LITERATURE CITED

Chabreck, R. H. 1960. Coastal marsh impoundments for ducks in Louisiana. Proceedings 14th Annual Conference Southeastern Association of Game and Fish Commissioners. pp. 24-29.

Ensminger, A. B. 1963. Construction of levees for impoundments in Louisiana marshes. Proceedings 17th Annual Conference Southeastern Association of Game and Fish Commissioners. pp. 440-446.

LaCaze, C. G. 1966. More about crawfish. Louisiana Wild Life and Fisheries Commission. Wildlife Education Bulletin No. 96. 16 p.

Perry, W. G. and C. G. LaCaze. 1969. Preliminary experiment on the culture of red swamp crawfish, *Procambarus clarki*, in brackish water ponds. Proceedings 23rd Annual Conference Southeastern Association of Game and Fish Commissioners. (In press).

Thomas, C. H. 1963. A preliminary report on the agricultural production of the red swamp crawfish, *Procambarus clarki* (Girard), in Louisiana rice fields. Proceedings Southeastern Association of Game and Fish Commissioners. 17: 180-186.

Viosca, P., Jr. 1961. Crawfish culture, mudbug farming. Louisiana Conservationist. 13(3): 5-7.

INFLUENCE OF TEMPERATURE AND PHOTOPERIOD ON GROWTH, FOOD CONSUMPTION AND FOOD CONVERSION EFFICIENCY OF CHANNEL CATFISH

by

R. V. Kilambi, J. Noble and C. E. Hoffman
Department of Zoology, University of Arkansas
Fayetteville, Arkansas 72701

ABSTRACT

A total of 275 channel catfish, measuring on the average of 21.4 mm in total length were raised in the laboratory for 120 days under controlled temperatures of 26, 28, and 32 C with 10-hr and 14-hr photoperiods. Data on growth, food consumption, food conversion efficiency, and water quality were collected at 15-day intervals.

Analysis of length-weight relationship showed that the experimental conditions had no effect on body shape. The fish under 28C-10L had slow growth in length throughout the study period. Variations in food consumption and food conversion efficiency in 15-day intervals were discussed. Average food consumption and food conversion efficiency for the entire study period were discussed in relation to temperature-photoperiod combinations. The fish at 28 and 32 C consumed more food under 10-hr than under 14-hr light conditions. There was a direct relationship between photoperiod and food conversion efficiency for the fish at all the three temperatures. Based on overall evaluation of growth, food consumption, food conversion efficiency, water quality, and mortalities, it was concluded that the optimum condition for raising channel catfish was at 32 C under a 14-hr photoperiod.

INTRODUCTION

Seasonal growth cycles of fishes have been attributed to seasonal changes in environmental temperature. Temperature may affect the growth of poikilothermic animals by altering the metabolic rate. However, light also varies with seasons and thus any interpretation of growth cycles should take temperature as well as photoperiod into consideration. These two factors independently or together influence the endocrine organs, activity of fish, food consumption, and food conversion efficiency and thereby the growth of fishes.

An enormous amount of literature on field studies on growth of fishes is available but there is a paucity of experimental work on fishes. Baldwin (1956), Brown (1946), Felin (1951), and Strawn (1961) reported on the effects of temperature on growth of fishes. Gibson and Hirst (1955) and Kinne (1960) studied the effects of temperature and salinity on the growth of guppies and desert pupfish, respectively. Eisler (1957), and Gross, Roelfs and Fromm (1965) worked on the effect of light on the growth of chinook salmon and green sunfish, respectively.

Published work on channel catfish with controlled experimental conditions is meager. West (1966) studied the effects of temperature on growth, food consumption, food conversion efficiency and survival of channel catfish. The purpose of this study was to evaluate the combined effects of temperature and photoperiod on growth, food consumption and food conversion efficiency of channel catfish.

MATERIALS AND METHODS

Channel catfish obtained on July 8, 1968 from the Centerton State Fish Hatchery of the Arkansas Game and Fish Commission were initially kept in three 60-gallon capacity tanks at 23 C, the same as the hatchery pond temperature. Temperature in the tanks was gradually raised until the experimental temperatures of 26, 28, and 32 C were reached. The fry were kept in the above temperatures under 24-hour light condition. On August 6, 1968, a total of 275 fry were distributed equally (42 to 48 fish) into tanks of 26, 28, and 32C with 10-hour and 14-hour light conditions. Two Gro-Lux (Sylvania) 30 Watt cool white flourescence bars were used for the light source.

