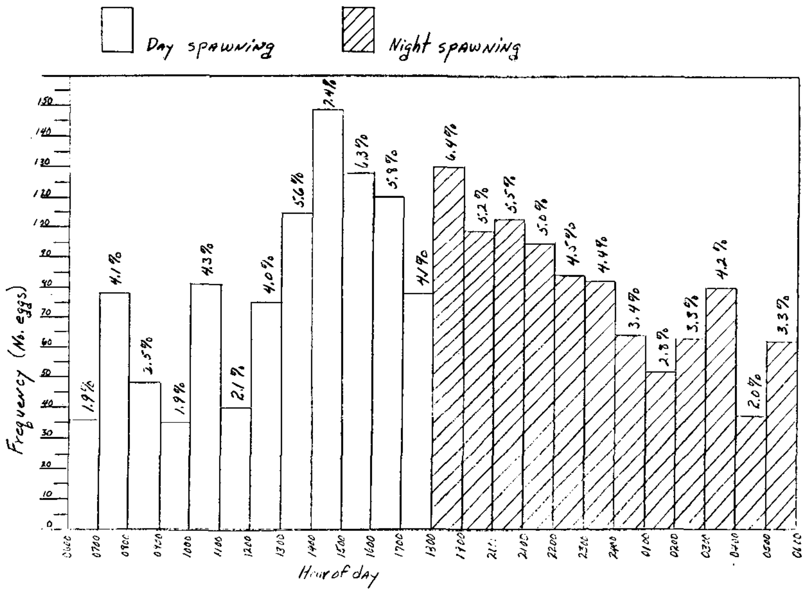

Figure 5 — Relative intensity of spawning activity exhibited by striped bass in the Congaree River during the 1961 spawning season.

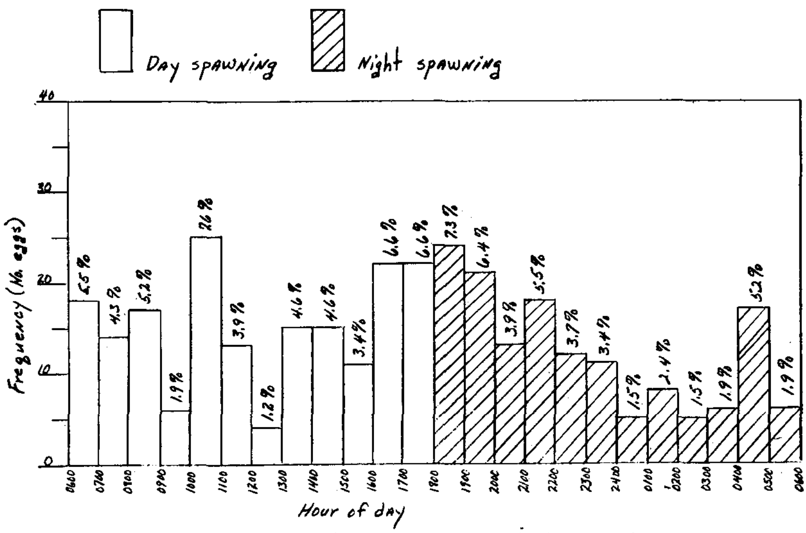

Figure 6 — Relative intensity of spawning activity exhibited by striped bass in the Wateree River during the 1961 spawning season.

between day and night (50 percent during the day and 50 percent at night). The striped bass in the Wateree River exhibited a slight preference for daytime spawning—55.4 percent during the day and 44.6 percent during the night.

SUMMARY

The Santee-Cooper Reservoirs support a large population of landlocked striped bass which is unique in nature and which owes its existence in main, to the spawning areas afforded by the Congaree River. In the past seven years 727,470 fishermen have removed 1,575,360 striped bass, valued at 2,182,410 dollars from the two reservoirs. In 1961 alone striped bass fishing in the reservoirs netted 353,160 dollars. Approximately 95 to 97 percent of this population is sustained by eggs spawned in the Congaree River. Data obtained from D-J Project F-1-R during the past seven years indicate that the average annual man-day utilization of the striped bass fishery in the two reservoirs has been approximately 104,000 with an average net value of approximately 312,000 dollars. An average catch of 14 pounds per man-day utilization has been maintained for the seven-year period 1954-1961.

It is estimated that at the end of 50 years the existing striped bass fishery will support approximately 800,000 man-days utilization valued at approximately 2,400,000 dollars—providing that the striped bass fisherman will accept an average catch of two pounds per man-day utilization. Therefore, the striped bass fishery in these two reservoirs can be expected to support an average annual man-day utilization of 425,000 man-days during the next 50 years. The average annual value of the striped bass fishery will be approximately 1,275,000 dollars or more than 63 million dollars during the next 50 years.

Investigations are currently being made as to the possibilities of making the Congaree River, and, possibly the Wateree River, navigable for river barge traffic. If navigation locks and dams are constructed on the Congaree River the physical characteristics of the striped bass spawning grounds will be altered to such an extent that maintenance of a sport fishery for the species will be extremely doubtful. The data from the two-year study clearly indicate that each mile upstream is progressively more important to a successful spawn than the mile preceding it.

