ASSESSMENT OF THE EFFECTS OF ENVIRONMENTAL VARIABLES ON THE FISHERY OF THE KAW LAKE TAILWATER, OKLAHOMA

By

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Bachelor of Science

Southeastern Oklahoma State University

Durant, Oklahoma

1986

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1991

ASSESSMENT OF THE EFFECTS OF
ENVIRONMENTAL VARIABLES ON
THE FISHERY OF THE KAW
LAKE TAILWATER,
OKLAHOMA

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ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to Dr. A. V. Zale for his encouragement, patience, and advice throughout my graduate candidacy. I would also like to thank Drs. S. L. Burks, L. G. Talent, and W. D. Warde for serving on my graduate committee.

I would like to thank the staff, fellow graduate students, and technicians of the Oklahoma Cooperative Fish and Wildlife Research Unit for their assistance during this project. I would also like to acknowledge the financial support provided by the Oklahoma Municipal Power Authority, as well as the cooperation provided by the Oklahoma Department of Wildlife Conservation and the U. S. Army Corps of Engineers.

Above all I am grateful to my family, and especially my wife, Susie. Their patience and inspiration were major factors in the completion of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

Chapter II

Chapter III

Table Page

Table Page

Chapter IV

LIST OF FIGURES

Figure Page

Chapter II

Chapter III

Chapter IV

CHAPTER I

Introduction

This thesis is composed of three manuscripts written in formats suitable for submission to the Transactions of the American Fisheries Society. Each manuscript is complete without supporting materials. Chapter I is an introduction to the rest of the thesis. The manuscripts are as follows; Chapter II, "Environmental variables affecting angler effort in an Oklahoma tailwater fishery", Chapter III, "Environmental variables affecting angling success in an Oklahoma tailwater fishery", and Chapter IV, "Environmental variables affecting harvest of white crappie in an Oklahoma tailwater fishery".

CHAPTER II

ENVIRONMENTAL VARIABLES AFFECTING ANGLER EFFORT IN AN OKLAHOMA TAILWATER FISHERY

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Abstract.—An access-point creel survey of anglers using the Kaw Dam tailwater in north-central Oklahoma was conducted to evaluate environmental factors influencing angler effort. Relationships among daily pressure estimates and concurrent water quality measurements and climatological data were determined by multiple regression analyses. Angler effort was positively correlated with day-length, air temperature, and precipitation, and negatively correlated with wind velocity. Angler effort was also enhanced during weekends and evening hours. Discharge affected angler effort during both years, but the relationship was negative in 1987 (a wet year) and positive in 1988 (a dry year).

Information on tailwater fisheries is limited, but indicates that these areas are important sites for recreational angling in the United States (Pfitzer 1967). Webster's Dictionary (1986) defines a tailwater as "any water below a dam or waterpower development." A tailrace is defined as "a channel for conveying water away from a point of industrial application." For purposes of this treatise, the term tailwater will be used to denote both the tailrace and its accompanying tailwater in aggregate.

Tailwaters are popular among anglers in part because of the availability and variety of fishes that reside there. Dams often block upstream migration of fish, thereby increasing fish concentrations in tailwaters and simultaneously create large and varied sport fisheries (Eschmeyer and Miller 1949; Carter 1955). In the Tennessee Valley, tailwaters of mainstream dams account for about 35% of the estimated two million regional fishing trips made annually (Miller and Chance 1954). Of the estimated 3.15 million kg of fish harvested from these waters, 52% were harvested by tailwater anglers (Miller and Chance 1954).

The tailwaters of Table Rock, Tanneycomo, and Clearwater Reservoirs in Missouri received 7, 10, and 16 times more fishing pressure, per area, respectively, than the corresponding reservoirs (Fry 1962). Considering these reservoirs and tailwaters in aggregate, about 10% of fishing trips occurred on the tailwaters, which comprised only 1.5% of the combined area. In Oklahoma, the tailwater below Canton Reservoir comprised only 0.03% of the total sport fishing area of the reservoir but supported 37% of the annual fishing pressure (Moser and Hicks 1970).

Fishing pressure is directly related to the presence or absence of anglers, who are in turn influenced primarily by variations in climate. This can be a direct effect, such as unfavorable weather conditions, or an indirect effect, such as the unfavorable effects of the environment on fish behavior (Malvestuto et al. 1979). A creel survey and environmental monitoring were conducted to determine the effects of various environmental factors (Kaw Dam discharge, air temperature, barometric pressure, wind velocity, day-length, and precipitation) on fishing pressure in an Oklahoma tailwater fishery. This study addressed the hypothesis that environmental variables do not have a significant effect on fishing pressure in the Kaw tailwater.

Methods

Study Area

Kaw Lake is located on the Arkansas River about 13 km east of Ponca City, in Kay County, Oklahoma. Kaw Lake was authorized as part of the Flood Control Act of 1962 and was impounded in 1976. In addition to providing flood control, it is a component of the system of upstream reservoirs that maintains adequate flows for the Arkansas River navigational system. It also provides water for municipal and industrial uses in north central Oklahoma and is used intensively for recreation, including angling. The drainage area of Kaw Lake is about 18,850 km^2. Maximum water depths near the dam range from 17 to 26 m. Stratification usually occurs from late spring through early autumn with a thermocline at depths of 13 to 17 m.

The tailwater below the dam is accessible to both bank and boat anglers. Bank accessibility extends about 1.5 km downstream. Kaw Dam has a maximum recorded discharge capacity of 1200 cubic meters per second (cms). During the course of this study, fluctuations in discharge resulted mainly from a combination of weather factors and downstream requirements. Sport fishes present in the tailwater included white bass (Morone chrysops), striped bass (M. saxatilis), white crappie (Pomoxis annularis), walleye (Stizostedion vitreum), channel catfish (Ictalurus punctatus), and flathead catfish (Pylodictis olivaris) (Zale 1988).

Recreational Fishery Investigation

An access-point creel survey was used to obtain estimates of angler effort in the Kaw tailwater. The survey was conducted from March through October in 1987 and 1988. The survey consisted of ten randomly selected 8-hour periods per month. Sixty percent (6) of the creel periods occurred on weekends; 40% (4) occurred on weekdays. The 8-hour periods occurred between the following times: 0000-0800; 0800-1600; or 1600-2400. The creel periods were divided equally between the east and west banks of the dam. One access road leads to each bank; a roadblock creel was used to intercept anglers as they departed. A roving creel was performed following each roadblock creel period to survey anglers who were still fishing. Duration of angler use was recorded as the difference between time started fishing and time of interview.

Monitoring of Environmental Variables

Daily discharge rates from Kaw Dam were provided by the U.S. Army Corps of Engineers office at Kaw Lake. Discharge (cms) was expressed as instantaneous discharge for each creel period and as average daily discharge for the 7 and 14 days preceding each creel period. Air temperature (C), barometric pressure (mm Hg), and wind velocity (km/h) for each creel period were provided by the Federal Aviation Administration weather station at the Ponca City Airport. SUNRISE, a software program written to determine sunrises and sunsets, was used to determine hours of daylight during each creel period (Nickell 1983).

Rainfall was included in the study as two different variables because rainfall often has patchy distributions and because anglers from other areas, particularly southern Kansas, use the tailwater extensively. Precipitation, obtained from National Weather Bureau records, was expressed as cm of rainfall/day for the Kaw Lake area and as cm of rainfall/day for the southern Kansas area. A summary of all environmental and climatic variables used in the study is included in Table 1.