The fish were fed daily on unlimited food supply of Purina Fish Chow containing not less than 35% of crude protein, 2.5% crude fat and not more than 8% crude fiber. Finely ground and sieved fish chow was weighed, soaked with water, and placed in a plastic bowl in each tank between 6 and 8 P. M. The next day, left over food was removed and the scattered food around the bowl was siphoned out. This food was dried at 70 C for 24 hr and its weight was recorded for each experimental condition for food consumption determination.

Total lengths in millimeters and weights in grams of the experimantal fish were recorded at 15-day intervals. Five fish from each of the experimental conditions were measured up to 45 days and from then on unequal numbers of fish were measured until the termination of the experiments at 120 days. Total weight of a sample fish for each of the experimental conditions was recorded to the nearest 0.01 g by placing them in a bowl of water on the weighing pan after the moisture on the fish was removed by blotting.

A record of daily mortalities was maintained. Water quality criteria for dissolved oxygen, free carbon dioxide and pH were determined at 15-day intervals.

Statistical analyses were performed partly by an IBM 7040 computer and partly by a desk calculator. For each type of statistical analysis, significance was expressed at the 0.01 level unless otherwise stated.

RESULTS

Length - Weight Relationship

Length-weight relationship for channel catfish from each of the experimental conditions was calculated using average length and average weight of fish for each of the 15-day intervals up to 120 days (Table I). Since the differences between the slopes were not significant ($F_{5,42} = 0.34$), it was concluded that temperature and photoperiod combinations had no effect on the body shape of channel catfish.

Growth in Length

Soon after the fish were transferred to the experimental tanks, total lengths of five fish from each experimental condition were measured. The differences in the mean lengths of fish among the experimental conditions were not significant ($F_{5,25} = 1.6$) indicating that each of the experimental conditions had the same size fish at the start of the experiments (average total length of fish was 21.4 mm).

Analysis of variance tests on length data for each 15-day interval showed significant differences, hence Duncan's multiple range test was used for each of the time periods. Details of the test results are given in Table 2. The analyses showed that the 28C-10L combination from 45 days on occupied the last position in the ranking and thus was not a favorable condition for the growth of channel catfish. It was also observed that the fish of the above combination were black in color with enlarged heads when compared to the rest of the body.

The combined effects of temperature and photoperiod on growth are shown in Figure 1. The growth in length of channel catfish at the end of 30 days was greater in 32C-14L, intermediate in 26C-14L and low in 28C-14L, while in 10-hr light condition the growth was higher at 26 than at 28 and 32 C. At the end of 60 days the growth in lower light condition was intermediate at 26 C and the growth for fish at 32 C was the same under both the light conditions, while the 28C-14L group grew faster than all the other groups. The growth was comparatively slow in the 28C-10L group. The growth at the end of 90 days was parallel in both groups at 32 C and more than the rest of the combinations. At the termination of the experiments (120 days), growth of fish in 28C-14L combination was more than the rest of the groups. Under 10-hr photoperiod, the fish at 26 C occupied an intermediate position at the end of 60, 90 and 120 days. It was also evident that the growth of 28C-10L group was slow throughout the study period. The growth of channel catfish at different temperature - photoperiod combinations is shown in Figure 2.

Food Consumption

Food consumption was expressed as grams of food consumed per gram of body weight of channel catfish, and was estimated at the end of each 15-day interval. The relationship between food consumption and time was expressed as:

$$FC = e^{Bt}$$

where, FC = food consumption

t = time in days from the start of the experiments

The regression equations for each of the experimental conditions are given in Table 3. The respective regression equations were used to estimate the amount of food consumed at 30, 60, 90, and 120 days for each of the combinations.

The combined effects of temperature and photoperiod on food consumption are shown in Figure 3. At the end of 30 days, food consumption for fish raised at 32 and 26 C was greater at 10-hr than at 14-hr photoperiods, whereas for the fish at 28 C food consumption increased with photoperiod. At 60 days the food consumption for fish at 26 C was almost the same at both the light conditions. While there was no change from the previous period in food consumption pattern with the photoperiod for fish at 32 C, the food consumption for fish at 28 C showed an inverse relationship with photoperiod. The fish at 28 C consumed more food than the fish at 26 and 32 C at both photoperiods. The inverse relationship between food consumption and photoperiod for the fish at 28 and 32 C still existed by the end of 90 days, but the fish at 26 C consumed more food at the 14-hr than at the 10-hr photoperiod. During the last 15-day period (120 days) of the experiments, for the fish at 32 C food consumption was the same at both the photoperiods, while the food consumption in relation to light showed the same trends for the fish at 26 and 28 C as in the previous time period.

