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EFFECTS OF A THERMAL EFFLUENT ON AQUATIC LIFE IN AN EAST TEXAS RESERVOIR [1]

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ABSTRACT

Five data collecting stations were designated within Wilkes Reservoir, a 900 surface acre power plant reservoir in Marion County Texas, to gather information relative to the effects of a steam-electric effluent upon aquatic life. Temperature and dissolved oxygen readings were obtained with a YSI model 51A oxygen meter. Readings taken at designated intervals indicated the degree and extent of the heated water. Dissolved oxygen readings indicated no adverse dissolved oxygen concentrations. Twelve species of fish were collected and examined for external and internal parasites. Almost 59% of 161 game fish specimens, and almost 83% of 50 rough fish specimens were parasitized with trematodes, nematodes, cestodes, acanthocephalans, and parasitic copepods. The extent of parasitization in this reservoir indicated optimum or near optimum temperature conditions throughout the year. Parasitic copepods were more evident on bullhead catfish (*Ictalurus sp.*) during February, March, and April. There did not appear to be any seasonal

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fluctuation of parasitization, or degree of infection on other parasites encountered. Plankton samples were collected with a plankton tow net and volumetrically measured in the laboratory. For a given date, the majority of the plankton consisted of copepods and was more numerous in the warmer water. However, plankton abundance within the entire reservoir was greater during the colder periods of the year. Chemical water quality was checked with a Hach DR EL portable chemistry kit and did not undergo any significant changes. Fish were collected in water with temperatures in excess of 100 F, surface temperature 107 F on afternoon of collection. Specimens netted in this heated water had high mortality rates.

INTRODUCTION

Increasing amounts of freshwater runoff are used annually for industrial cooling water. About 80% of this industrial cooling water is used by the power industry, the remaining 20% by manufacturing industries. Nuclear power plants are becoming more prevalent, replacing the conventional fossil fuel plants. Nuclear power plants are less efficient than fossil fuel plants, ultimately producing more waste heat.

The objective of this study was to determine the effects of a steam-electric thermal effluent on aquatic life in Wilkes Reservoir, a 900 surface acre reservoir in Marion County, Texas. Secondary objectives making up this study were: to monitor chemical water quality and temperatures at selected stations within the reservoir, to record fish population movements in relation to oxygen and temperature fluctuations or variance, and to identify fish parasites and correlate parasite incidence and life cycles with water quality.

Wilkes Reservoir was built and is operated by the Southwestern Electric Power Company of Shreveport Louisiana. The primary use of the reservoir is for the steam-electric production of electricity.

During this process of electricity production, water is superheated into steam. The high pressure of this steam is the force which turns the turbines and generates electricity. Because it is much more efficient to transport water back through the system in relation to steam, the steam is passed through a coolant by means of condensers thus changing it back into water. The coolant is water from Wilkes Reservoir.

Wilkes Reservoir is semi-horseshoe shaped, figure 1, with the intake on one end and the discharge on the other. Water from the reservoir passes over the condensers, then travels approximately ½ mile through a canal to the discharge point. During this process, the water absorbs the heat of the steam. The effects of this heated water was the concern in this study.

The physiology of fishes is directly affected by temperature. Fishes are classed as poikilothermic animals, their body temperature following changes in environmental temperatures rapidly and precisely. Fish seem to seek out the temperature that is best suited for their survival.

Fish parasites encountered in this study as well as all other fish parasites have optimum temperatures. Fish parasites are affected by water temperatures in all of their phases and must adapt themselves to fluctuations (1). Temperature increases or decreases affect the duration of egg incubation, the length of embryonic development, the synchronization of hatching, protozoal reproduction, and the longevity and activity of fish-parasite active invasive phases.

The parasitic copepod *Argulus* is dependent on temperature in all its phases and developmental stages. Keselev and Ivlieva (1) show that development takes 30 to 40 days at 62 F to 68 F; at 68 F to 77 F this is shortened to 22 to 30 days, and at 77 F to 82 F, to 15 to 18 days. The mature *Argulus* is also very sensitive to temperature, the optimum is about 82 F. In the temperature range of 77 F and 82 F reproduction is very rapid and may produce up to three generations per season.