Four indicator variables were included in the study to account for differences in angler effort due to the time of day (0000-0800 h vs. 0800-1600 h, 0800-1600 h vs. 1600-2400 h, and 0000-0800 h vs. 1600-2400 h) or the day-type (weekday vs. weekend) in which the creel periods occurred. A summary of the indicator variables and their numeric values is included in Table 2.

Analyses

Estimates of total angler effort (AE) in angler hours were determined by multiplying the number of anglers in each angling party by the number of hours that party fished. These values were then summed for each creel period. These procedures were built in to a Statistical Analysis Systems (SAS) computer program specifically written for this study. Multiple-regression procedures (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984; SAS 1988) were used to generate a model for each year to determine if relationships existed and the degree of association between total angler effort and the environmental variables. The lowest mean square error value was used as the criterion for choosing the best model for each year (Montgomery and Peck 1982). Standardized partial regression coefficients were used to determine the importance of the environmental variables for each model (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984). Residual analyses were performed on each model to test for normality, linearity, and homogeneity of variance. The models were also tested for multicollinearity (Montgomery and Peck 1982; Zar 1984).

Results

Angler effort trends for the Kaw Dam tailwater in 1987 and 1988 were similar, but monthly estimates in 1987 were higher than in 1988 (Figure 1). Total angler effort gradually increased from March through June, and then decreased from June through the remainder of the creel season. Angler effort was artificially reduced during May of both years because the tailwater was closed to angling from May 16 to May 31 to protect spawning striped bass. During May 1988, road construction closed one bank of the tailwater, further decreasing effort estimates.

The multiple-regression models describing angler effort during 1987 and 1988 accounted for 71% and 49% of the variance, respectively (Tables 3 and 4). Both models were significant ($P = 0.0001$). Results of the residual analyses indicated that the variances were not homogeneous for either model. Log_{10} $(Y + 1)$ transformations were performed on angler effort values to homogenize variances.

During 1987, angler effort was positively correlated with hours of daylight during the creel period, air temperature, indicator variable 2 (0800-1600 h vs. 1600-2400 h), and indicator variable 4 (weekdays vs. weekends). Angler effort was negatively correlated with barometric pressure, average daily discharge for the previous 14 days, and wind velocity. Standardized partial regression coefficients indicated that hours of daylight during the creel period was the variable that best described angler effort during 1987.

Angler effort during 1988 was positively correlated with hours of daylight during the creel period, indicator variable 2 (0800-1600 h vs. 1600-2400 h), air temperature, average daily discharge for the previous 14 days, and daily precipitation for the southern Kansas area. Standardized partial regression coefficients indicated that hours of daylight during the creel period was the variable that best described angler effort during 1988.

Discussion

Anglers using the Kaw tailwater responded favorably to increases in day length and air temperature during both 1987 and 1988. During 1987, angler effort was enhanced during weekends (indicator variable 4) and anglers exhibited a preference for days when wind speeds were minimal or nonexistent.

During both years, anglers exhibited a preference for the 1600-2400 time period as opposed to the 0800-1600 time period (indicator variable 2). Anglers who worked during the day may have used late afternoon and evening hours to fish after leaving work.

Negative correlations existed between angler effort and barometric pressure at Jordan Dam tailwater, Alabama (Jackson and Davies 1988). Jackson and Davies hypothesized that anglers from Jordan Reservoir were seeking shelter in the tailwater area as a protection from incoming thunderstorms. I observed a similar response at the Kaw tailwater during 1987.

Previous studies have determined that angler effort can be enhanced under moderate or minimal-flow regimes (Tenant 1976; Jackson and Davies 1988), while high flows can be detrimental (White 1969). Kaw tailwater anglers exhibited similar responses by avoiding extremely high discharges during 1987, a high discharge year, and avoiding extremely low discharges during 1988, a low discharge year. Angler effort during 1988 increased as precipitation increased, indicating that anglers may have associated increased precipitation with increases in discharge. Precipitation amounts may have been more important to anglers during 1988, a dry year, than during 1987 when rainfall was plentiful.

Discharge was not the most important variable affecting angler effort in the Kaw tailwater, but it was the only manageable variable included in the models. Because anglers seemed to avoid extremely high and extremely low discharges, median discharges should be maintained whenever possible to elicit maximum recreational use of this fishery. However, these discharges may not be feasible at all times because of downstream flow requirements and fluctuating weather patterns.

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Table 1. Environmental and climatic variables used to describe angler effort in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987 and 1988.

Variable
Instantaneous discharge (cms)
Average daily discharge, previous 7 days (cms)
Average daily discharge, previous 14 days (cms)
Air temperature (C)
Barometric pressure (mm Hg)
Daily precipitation, Kaw Lake area (cm)
Daily precipitation, southern Kansas area (cm)
Wind velocity (km/h)
Hours of daylight during the creel period

Table 2. Summary of indicator variables used to describe the differences in angler effort due to the time of day (0000-0800 h vs. 0800-1600 h, 0800-1600 h vs. 1600-2400 h, and 0000-0800 h vs. 1600-2400 h) or day-type (weekday vs. weekend) in which the creel period occurred. Indicator variables describe the difference between those creel periods (one = 0000-0800, two = 0800-1600, three = 1600-2400) or day-types (wd = weekdays, we = weekends) listed in parentheses. Numeric values for the indicator variables are also listed.

		Variable 1	Variable 2	Variable 3	Variable 4
Daytype	Period	(one and three)	(two and three)	(one and two)	(wd and we)
weekday	one	-1	0	-1	-1
	two	0	-1	1	-1
	three	1	1	0	-1
weekend	one	-1	0	-1	1
	two	0	-1	1	1
	three	1	1	0	1

Table 3. Multiple-regression model describing total angler effort (AE, angler-hours) in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987. Standardized partial regression coefficients (b') and P values are listed for the model variables.

Log10 (total AE + 1) = 1.2917 + 0.1176(hours of daylight) + 0.0234(air temperature)
+ 0.1833(indicator variable 2) + 0.1331(indicator variable 4)
- 5.9052(barometric pressure) - 0.0008(average daily discharge, previous 14 days)
- 0.0194(wind velocity)

Model $R^2 = 0.71$
Model P = 0.0001

Variable	b'	P value
hours of daylight during the creel period	0.72	0.0001
air temperature	0.38	0.0001
indicator variable 2	0.37	0.0002
indicator variable 4	0.30	0.0001
barometric pressure	0.27	0.0008
average daily discharge, previous 14 days	0.24	0.0012
wind velocity	0.23	0.0010

Table 4. Multiple-regression model describing total angler effort (AE, angler-hours) in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988. Standardized partial regression coefficients (b') and P values are listed for the model variables.