Successful spawning of the species occurred in the Wateree River, possibly to a greater extent than that indicated by the study, during the 1961 and 1962 seasons. The 1961-1962 study indicated that only five percent or less of the potential recruitment of the reservoir striped bass fishery occurred in the Wateree River. It is highly improbable that the striped bass fishery can maintain itself anywhere near its present level by receiving only one-twentieth of its normal potential recruitment. A fishery dependent on such a small portion of its original reproduction will, at best, have only minor significance in the species composition of the reservoirs and any unfavorable condition, however slight, could bring about its total extinction.

ACKNOWLEDGMENTS

Funds for conducting this study were provided, in main, through Dingell-Johnson Projects F-9-R-2 and F-9-R-3, South Carolina.

This paper is based, in part, on data analyzed in report form by the Bureau of Sport Fisheries and Wildlife, Branch of River Basin Studies. For this and their cooperation in planning the 1961 study and assistance in collecting the field data, we express our thanks. Special thanks are due Mr. William E. Neal, and those of North Carolina State College with whom he consulted, for his cooperation in helping design the project and his assistance in collecting and analyzing the data.

We wish to thank Mr. Braden Pillow for his helpful suggestions during the study and for his assistance in collecting the field data.

Special thanks are due Dr. William W. Hassler for his consultation during the study and his aid in analyzing the 1961 data, and, also, thanks to those of the Statistical Department of North Carolina State College and "Scotty" Overton who handled the statistics involved in the study.

We wish to extend our personal thanks to the Law Enforcement Division of the South Carolina Wildlife Resources Department and especially to the following game wardens: O. M. Dennis, W. T. Tolar, Jr., Frank Weeks, D. H. Hill, E. M. Rush, W. E. Jackson, M. C. Parler, B. E. Richburg and M. A.

Bilton for their splendid cooperation in collecting the field data. Their cooperation was responsible, in great part, for the success of the study.

We would also like to express our appreciation to Supervisors W. E. Howell, A. M. Flood, Jr. and B. A. Gregg for their cooperation during the study, and also to Game Wardens G. M. Early and W. W. Cross for stepping in for relief of regular project personnel who had to be absent for one reason or another. Also, Mrs. Marie Bostain for her secretarial aid.

PRELIMINARY STUDY OF THE EFFECTS OF DIQUAT ON THE NATURAL BOTTOM FAUNA AND PLANKTON IN TWO SUBTROPICAL PONDS

By WALTER M. TATUM and ROBERT D. BLACKBURN [1]

ABSTRACT

Two farm ponds in south Florida were treated with a concentration of 0.5 part per million by weight of 1,1'-ethylene-2,2'-dipyridylium dibromide (diquat) on April 4, and May 21, 1962, to determine the effect this aquatic herbicide may have on the bottom fauna and plankton naturally existing in these two bodies of water.

Bottom samples were taken from the ponds with a 6" by 6" Ekman dredge before and after treatment. The organisms were sorted from the debris and counted. Plankton samples were also taken before and after treatment to evaluate the effect of this herbicide on the plankton.

The results in pond number one indicated no change in the number of bottom organisms before and after treatment. However, Chironomids failed to appear in the samples for the first 2 weeks after treatment. The second pond failed to show any reduction in numbers of this particular group of organisms. A large increase in the average number of organisms occurred after treatment in pond number two. Most of this increase in numbers came from the tremendous numbers of *Chaoborus* spp.

Plankton samples before and after treatment in pond number one did not show any measurable difference. The volume of plankton per cubic meter in pond number two decreased the third day after treatment. However it increased during the next seven days to give a greater volume of plankton than before treatment.

Water samples were taken from pond number two at periodic intervals after treatment to determine the persistence of diquat in the pond water. Duckweed *(Lemna minor)*, being very sensitive to diquat, was used as an indicator plant. Diquat was present in the pond water at a concentration of 0.25 p.p.m.w. after three days, 0.01 p.p.m.w. after eleven days, and no detectable diquat sixteen days after treatment.

INTRODUCTION

A considerable amount of information is available on chemical aquatic weed control (Lawrence, 1958; Blackburn and Weldon, 1962). Also, a great deal of information is available on the effects of chemicals on fishes that might exist in waters treated with herbicides (Springer, 1957; Lawrence, 1958; Bond, Lewis, and Fryer, 1959; Surber and Pickering, 1961). However, little is known of the effects of certain promising herbicides on the fish food organisms existing in treated bodies of water.

If a chemical controls aquatic weeds in a body of water, but also kills fish at concentrations necessary to control these aquatic weeds its uses are somewhat limited. Also, if a chemical was found to be an effective herbicide and non-

[1] Fisheries Biologist, Florida Game and Fresh Water Fish Commission, Fort Lauderdale, Florida, and Research Agronomist, Crops Protection Research Branch, Agricultural Research Service, U. S. Department of Agriculture, Fort Lauderdale, Florida, respectively.