Many trematodes are also affected by temperature fluctuations. The genus *Hysteromorpha*, a representative trematode with a life cycle involving fish and fish eating birds, is one of these. E. Huggins (2) es-

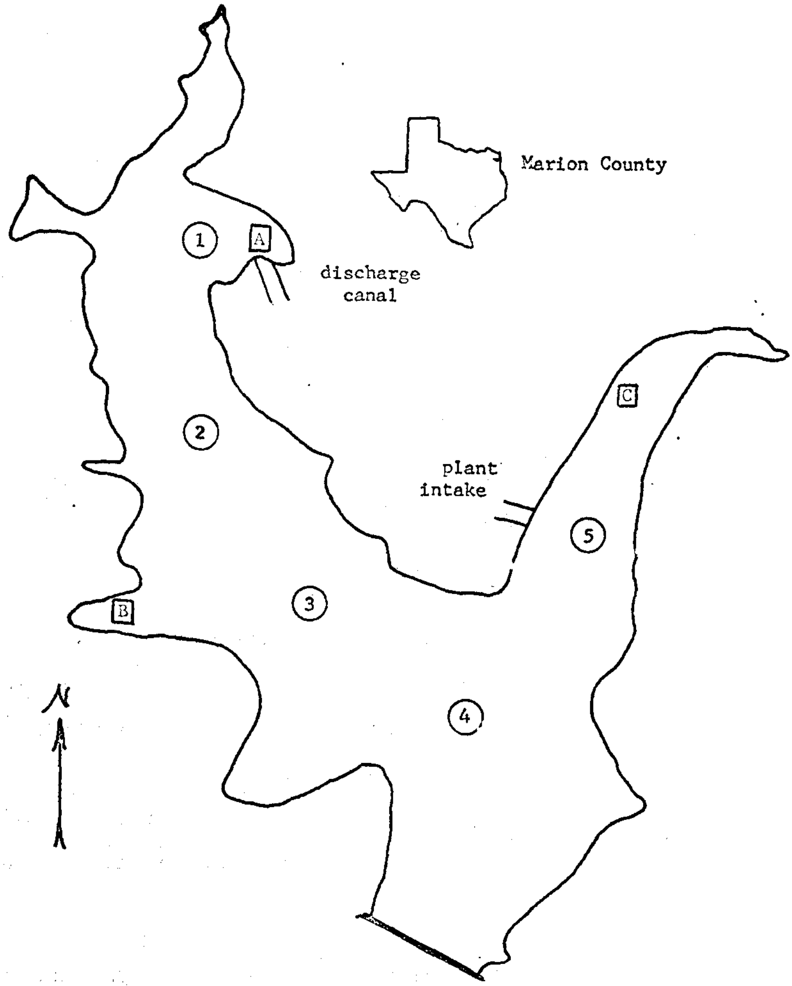

FIGURE 1. Wilkes Reservoir (Johnson Creek Reservoir) Marion County, Texas, showing collecting sites. Numerals designate permanent sampling stations Letters designate permanent seine stations. Scale: 2½ inches equals approximately one mile.

tablished that particularly rapid incubation occurs at temperatures higher than 86 F for *Hysteromorpha*. At a lower temperature development of the eggs is slower. Hatching of miracidiae at room temperature, 66F–72F, is very prolonged; at 98F the process is shorter and hatching is maximal, at 46 F development stops altogether. Metacercariae of the trematode live in fish muscle. Some writers believe these cysts may impair normal muscle function and cause hemorrhage and separation of muscle fibers.

MATERIALS AND METHODS

Five permanent sampling stations were designated within Wilkes Reservoir. Station 1 was approximately 200 yards from the mouth of the discharge canal. The remaining four stations were equally spaced throughout the reservoir to the intake. Three seine sampling stations were designated: station A at the discharge canal, station B in a cove area midway in the lake, and station C past the intake in one of the arms of the lake.

Data collected at each station included temperature and dissolved oxygen readings, plankton samples, chemical water analyses, and fish collections.