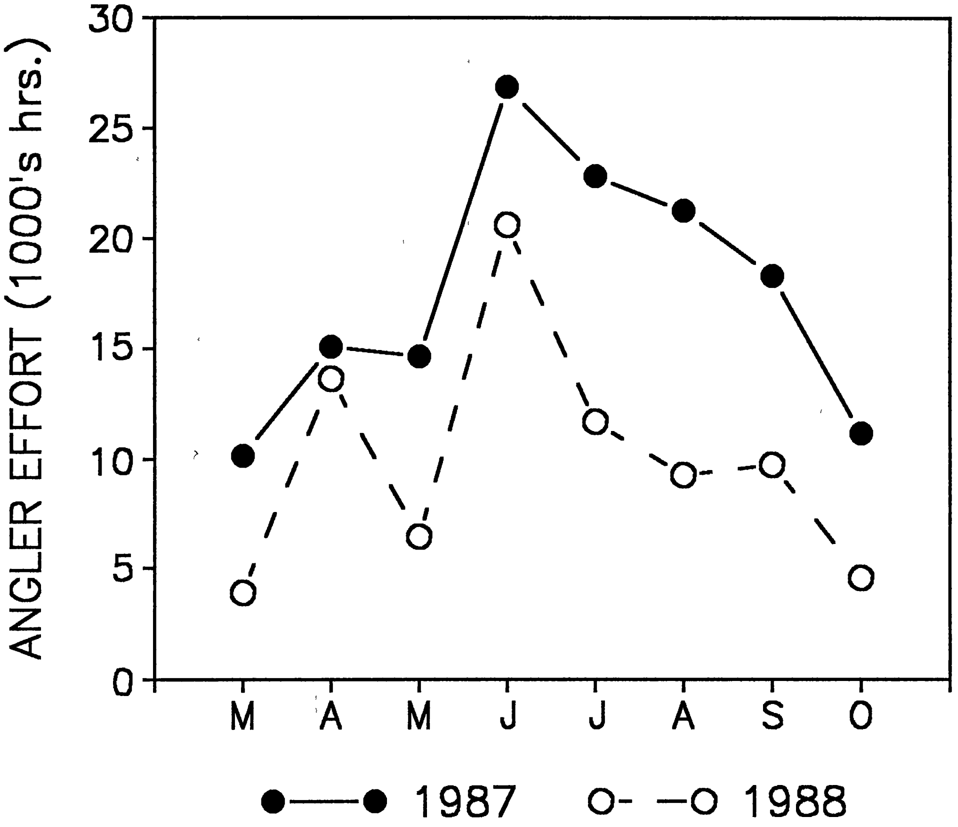
$$\text{Log10 (total AE + 1)} = 0.1434 + 0.1644(\text{hours of daylight}) + 0.2978(\text{indicator variable 2})$$
$$+ 0.0272(\text{air temperature}) + 0.0009(\text{average daily discharge, previous 14 days})$$
$$+ 0.2006(\text{daily precipitation, southern Kansas area})$$

Model $R^2 = 0.49$
Model $P = 0.0001$

Variable	b'	P value
hours of daylight during the creel period	0.75	0.0001
indicator variable 2	0.42	0.0004
air temperature	0.33	0.0004
average daily discharge, previous 14 days	0.16	0.0693
daily precipitation, southern Kansas area	0.13	0.1371

Figure Caption

1. Total angler effort estimates for the tailwater of the Arkansas River below Kaw Dam, Oklahoma, March-October, 1987-1988.


ANGLER EFFORT (1000's hrs.)
30
25
20
15
10
5
0
M
A
M
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S
O
●——● 1987
○- —○ 1988

CHAPTER III

ENVIRONMENTAL VARIABLES AFFECTING ANGLING SUCCESS IN AN OKLAHOMA TAILWATER FISHERY

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Abstract.—An access-point creel survey of anglers using the Kaw Dam tailwater in north-central Oklahoma was conducted to evaluate environmental factors influencing angling success. Relationships among weekly success estimates and concurrent water quality measurements and climatological data were determined by multiple regression analyses. Although water temperature, dissolved oxygen concentration, pH, conductivity, barometric pressure, and photoperiod affected angling success during both years, these relationships probably resulted from seasonal variations in these variables. Discharge affected angling success during both years, but the relationship was negative in 1987 (a wet year) and positive in 1988 (a dry year).

Information on tailwater fisheries is limited, but indicates that these areas are important sites for recreational angling in the United States (Pfitzer 1967). Webster's Dictionary (1986) defines a tailwater as "any water below a dam or waterpower development." A tailrace is defined as "a channel for conveying water away from a point of industrial application." For purposes of this treatise, the term tailwater will be used to denote both the tailrace and its accompanying tailwater in aggregate.

Tailwaters are popular among anglers (Miller and Chance 1954; Fry 1962; Moser and Hicks 1970), in part because of the availability and variety of fishes that reside there.

Dams often block upstream migration of fish, thereby increasing fish concentrations in tailwaters (Eschmeyer and Miller 1949; Carter 1955). Tailwaters below Tanneycomo and Clearwater reservoirs in Missouri yielded 847 and 2297 fish per hectare, respectively (Fry 1962). Angler catch in the tailwaters of Carlyle Reservoir, Illinois, consisted of 31 different species of fish (Fritz 1969).

Angling success is directly related to the presence or absence of anglers and fish, which are in turn influenced primarily by variations in climate and the environment (Malvestuto et al. 1979). A creel survey and environmental monitoring were conducted to determine the effects of various environmental factors (Kaw Dam discharge, water temperature, dissolved oxygen concentration, pH, conductivity, barometric pressure, and photoperiod) on angling success (catch-per-unit-effort, CPUE, and harvest-per-unit-effort, HPUE) for selected species in an Oklahoma tailwater fishery. This study addressed the hypothesis that environmental variables do not have a significant effect on angling success in the Kaw tailwater.

Methods

Study Area

Kaw Lake is located on the Arkansas River about 13 km east of Ponca City, in Kay County, Oklahoma. Kaw Lake was authorized as part of the Flood Control Act of 1962 and was impounded in 1976. In addition to providing flood control, it is a component of the system of upstream reservoirs that maintains adequate flows for the Arkansas River navigational system. It also provides water for municipal and industrial uses in north central Oklahoma and is used intensively for recreation, including angling. The drainage area of Kaw Lake is about 18,850 km^2. Maximum water depths near the dam range from 17 to 26 m. Stratification usually occurs from late spring through early autumn with a thermocline at depths of 13 to 17 m.

The tailwater below the dam is accessible to both bank and boat anglers. Bank accessibility extends about 1.5 km downstream. Kaw Dam has a maximum recorded discharge capacity of 1200 cubic meters per second (cms). During the course of this study, fluctuations in discharge resulted mainly from a combination of weather factors and downstream requirements. Sport fishes present in the tailwater included white bass (Morone chrysops), striped bass (M. saxatilis), white crappie (Pomoxis annularis), walleye (Stizostedion vitreum), channel catfish (Ictalurus punctatus), and flathead catfish (Pylodictis olivaris) (Zale 1988).

Recreational Fishery Investigation

An access-point creel survey was used to obtain estimates of angler success in the Kaw tailwater. The survey was conducted from March through October in 1987 and 1988. The survey consisted of ten randomly selected

8-hour periods per month. Sixty percent (6) of the creel periods occurred on weekends; 40% (4) occurred on weekdays. The 8-hour periods occurred between the following times: 0000-0800; 0800-1600; or 1600-2400. The creel periods were divided evenly between the east and west banks of the dam. One access road leads to each bank; a roadblock creel was used to intercept anglers as they departed. A roving creel was performed following each roadblock creel period to survey anglers who were still fishing. Duration of angler use (the difference between time started fishing and time of interview) was recorded as well as species caught and harvested.

Monitoring of Environmental Variables

Daily discharge rates (cms) from Kaw Dam were provided by the U.S. Army Corps of Engineers office at Kaw Lake. Other water quality parameters (water temperature (C), dissolved oxygen concentration (mg/liter), conductivity (S), and pH) were monitored 2-3 times per week using a Hydrolab Surveyor II. Barometric pressure (mm Hg) was obtained from the Federal Aviation Administration weather station at the Ponca City Airport. SUNRISE, a software program written to determine sunrises and sunsets, was used to determine photoperiod (Nickell 1983).

Analyses

White bass, channel catfish, and white crappie were the principal species composing harvest in the Kaw tailwaters during 1987 and 1988, and white bass, catfish in aggregate (channel catfish, flathead catfish, blue catfish, and black bullhead), and crappie in aggregate (white crappie and black crappie) were the principal taxa composing catch (Zale 1988). Catch data for catfish were grouped together to prevent possible bias from anglers misidentifying fish that were released. Catch data for crappie were similarly grouped. Analysis of angler success was limited to data concerning these three species or taxonomic groups individually.

Estimates of CPUE and HPUE (numbers of fish caught and harvested per angler hour) were calculated by calendar weeks (7-day intervals) for both years. Estimates of angler effort in angler hours were determined by multiplying the number of anglers in each angling party by the number of hours that party fished. These values were then summed for each 7-day interval, and CPUE and HPUE were determined using the equations

$$CPUE = Ct/AE$$

and

$$HPUE = Hv/AE;$$

Ct is the number of white bass, total crappie, or total catfish caught during a 7-day interval, Hv is the number of white bass, white crappie, or channel catfish harvested during a 7-day interval, and AE is the number of hours spent fishing during a 7-day interval. These procedures were built into a Statistical Analysis Systems (SAS) computer program specifically written for this study.

Discharge was expressed as a mean of the seven daily mean discharges for each calendar week (7-day interval). Water temperature, dissolved oxygen concentration, pH, and conductivity were expressed as a mean of those values collected for each calendar week. Barometric pressure and photoperiod were expressed as a daily mean for each calendar week. A summary of all environmental and climatic variables used in the study is included in Table 1.

Multiple-regression procedures (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984; SAS 1988) were used to generate models for each angler-success parameter to determine if relationships existed and the degree of association between angler-success and the environmental variables. The lowest mean square error value was used as the criterion for choosing the best angler success models for each year (Montgomery and Peck 1982). Standardized partial regression coefficients were used to determine the importance of the environmental variables for each model (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984). Residual analyses were performed on each model to test for normality, linearity, and homogeneity of variance. The models were also tested for multicollinearity (Montgomery and Peck 1982; Zar 1984).

Results

White Bass

White bass catch rates during both years were generally high during spring months (Figure 1). Catch rates during June and July were considerably lower then spring months. During 1988, catch rates remained depressed throughout the remainder of the creel season. However, catch rates steadily increased throughout the remainder of the 1987 creel season. White bass harvest trends were similar to catch trends.

The multiple-regression models describing white bass catch during 1987 (Table 2) and 1988 (Table 3) accounted for 41% and 49% of the variance, respectively, while the models describing white bass harvest accounted for 34% and 42% of the variance for each year, respectively. All models were significant. Because variances were not homogenous for any of the models, $\log_{10}(Y + 1)$ transformations were performed to homogenize variances.

During 1987, white bass CPUE was negatively correlated with discharge, pH, and photoperiod (Table 2). Standardized partial regression coefficients indicated that discharge was the variable that best described white bass catch. White bass HPUE was negatively correlated with discharge and pH

(Table 2). Standardized partial regression coefficients indicated that discharge was the variable that best described white bass harvest.

During 1988, white bass CPUE was positively correlated with discharge and was negatively correlated with dissolved oxygen concentration and conductivity (Table 3). Standardized partial regression coefficients indicated that discharge was the variable that best described white bass catch. White bass HPUE was positively correlated with discharge and was negatively correlated with dissolved oxygen concentration, photoperiod, and conductivity (Table 3). Standardized partial regression coefficients indicated that discharge was the variable that best described white bass harvest.

Crappie

Catch rates of crappie increased from March through late April or early May during both years (Figure 2). Catch rates then declined through June and into July, and remained depressed throughout the remainder of the creel season. White crappie harvest trends were similar to catch trends.

The multiple-regression models describing crappie catch during 1987 (Table 4) and 1988 (Table 5) accounted for 69% and 44% of the variance, respectively, while the models describing white crappie harvest accounted for 70% and 42% of the variance for each year, respectively. All models were significant. Because variances were not homogenous for any of the models, $\log_{10}$ (Y + 1) transformations were performed to homogenize variances. The models for 1988 included residuals which could not be normalized.

During 1987, crappie CPUE and white crappie HPUE were positively correlated with photoperiod and barometric pressure (Table 4). Crappie CPUE was also positively correlated with pH. Crappie CPUE and white crappie HPUE were negatively correlated with water temperature and discharge. Standardized partial regression coefficients indicated that water temperature was the variable that best described crappie catch and white crappie harvest.

During 1988, crappie CPUE and white crappie HPUE were positively correlated with photoperiod and discharge, and were negatively correlated with pH (Table 5). Standardized partial regression coefficients indicated that pH was the variable that best described crappie catch and white crappie harvest.

Catfish

Catfish catch rates during both years was highly variable and showed no distinct annual or seasonal patterns (Figure 3). Channel catfish harvest trends were similar to catch trends.

The multiple-regression models describing catfish catch during 1987 (Table 6) and 1988 (Table 7) accounted for only 15% and 19% of the variance, respectively, whereas the models describing channel catfish harvest accounted for 17%

and 14% of the variance, respectively. The model for channel catfish harvest during 1987 was the only significant model ($P = 0.05$). Because variances were not homogenous for any of the models, $\log_{10} (Y + 1)$ transformations were performed on catfish catch and channel catfish harvest values. The models for 1988 included residuals which could not be normalized.

During 1987, catfish CPUE was positively correlated with discharge (Table 6). Channel catfish HPUE was positively correlated with barometric pressure and discharge (Table 6). Standardized partial regression coefficients indicated that barometric pressure was the variable that best described channel catfish harvest.

During 1988, catfish CPUE was positively correlated with dissolved oxygen concentration and photoperiod, and was negatively correlated with discharge (Table 7). Standardized partial regression coefficients indicated that discharge was the variable that best described catfish catch. Channel catfish HPUE was positively correlated with water temperature (Table 7).

Discussion

The models generated for crappie catch, white crappie harvest, catfish catch, and channel catfish harvest during 1988 contained residuals which could not be normalized. However, multiple regression statistics are robust enough to perform well even if the residuals deviate somewhat from the requirement of normality (Zar 1984). Shapiro and Wilk's W statistic calculated for these models indicated the deviations were not severe (SAS 1988).

Water quality parameters can have significant effects on fish populations (Summers 1954; Fry 1960; Charles and McLemore 1973; Ball and Pettit 1974). Trends for water temperature, dissolved oxygen concentration, pH, and conductivity were similar for both years of my study, and values for these variables conformed to the minimum levels required for warm-water biological systems (FWPCA 1968). Although these variables were included in my models, these relationships showed little consistency between years or species. Therefore, the relationships that existed probably resulted from the seasonal variations in these variables combined with changes in angler catch and harvest rates associated with fluctuating discharge rates.