Dissolved oxygen and temperature analyses were made at each permanent sampling station with a YSI model 51A oxygen meter. Readings were taken at the surface, 2 feet, 5 feet, 10 feet, 12 feet, 15 feet, and then in five foot increments on to the bottom. These readings were profiled on a data sheet in order to determine the distribution and influence of the heated water.

Vertical plankton samples were taken at the sampling stations with a plankton tow net. Near normal temperatures were usually present to 15 feet, therefore, two 15 foot samples were taken at each station. These samples were placed in formalin, taken to the laboratory where a volume measurement was done on each sample collected. This measurement was converted into a milliliter per cubic foot figure. Plankton samples were checked for species composition. This was done to estimate plankton abundance throughout the reservoir.

Chemical water analysis was conducted at each station on sampling trips. Three samples were collected from each station with a Kemmerer water sampler; a surface sample, a sample from 15 feet, and a bottom sample. These samples were taken to the laboratory where the analysis was conducted using a Hach portable DR EL chemistry kit. Turbidity, pH, sulfate, phosphate, total alkalinity, total hardness, and chlorides were checked.

Specially designed experimental gill nets were prepared for collecting fish at each station. These nets measured 75 feet in length; 25 feet of 3 inch mesh, 25 feet of 2 inch mesh, 25 feet of 1 inch mesh, and were 24 feet deep. It was thought this type of net would offer some insight as to fish movement and distribution. Standard experimental gill nets are 150 feet in length with mesh size varying from 1 to 3½ inches in 25 foot increments. These nets are 8 feet deep. Fish collected were weighed, measured, length-frequency obtained, and examined for external and internal parasites. Fish specimens collected at the various stations were kept separate to better ascertain fish movement and distribution within the reservoir.

RESULTS

During February, the heated water was detected to a depth of 10 feet at station 1, and 5 feet at station 2. There was no noticeable effect of the heated water at stations 4 and 5. Figure 2 gives the maximum, minimum, and mean temperature during the sampling period. The heated water caused the range of temperature at stations 1 and 2 to be somewhat greater than the other stations.

During April, May, and June the extent of the heated water slowly spread throughout the reservoir. The temperature range increased as did the mean temperature during these months. The influence of the heated water was initially detected on the bottom at stations 1 and 2 during May, and increased during June. Station 1 at all times was affected more than the others.

In August temperature readings exceeding 100 F were taken throughout the reservoir to a depth of 10 feet. Surface temperature at the first two stations was 107.6 F-discharge canal reading was approximately 116 F. The mean temperature and the minimum temperature for station 4 was noticeably lower because the depth of this station is greater than the rest. All temperature readings from the bottom during August exhibited the influence of the heated water except station 4.

From August to November temperatures dropped considerably. The influence of the heated water had withdrawn to the top 5 feet at stations 1, 2, and 3. Temperature ranges during January were slightly

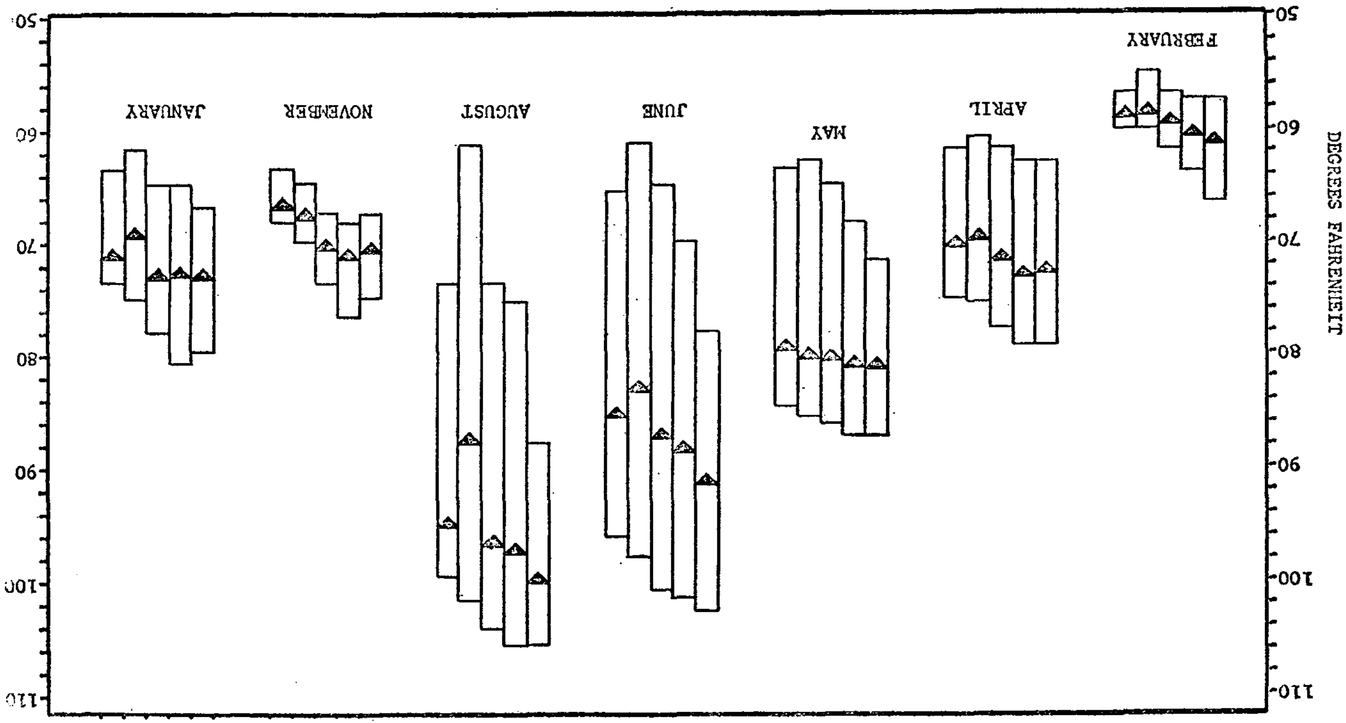

FIGURE 2. Maximum, minimum, and mean temperatures for permanent sampling stations, Wilkes Reservoir. Monthly readings given successively from station 1 to station 5.

► designates mean temperature.

higher than in November with the heated water most noticeable to a depth of 5 feet at the first three stations.

Dissolved oxygen was inversely proportional to the heated water with the lower readings at station 1, then progressively increasing to the last station. Acceptable dissolved oxygen concentrations were evident at all stations to near the bottom, during February, April, November, and January, and from the surface to 12-15 feet during May, June, and August. Like most lakes during summer months, the range of dissolved oxygen was considerably greater, figure 3. At no time did the dissolved oxygen approach unacceptable concentrations, or approach a condition more adverse than other area lakes not affected by a thermal effluent.

During June and August, conditions which fit the description of a thermocline were present throughout the reservoir at all depths. April exhibited a clearly defined thermocline between 12 and 15 feet. No clear thermocline could be designated at other times of the year.

Plankton samples were much greater during February than during other times of the year. Station 1 consistently had higher volumes of plankton than the other stations, figure 4. The volume of plankton declined as the water warmed until it reached a low volume during August. As a result of this decline in plankton volume, one sample was taken from 15 feet to surface, the other from the bottom at each station. There was no appreciable increase in plankton volume. The plankton volume increased steadily during October and November and into January. The majority of the plankton was composed of copepods, some cladocera were also noted. A small volume of phytoplankton was present, but no attempt to measure its volume alone was made. The phytoplankton was composed mainly of diatoms.

Wilkes Reservoir is exceptionally clear. The plankton net could almost always be seen to a depth of 12 feet.

Chemical water quality underwent no significant changes during the sampling period. There was a slight stratification of water quality during August.

A total of 211 fish were collected for examination. One hundred and sixty-one of these were game fish, and 50 were rough fish specimens.

The dominant species examined was the bluegill sunfish *(Lepomis macrochirus)* figure 5. Bluegill sunfish, largemouth bass *(Micropterus salmoides,)* and redear sunfish *(L. microlophus)* were the only game fish species caught in any significant number.

One hundred and twenty-nine of the 161 game fish collected were examined for parasites. Of the 129 examined, 86 or 66.6% were infected by at least one type of parasite. The most common parasite encountered in the examinations were trematodes.