The effects of climate on angling success are not well documented. Photoperiod and barometric pressure were included in the models, but these relationships showed little annual consistency, and partial regression coefficients suggested that these variables were relatively unimportant. These relationships were probably also seasonal in nature.

Angling success can be enhanced during both low discharge periods (White 1969; Tennant 1976) and high discharge periods (Hanson 1977; Hamilton et al. 1985;

Jackson and Davies 1986). Discharge was an important environmental variable affecting white bass and crappie angling success during both years of my study. High discharges proved detrimental to white bass and crappie angling success during 1987, a high discharge year, whereas low discharges were detrimental during 1988, a low discharge year.

During 1987, white bass catch and harvest rates were generally higher during late summer months, when median discharges were present, than during spring months, when discharges were high. Consequently, white bass catch and harvest rates were negatively correlated with discharge during 1987. Conversely, white bass catch and harvest rates during 1988 were much lower during late summer months, when discharges were low, than during spring months, when discharges were higher. Consequently, white bass catch and harvest rates were positively correlated with discharge during 1988. Increases in white bass catch and harvest during spring months were probably less attributable to discharge than to annual prespawning migrations (Eschmeyer and Manges 1945; Miller and Chance 1954; Pfitzer 1962; Adornato 1990). Conversely, elevated white bass catches during the latter half of 1987 were probably the result of higher than usual forage abundances resulting from increased discharge rates. White bass prefer feeding in areas where food is abundant and then move on when the supply is exhausted (Walburg et al. 1981). Gizzard shad are often entrained into tailwaters (Louder 1958; Pfitzer 1962; Walburg 1971), and this species is the predominant forage species found in Kaw Lake (Hicks and Wolf 1982; Hicks and Wentroth 1983; Hicks 1988).

Discharge was also an important environmental variable affecting angling success for crappie during both years of my study. During spring months, white crappie move into shallow areas of reservoirs to spawn (Walburg 1981), and as a result are often carried over dams during periods of high discharge (Carter 1968; Cavender and Crunkilton 1974). High discharges can also promote emigration of white crappie out of tailwaters (Cross 1950). Increases in catch and harvest during spring months were probably attributable to immigration of spawning crappie from Kaw Lake caused by high discharge rates. However, extremely high discharges during March, 1987 may have caused the downriver migration of a sizable percentage of entrained crappie. This may account for the negative correlation between discharge and crappie catch and harvest during 1987. Positive correlations existed between discharge and crappie catch and harvest during 1988 because crappie were almost completely absent from angler catches during late summer months.

Channel catfish are an important species in those tailwaters where warm-water releases are prevalent (Walburg 1971; Goodno 1975), including the Kaw tailwater fishery

(Zale 1988). The catfish fishery seemed to be largely unaffected by environmental variables. Catch and harvest trends for catfish indicated no major seasonal or annual differences. The models generated for catfish catch and channel catfish harvest indicated considerable unexplained variance for both years.

Discharge was the most important environmental variable affecting angler success in the Kaw tailwater. Because extremely high and extremely low discharges proved detrimental to angler success, I recommend that intermediate discharges be maintained whenever possible. These discharges would promote migration of crappie into the tailwater from Kaw Lake as well as attract white bass into the tailwater during autumn. However, these discharges may not be feasible at all times because of downstream flow requirements and fluctuating weather patterns.

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Table 1. Environmental and climatic variables used to describe angler success in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987 and 1988.

Variable
Mean discharge (cms)
Mean water temperature (C)
Mean dissolved oxygen concentration (mg/liter)
Mean pH
Mean conductivity (S)
Mean barometric pressure (mm Hg)
Mean photoperiod (h)

Table 2. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for white bass in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987. Standardized partial regression coefficients (b') and P values are listed for the model variables.

Log10 (white bass CPUE + 1) = 4.1279 - 0.0007(discharge) - 0.4330(pH) - 0.0268(photoperiod)
Model R^2 = 0.41
Model P = 0.0030

Variable	b'	P value
discharge	0.63	0.0022
pH	0.43	0.0259
photoperiod	0.20	0.2281

Log10 (white bass HPUE + 1) = 2.6799 - 0.0005(discharge) - 0.3155(pH)
Model R^2 = 0.34
Model P = 0.0034

Variable	b'	P value
discharge	0.66	0.0013
pH	0.51	0.0095

Table 3. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for white bass in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988. Standardized partial regression coefficients (b') and P values are listed for the model variables.

Log_{10} (white bass CPUE + 1) = 0.3303 + 0.0006(discharge) - 0.0163(dissolved oxygen concentration) - 129.3417(conductivity)

Model R^2 = 0.49

Model P = 0.0009

Variable	b'	P value
discharge	0.66	0.0111
dissolved oxygen concentration	0.39	0.0651
conductivity	0.28	0.1330

Log_{10} (white bass HPUE + 1) = 0.3643 + 0.0002(discharge) - 0.0093(dissolved oxygen concentration) - 0.0142(photoperiod) - 73.3630(conductivity)

Model R^2 = 0.42

Model P = 0.0112

Variable	b'	P value
discharge	0.67	0.0174
dissolved oxygen concentration	0.60	0.0210
photoperiod	0.57	0.0384
conductivity	0.44	0.1387

Table 4. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for crappie in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987. Standardized partial regression coefficients (b') and P values are listed for the model variables.

$$\text{Log10 (crappie CPUE + 1)} = -0.8600 - 0.0112(\text{water temperature}) + 0.0490(\text{photoperiod}) - 0.0003(\text{discharge}) + 0.9560(\text{barometric pressure}) + 0.0655(\text{pH})$$

Model $R^2 = 0.69$

Model $P = 0.0001$

Variable	b'	P value
water temperature	1.24	0.0001
photoperiod	1.15	0.0001
discharge	0.70	0.0014
barometric pressure	0.27	0.0478
pH	0.21	0.1582

$$\text{Log10 (white crappie HPUE + 1)} = -0.2361 - 0.0071(\text{water temperature}) + 0.0322(\text{photoperiod}) - 0.0002(\text{discharge}) + 0.5698(\text{barometric pressure})$$

Model $R^2 = 0.70$

Model $P = 0.0001$

Variable	b'	P value
water temperature	1.34	0.0001
photoperiod	1.28	0.0001
discharge	0.86	0.0001
barometric pressure	0.28	0.0370

Table 5. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for crappie in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988. Standardized partial regression coefficients (b') and P values are listed for the model variables. Models denoted with an (*) contained residuals which could not be normalized.

Log10 (crappie CPUE + 1) = 0.6524 - 0.1013(pH) + 0.0115(photoperiod) + 0.0001(discharge)*
Model R^2 = 0.44
Model P = 0.0028

Variable	b'	P value
pH	0.39	0.0375
photoperiod	0.36	0.0342
discharge	0.31	0.0871

Log10 (white crappie HPUE + 1) = 0.5453 - 0.0828(pH) + 0.0084(photoperiod) + 0.0001(discharge)*
Model R^2 = 0.42
Model P = 0.0040

Variable	b'	P value
pH	0.46	0.0161
photoperiod	0.38	0.0266
discharge	0.20	0.2692

Table 6. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for catfish in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1987. Standardized partial regression coefficients (b') and P values are listed for the model variables.