Eight channel catfish *(Ictalurus punctatus)* were examined, and all eight were infected. Three of these were heavily infected with trematodes and nematodes, and had condition indexes of 1.44, 1.58, and 1.84. The fish with the least amount of parasitization had a condition index of 2.42.

Fifty-six percent of the largemouth bass were parasitized, mainly with trematodes. Some of the largemouth bass fingerlings were parasitized with acanthocephalans. The average condition index for 24 largemouth bass was 2.18. This figure was lower than condition indexes from most East Texas reservoirs during 1969. Condition indexes on other game fish collected were generally average compared to figures collected during 1969 on another Federal Aid Job.

Fifty rough fish specimens have been collected with examinations conducted on 47. The dominant species have been the yellow and black bullhead *(Ictalurus natalis* and *I. melas)*. Yellow bullhead and black bullhead catfish were parasitized at the rate of 86% and 93% respectively. During February, March, and April, nearly all bullheads examined were infected with *Argulus*. As the temperature rose above 86F this infestation dropped considerably both in number of infected fish and in number of parasites.

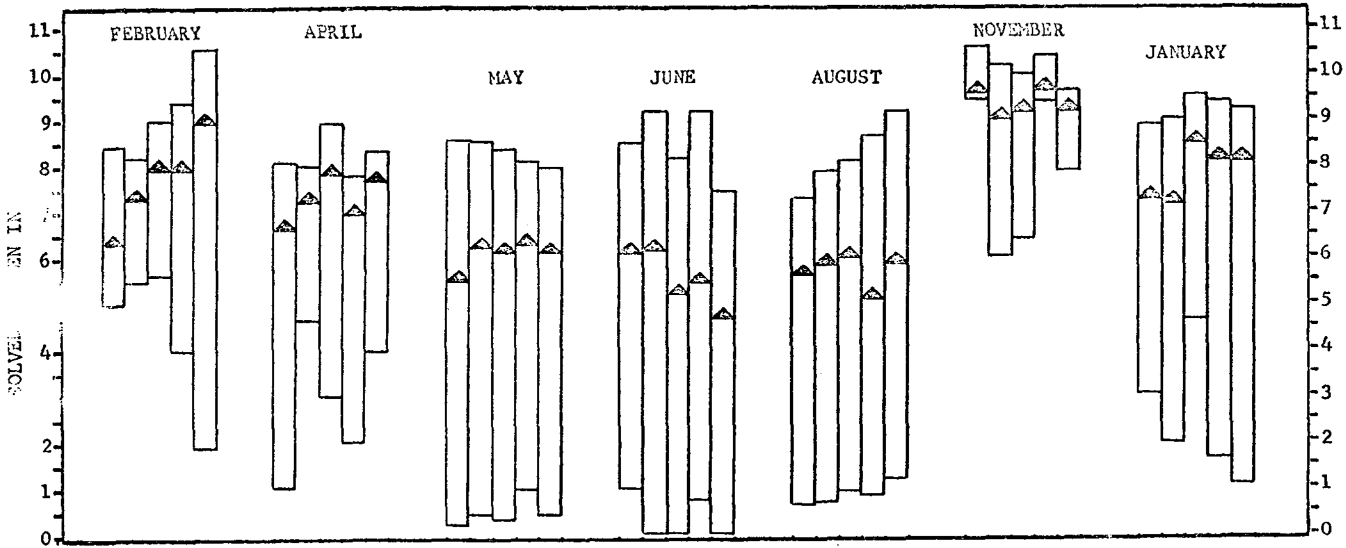

FIGURE 3. Maximum, minimum, and mean dissolved oxygen concentrations for permanent sampling stations, Wilkes Reservoir. Monthly readings given successively from station 1 to station 5.

► designates mean dissolved oxygen concentration.