$\mathrm{Log10}\ (\text{catfish CPUE} + 1) = 0.0426 + 0.0001(\text{discharge})$
Model $R^2 = 0.15$
Model $P = 0.0377$

Variable	b'	P value
discharge	0.38	0.0377

$\mathrm{Log10}\ (\text{channel catfish HPUE} + 1) = 0.0148 + 0.4774(\text{barometric pressure})$
$+ 0.0001(\text{discharge})$
Model $R^2 = 0.17$
Model $P = 0.0815$

Variable	b'	P value
barometric pressure	0.34	0.0694
discharge	0.29	0.1087

Table 7. Multiple-regression models describing angler success (CPUE, catch-per-unit-effort and HPUE, harvest-per-unit-effort) for catfish in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988. Standardized partial regression coefficients (b') and P values are listed for the model variables. Models denoted with an (*) contained residuals which could not be normalized.

Log10 (catfish CPUE + 1) = -0.2279 - 0.0004(discharge) + 0.0137(dissolved oxygen concentration) + 0.0137(photoperiod)*

Model R^2 = 0.19

Model P = 0.1619

Variable	b'	P value
discharge	0.61	0.0302
dissolved oxygen concentration	0.48	0.0953
photoperiod	0.30	0.1695

Log10 (channel catfish HPUE + 1) = -0.0058 + 0.0016(water temperature)*

Model R^2 = 0.14

Model P = 0.0541

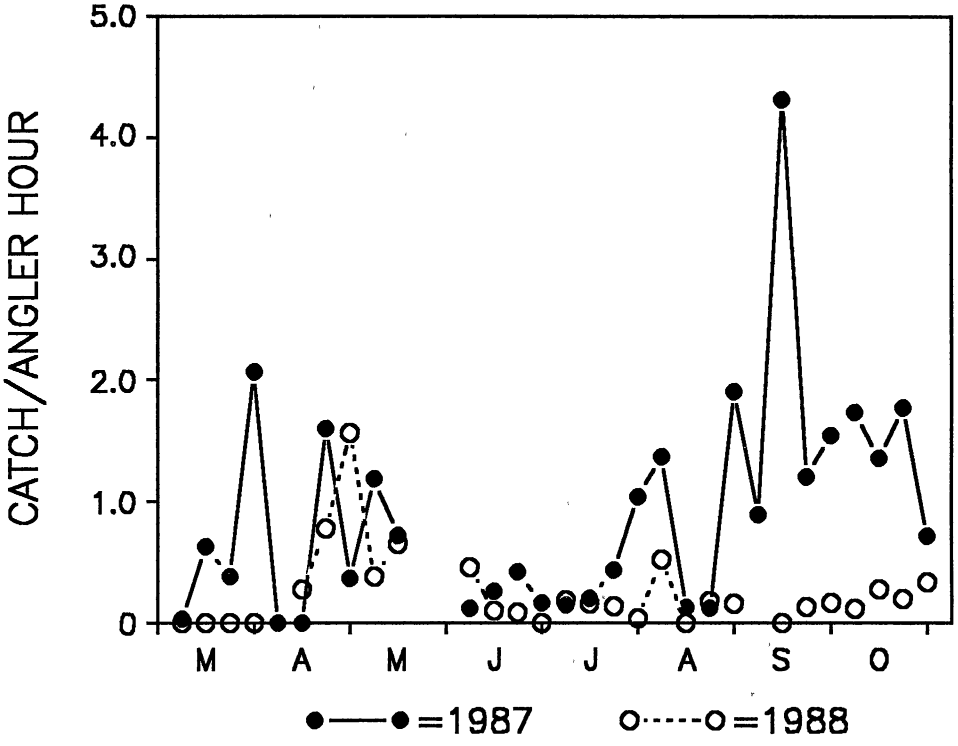
Variable	b'	P value
water temperature	0.37	0.0541

Figures Captions

1. Weekly CPUE estimates for white bass in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, March-October, 1987-1988.

2. Weekly CPUE estimates for crappie in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, March-October, 1987-1988.

3. Weekly CPUE estimates for catfish in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, March-October, 1987-1988.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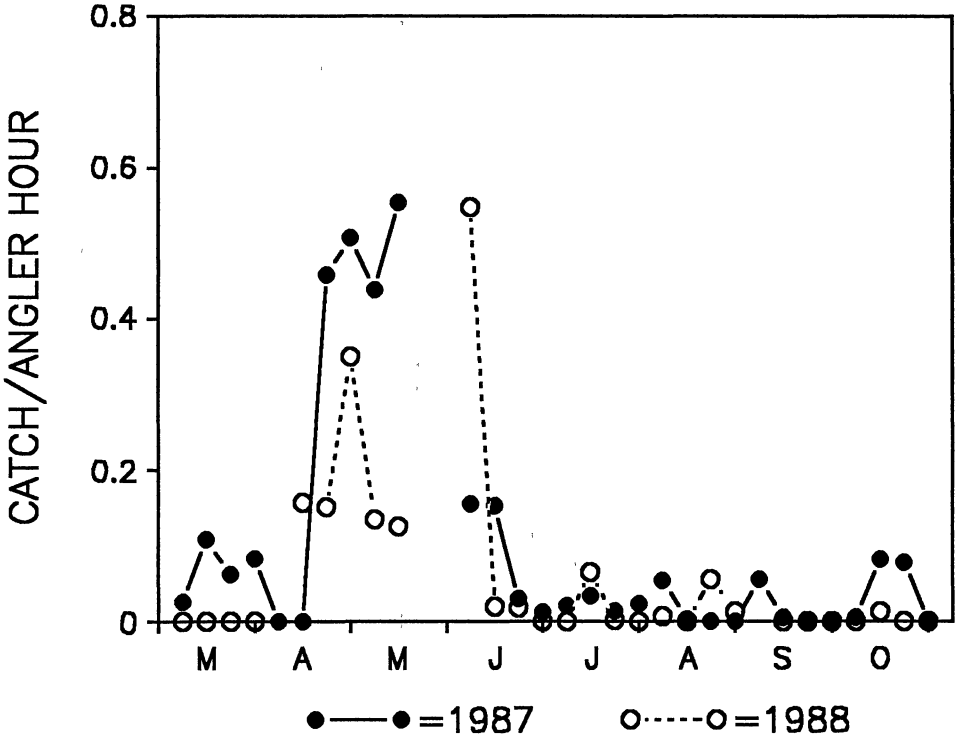
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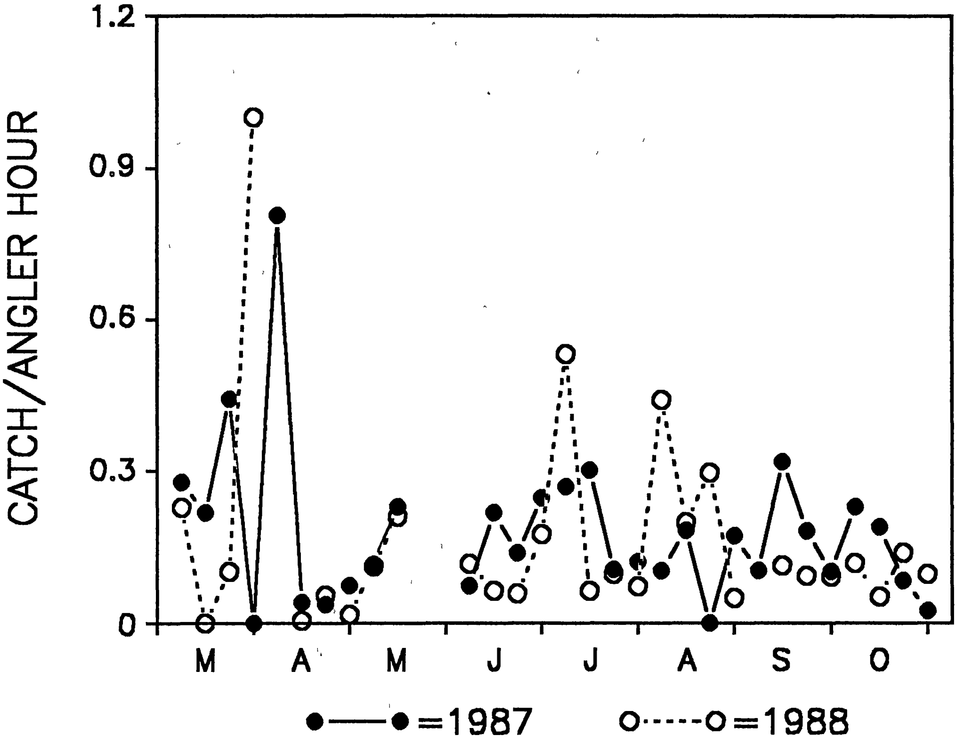
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CHAPTER IV