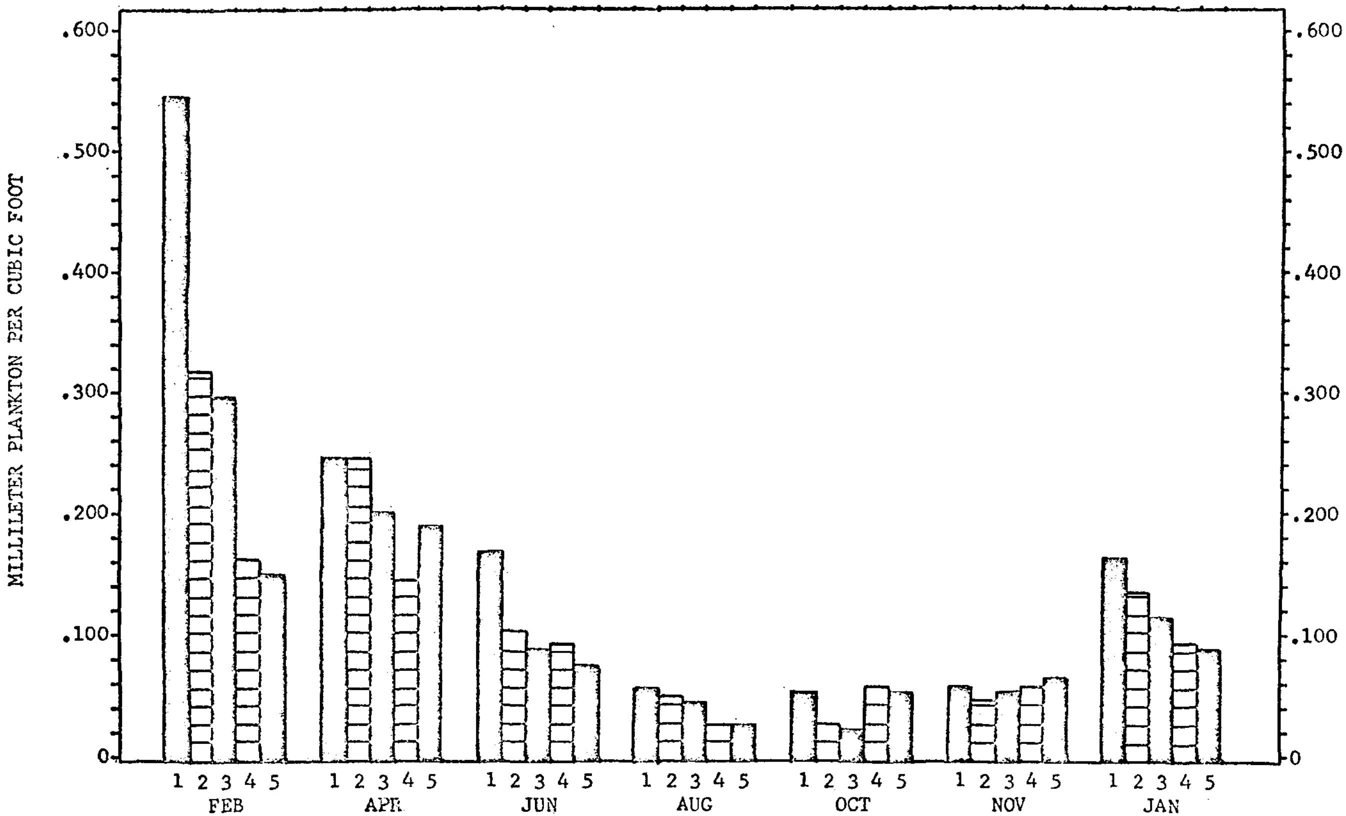

FIGURE 4. Plankton volumes for Wilkes Reservoir. Monthly readings given successively from station 1 to station 5.

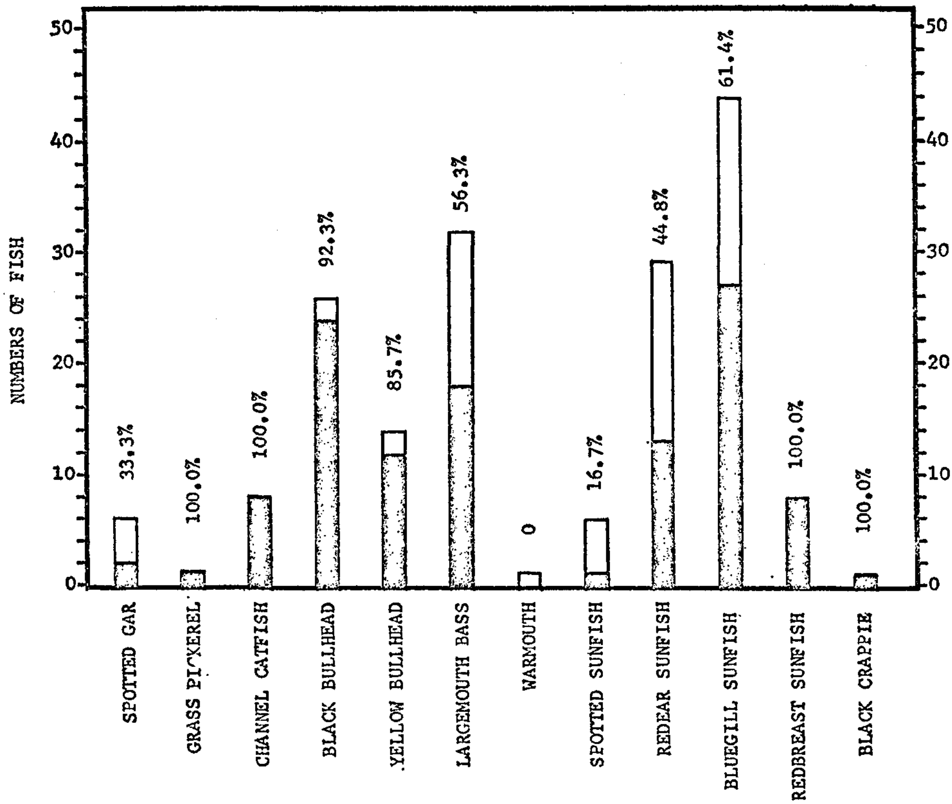

FIGURE 5. Showing fish species examined for parasites and number infected, Wilkes Reservoir.
☐ number examined ☐ number infected.

Game fish reproduction as reflected by seine samples was good. Fry of game fish species were not collected earlier than other area lakes not affected by a warm water effluent. The initial growth rates for the largemouth bass, however, was better than samples collected from nearby Lake O' the Pines.

Visual observations and seine sampling at the mouth of the discharge canal during August failed to produce any fish. Visual observations and seine sampling at seine station B showed the largemouth bass and sunfish to be in extremely shallow water along the shoreline. These samples were conducted during the morning hours and this water was much cooler than water 10 to 15 feet from the shoreline. This extremely shallow water still remained cool from the previous night.

During the experimental gill net sampling in August, standard experimental gill nets were set at stations 1, 3, and 5. The two specially built nets were set at stations 2 and 4. When the nets were set in the evening, surface temperature at station 1 was 107.6 F and declined progressively to 99.5 F at station 5. An early morning check of the nets revealed 43 fish at station 1, 2 fish at station 2, 16 fish at station 3, 1 fish at station 4, and 6 fish at station 5. Of the 68 fish collected, only 16 were alive. This is an extremely high percentage of dead fish in relation to mortality of netted fish conducted on other waters.

Fish within Wilkes Reservoir tend to congregate at the discharge canal during winter months. During this time of year, this area is a popular fishing area for various sunfish and catfish species.

Only 12 species of fish were collected either by seining or experimental gill net capture. In addition to these a small number of shiners (*Notropis sp.*) topminnows (*Fundulus sp.*), and mosquitofish (*Gambusia affinis*) were collected by seining. The chain pickerel (*Esox niger*) and flathead catfish (*Pylodictus olivaris*) are abundant in this drainage, but were not collected in Wilkes Reservoir. Only one black crappie (*L. nigromaculatus*) was collected, although it too is present in abundance within the drainage. The only rough fish species collected were the yellow and black bullhead. Smallmouth buffalo (*Ictiobus bubalus*) and spotted sucker (*Minytrema melanops*) are abundant in the drainage system, but were not collected in Wilkes Reservoir.

Circulation of water in the reservoir is very noticeable. Two units in operation have four water pumps with a combined pumping capacity of 214,000 gallons per minute. There is a strong pulling effect on a plankton tow net or Kemmerer water sampler at station 5—approximately 200 yards from the intake.