ENVIRONMENTAL VARIABLES AFFECTING HARVEST OF WHITE CRAPPIE IN AN OKLAHOMA TAILWATER FISHERY

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Abstract.—Quantitative information on white crappie (Pomoxis annularis) in tailwaters is limited. A tagging study was conducted to evaluate environmental variables influencing angler harvest rates of white crappie in the Kaw Dam tailwater in north-central Oklahoma. Relationships among harvest rates and concurrent water quality measurements and climatological data were determined by multiple regression analyses. Although pH, photoperiod, dissolved oxygen concentration, and barometric pressure affected white crappie harvest rates, these relationships probably resulted from seasonal variations in these variables. Discharge was an important environmental variable affecting white crappie harvest rates. While high discharges may promote immigration of crappie from Kaw Lake into the tailwater, they may also cause the downriver migration of a sizable percentage of these individuals.

Information on tailwater fisheries is limited, but indicates that these areas are important sites for recreational angling in the United States (Pfitzer 1967). Webster's Dictionary (1986) defines a tailwater as "any water below a dam or waterpower development." A tailrace is defined as "a channel for conveying water away from a point of industrial application." For purposes of this treatise, the term tailwater will be used to denote both the tailrace and its accompanying tailwater in aggregate.

Tailwaters are popular among anglers (Miller and Chance 1954; Fry 1962; Moser and Hicks 1970), and this is in part due to the availability and variety of fishes that reside there. Dams often block upstream migration of fish, thereby increasing fish concentrations in tailwaters (Eschmeyer and Miller 1949; Carter 1955). In the tailwaters below Tanneycomo and Clearwater reservoirs in Missouri, the yield per hectare was 847 and 2297 fish, respectively (Fry 1962). Angler catch in the tailwaters of Carlyle Reservoir, Illinois, consisted of 31 different species of fish (Fritz 1969).

White crappie (<u>Pomoxis</u> <u>annularis</u>) are an important sport species in many tailwaters (Hall and Latta 1951; Pfitzer 1962; Carter 1969). During spring months, white crappie move into shallow areas of reservoirs to spawn (Walburg 1981), and as a result are often carried over dams during periods of high discharge (Cross 1950; Carter 1968; Cavender and Crunkilton 1974). A tagging study and environmental monitoring were conducted to determine the harvest rate of white crappie and described the effects of various environmental factors (Kaw Dam discharge, water temperature, dissolved oxygen concentration, pH, conductivity, barometric pressure, and photoperiod) on the harvest of white crappie in an Oklahoma tailwater fishery. This study addressed the hypothesis that environmental variables do not have a significant effect on white crappie harvest rates in the Kaw tailwater.

Methods

Study Area

Kaw Lake is located on the Arkansas River about 13 km east of Ponca City, in Kay County, Oklahoma. Kaw Lake was authorized as part of the Flood Control Act of 1962 and was impounded in 1976. In addition to providing flood control, it is a component of the system of upstream reservoirs that maintains adequate flows for the Arkansas River navigational system. It also provides water for municipal and industrial uses in north central Oklahoma and is used intensively for recreation, including angling. The drainage area of Kaw Lake is about 18,850 km^2. Maximum water depths near the dam range from 17 to 26 m. Stratification usually occurs from late spring through early autumn with a thermocline at depths of 13 to 17 m.

The tailwater below the dam is accessible to both bank and boat anglers. Bank accessibility extends about 1.5 km downstream. Kaw Dam has a maximum recorded discharge capacity of 1200 cubic meters per second (cms). During the course of this study, fluctuations in discharge resulted mainly from a combination of weather factors and downstream requirements.

Sport fishes present in the tailwater included white bass (<u>Morone chrysops</u>), striped bass (<u>M. saxatilis</u>), white crappie, walleye (Stizostedion vitreum), channel catfish (Ictalurus punctatus), and flathead catfish (Pylodictis olivaris) (Zale 1988).

White Crappie Harvest Investigation

Harvest rates of white crappie in the Kaw tailwater were estimated by tagging in 1988. Tagging was conducted from February through May. Four trap nets fished for 24 hours two to three times per week were used to capture white crappie. Individuals captured in each net were enumerated and a numbered anchor tag was attached prior to release. Trap netting was discontinued after 21 June 1988. A total of 685 white crappie > 200 mm were tagged.

Signs detailing the tagging effort were posted in the tailwater area to familiarize anglers with the study and encourage return of tags. Tag check stations were set up at two local bait stores. Reward caps were provided to anglers as an incentive to return tags.

Monitoring of Environmental Variables

Daily discharge rates (cms) from Kaw Dam were provided by the U.S. Army Corps of Engineers office at Kaw Lake. Additional water quality parameters (water temperature (C), dissolved oxygen concentration (mg/liter), conductivity (S), and pH) were monitored 2-3 times per week using a Hydrolab Surveyor II. Barometric pressure (mm Hg) was provided by the Federal Aviation Administration weather station at the Ponca City Airport. SUNRISE, a software program written to determine sunrises and sunsets, was used to determine photoperiod (Nickell 1983).

Analyses

The absolute abundance of white crappie in the Kaw tailwater was estimated using Chapman's modified Schnabel equation,

$$N=\Sigma(C_tM_t)/(R+1);$$

N is the population abundance estimate, C_t is the total sample taken on day t, M_t is the total marked fish at large at the start of day t, and R is the total recaptures during the experiment (Ricker 1975; Seber 1973). The harvest rate of white crappie was determined by dividing the estimated number of white crappie harvested (Chapter III) by the population abundance estimate. A second independent harvest rate was determined by dividing the number of tags returned by anglers during the entire study by the total number of white crappie tagged. Harvest rates were also determined by calendar weeks and were expressed as the number of tags returned by anglers divided by the number of tagged white crappie still at large.

Discharge was expressed as a mean of the seven daily mean discharges for each calendar week (7-day interval). Water temperature, dissolved oxygen concentration, pH, and conductivity were expressed as a mean of those values collected for each calendar week. Barometric pressure and photoperiod were expressed as a daily mean for each calendar week. A summary of all environmental and climatic variables used in the study is included in Table 1.

Multiple-regression procedures (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984; SAS 1988) were used to generate a model to determine if a relationship existed and the degree of association between white crappie harvest and the environmental variables. The lowest mean square error value was used as the criterion for choosing the best model (Montgomery and Peck 1982). Standardized partial regression coefficients were used to determine the importance of the environmental variables (Steel and Torrie 1980; Montgomery and Peck 1982; Zar 1984). Residual analyses were performed on each model to test for normality, linearity, and homogeneity of variance. The model was also tested for multicollinearity (Montgomery and Peck 1982; Zar 1984).

Results

A total of 102 tagged white crappie were reported harvested by Kaw tailwater anglers, indicating a minimum harvest rate of 14.9%. The absolute abundance estimate (95% confidence limits) of white crappie in the Kaw tailwater was 7676 (6133-9885) individuals. An estimated total of 6965 white crappie were harvested from March-October, 1988 (Chapter III), suggesting a second independent harvest rate of 90.7%.

White crappie harvest rates increased during April and remained relatively high during May and into June. Harvest rates then declined during the latter part of June and remained depressed throughout the remainder of the study (Figure 1).

The multiple-regression model describing white crappie harvest accounted for 71% of the variance (Table 2). The model was significant (P=0.0001). Results of the residual analyses indicated that the variance was not homogenous for the model. Log_{10} (Y + 1) transformations were performed on white crappie harvest values to homogenize the variance.

White crappie harvest was positively correlated with discharge and photoperiod, and was negatively correlated with pH, dissolved oxygen concentration, and barometric pressure. Standardized partial regression coefficients indicated that pH was the variable that best described white crappie harvest.

Discussion

High discharges can promote immigration of white crappie into tailwaters (Carter 1968; Siefert 1969; Cavender and Crunkilton 1974) as well as promote emigration of white crappie out of tailwaters (Cross 1950). Tag return data indicated that most (97.1%) of the tagged white crappie returned were caught within 200-300 m of where they were released after tagging. However, one individual was caught during April, about 2 km from its release site and two individuals were caught during June, about 4 km from their release sites. These three individuals were all tagged during April when dam discharges were at their highest. High discharges may have caused the downriver migration of a sizeable percentage of tagged individuals. Angling pressure is more intense in the tailwater area directly below the dam than it is downriver, thereby decreasing the likelihood that tagged individuals would be caught once they moved out of the vicinity of the dam. This may help explain the discrepancy between the two harvest estimates. White crappie immigrating into the tailwater immediately previous to decreases in discharge were probably less likely to move downriver. Harvest of these individuals approached 100%. Although those white crappie flushed out of the tailwater area may have migrated downriver to Keystone Reservoir, it is also possible that these individuals sought refuge in pools and back-water areas along the river.

Although pH and dissolved oxygen concentration were included in the model, values for these variables conformed to the minimum levels required for warm-water biological systems (FWPCA 1968). Therefore, these relationships probably resulted from the seasonal variations in these variables combined with changes in angler harvest of white crappie associated with fluctuating discharge rates.

The effects of climate on harvest of white crappie are not well documented. Photoperiod was included in the model, indicating that white crappie harvest was enhanced as days became longer. Barometric pressure was also included, but partial regression coefficients indicate this variable was relatively unimportant to the model.

Angling success can be enhanced as discharges increase (Hanson 1977; Hamilton et al. 1985). Discharge was an important environmental variable affecting white crappie harvest during 1988. Low discharges proved detrimental to white crappie harvest rates. However, this relationship was in part due to the absence of crappie in the tailwater during late summer and autumn months when discharges were low. Although high discharges may promote migration of white crappie downriver, they also promote migration of white crappie into the tailwater from Kaw Lake. Therefore, these discharges should be maintained whenever possible. However, these discharges may not be feasible at all times because of downstream flow requirements and fluctuating weather patterns.

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Table 1. Environmental and climatic variables used to describe white crappie harvest in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988.

Variable
Mean discharge (cms)
Mean water temperature (C)
Mean dissolved oxygen concentration (mg/liter)
Mean pH
Mean conductivity (S)
Mean barometric pressure (mm Hg)
Mean photoperiod (h)

Table 2. Multiple-regression model describing harvest of white crappie in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, 1988. Standardized partial regression coefficients (b') and P values are listed for the model variables.

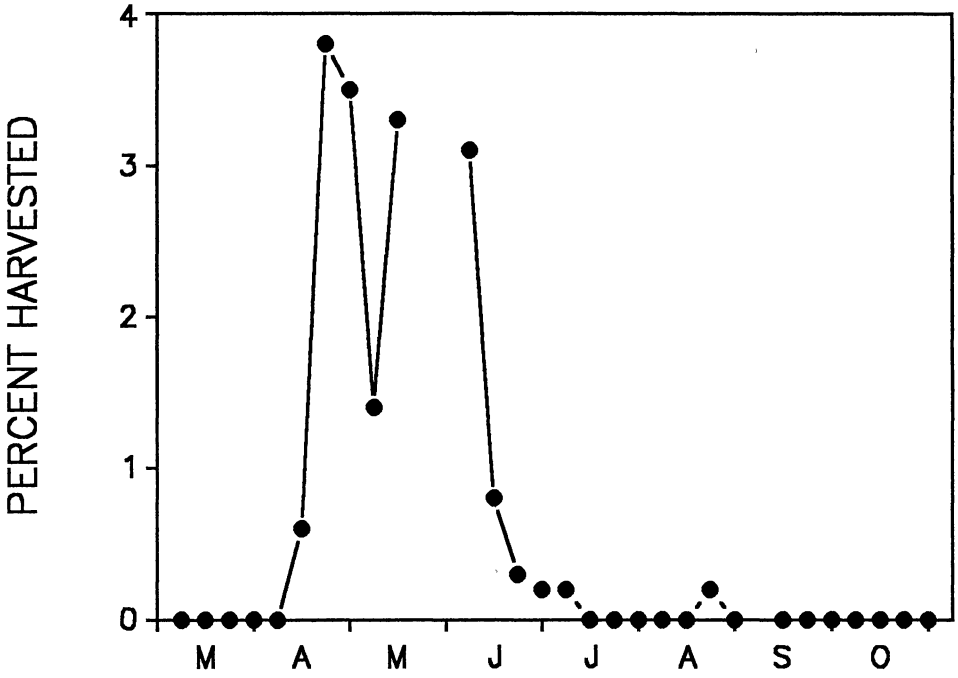
Log10 (percent harvested + 1) = 5.4536 - 0.7624(pH) + 0.0010(discharge) + 0.0592(photoperiod) - 0.2121(dissolved oxygen concentration) - 2.2255 (barometric pressure)

Model R^2 = 0.71
Model P = 0.0001

Variable	b'	P value
pH	0.56	0.0002
discharge	0.45	0.0172
photoperiod	0.35	0.0124
dissolved oxygen concentration	0.22	0.2136
barometric pressure	0.14	0.2575

Figure Caption

1. Weekly harvest rates (the number of tags returned by anglers weekly divided by the number of tagged white crappie still at large) for white crappie in the tailwater of the Arkansas River below Kaw Dam, Oklahoma, March-October, 1988.


PERCENT HARVESTED
0
1
2
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VITA

Kenneth Karl Cunningham

Candidate for the Degree of

Master of Science

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