Various molluscs are present in abundance within the lake and make up an important part of the diet of certain fish species. Different types of water birds utilize this lake and were usually seen on collecting trips.

DISCUSSION

No clearly defined thermocline was present during the year with the exception of April.

The heated effluent affected the upper limits of the lake until the temperature reached the extent to where it spread throughout the lake. A large percentage of the heat dissipates into the air between the discharge canal and station 1.

Dissolved oxygen remained acceptable within the upper limits of the lake during summer months, and within the entire lake during other periods of the year. The heated water apparently has little deleterious effect upon dissolved oxygen concentration.

Indications are the heated effluent during winter months caused a significant increase in plankton volume in the immediate area of the discharge canal. Wilkes Reservoir, unlike other area lakes, has a preponderance of zooplankton which manifests itself in the clearness of the water.

Heated effluents apparently have no significant effect upon chemical water quality.

The extent of parasite infestation is considerably greater in Wilkes Reservoir than in other area lakes. Optimum or near optimum temperature conditions are present in all or a part of the reservoir throughout the year. Wilkes Reservoir is a "closed system" so to speak and contains all necessary members of life cycles of parasites encountered. Temperature condition in conjunction with the prerequisites necessary for parasite production have undoubtedly contributed to the extent of parasitization within this reservoir.

Heavily infected fish seem to manifest the extent of their parasitization in a lower condition index. This was evidenced in the channel catfish and largemouth bass.

Game fish did not spawn earlier than expected, although growth rates of largemouth bass fingerlings did show faster growth rates.

As a result of visual observations and seine sampling during August, fish present in shallow water seek out a suitable water temperature. The fish in Wilkes Reservoir can move into water having temperatures in excess of 100 F. They have acclimated themselves to withstand short durations of exposure to this heated water but had high mortalities when caught and held in it.

Another significant factor within this lake is the low number of fish species present. This would indicate that these species present in few numbers or absent altogether, yet being abundant within the drainage, cannot acclimate themselves to withstand the high temperatures evident in this lake.

The circulation of water in Wilkes Reservoir precludes any stagnation or chemical stratification from occurring.

ACKNOWLEDGMENTS

I wish to thank Mr. Joe E. Toole, Project Leader, Texas Parks and Wildlife Department, for his guidance and counseling throughout this study. I also wish to thank Fish and Wildlife Technicians Will P. Fisher, Jr., Wayne C. Griffing, and William C. Hankins, Jr., for their help in collecting field data and conducting fish parasite examinations.

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THE EFFECTS OF THE LAKE CATHERINE STEAM ELECTRIC PLANT EFFLUENT ON THE DISTRIBUTION OF FISHES IN THE RECEIVING EMBAYMENT

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ABSTRACT

In 1967 the Arkansas Power and Light Company and the Arkansas Game and Fish Commission cooperated in a joint project to determine any changes in the stratification, flow pattern, and basic water quality in the lower end of Lake Catherine and in the Ouachita River below Remmel Dam as affected by the increased cooling water output and water temperature resulting from the construction of a new power unit proposed for the Lake Catherine Steam Electric Station, Hot Spring County, Arkansas. A follow-up study of the project was conducted in the summer of 1970 to obtain post-installation data to be compared to that information recorded previously in 1967. In connection with this project, nine gill netting samples were made during the period February 25, 1970 to January 16, 1971 to determine the effects of the plant effluent on the distribution of fishes within the receiving embayment.

Using five nets of varying mesh sizes, set overnight in predetermined locations, a total of eight hundred and forty-seven (847) fish were collected weighing eight hundred and twenty-six and seven tenths (826.7) pounds.

A seasonal migration of fishes was evident as a greater poundage of fishes was collected in winter samples than in summer. Individual species were graphed to show dominant fishes during winter and egress of particular species in summer.

A direct correlation could not be made between fishes present in the bay and water temperatures. The maximum water temperature was 90°F. The average temperature in the effluent receiving bay in the summer of 1970 was 84°F which is very near the optimum growth temperature for most of the native warmwater species of fish in Lake Catherine.

An obvious relationship was noted between the availability of food and dissolved oxygen concentrations to the abundance of fishes within the receiving embayment.