Food Conversion Efficiency

Food conversion efficiency for each of the experimental conditions was the "gross efficiency" (Brown, 1957) expressed as the weight gain per unit of food intake multiplied by 100. Estimates of food conversion parameters for each of the temperature - photoperiod combinations were made at 15-day intervals.

The relationship between the food conversion efficiency and time was expressed as:

$$FCE = e^{Bt}$$

where, FCE = food conversion efficiency

t = time in days from the start of the experiments

Regression equations for each of the experimental conditions are given in Table 4. Covariance analysis showed that the regression lines were parallel ($F_{5,36} = 0.43$).

The conversion efficiencies at 30, 60, 90, and 120 days were estimated from the regression equations and are shown in Figure 4. The conversion efficiencies were higher under 14-hr photoperiod up to 60 days for the three temperatures, and the fish at 28 C had lower efficiencies than those at 26 and 32 C. At 90 days, the conversion efficiency for fish at 32 C was the same under both the light conditions. The fish at 26 C had higher conversion efficiency under 10-hr photoperiod, than at 14-hr photoperiod, and the conversion efficiency for fish at 28 C still showed a positive relationship with photoperiod. In the last 15-day period (120 days), there was an inverse relationship between photoperiod and conversion efficiency for fish at 26 and 32 C; a direct relationship for fish at 28 C. For the fish under 10-hr photoperiod the conversion efficiency was highest at 26 followed by 32 and 28 C, while under 14-hr photoperiod the conversion efficiencies in decreasing order were at 28, 32, and 26 C.

TABLE I

LENGTH - WEIGHT RELATIONSHIP OF CHANNEL CATFISH GROWN IN DIFFERENT EXPERIMENTAL CONDITIONS.

Experimental Condition	Length-Weight Relationship
26C-14L	Log W = -5.0895 + 3.0510 Log L
28C-14L	Log W = -5.3069 + 3.0770 Log L
32C-14L	Log W = -5.2110 + 3.0890 Log L
26C-10L	Log W = -5.6962 + 3.4199 Log L
28C-10L	Log W = -5.3668 + 3.2610 Log L
32C-10L	Log W = -5.1173 + 3.0678 Log L

TABLE 2

MEANS AND DIFFERENCES AMONG MEANS IN DIFFERENT EXPERIMENTAL CONDITIONS.

Period: 15 days

Experimental Condition

	32C-14L	26C-14L	26C-10L	28C-10L	28C-14L	32C-10L
Mean	40.0	29.0	28.8	27.4	24.8	22.4

Period: 30 days

	32C-14L	26C-14L	26C-10L	28C-14L	28C-10L	32C-10L
Mean	41.0	36.4	32.2	30.8	27.2	27.2

Period: 45 days

	32C-14L	26C-14L	28C-14L	26C-10L	32C-10L	28C-10L
Mean	44.8	36.4	36.0	35.4	34.4	33.8

Period: 60 days

	28C-14L	32C-14L	32C-10L	26C-10L	26C-14L	28C-10L
Mean	46.9	46.2	46.0	42.4	39.3	33.9

Period: 75 days

	32C-14L	32C-10L	28C-14L	26C-14L	26C-10L	28C-10L
Mean	48.1	47.9	46.6	45.5	44.0	35.5

Period: 90 days

	32C-10L	32C-14L	28C-14L	26C-14L	26C-10L	28C-10L
Mean	49.9	49.6	48.7	48.5	45.6	36.7

Period: 105 days

	28C-14L	32C-10L	32C-14L	26C-14L	26C-10L	28C-10L
Mean	54.9	51.7	51.3	51.0	47.0	38.3

TABLE 2 (Continued)

Period: 120 days

	28C-14L	26C-14L	32C-10L	32C-14L	26C-10L	28C-10L
Mean	57.1	55.3	53.1	52.9	48.9	39.8

Note: Any means underscored by the same line are not significantly different.

TABLE 3

TIME AND FOOD CONSUMPTION RELATIONSHIP OF CHANNEL CATFISH AT DIFFERENT EXPERIMENTAL CONDITIONS.

Experimental Condition	Time and Food Consumption Relationship
26C-14L	Log Fc = 0.58703 + .00368t
28C-14L	Log Fc = 1.91717 - .011076t
32C-14L	Log Fc = 0.22757 + .00087t
26C-10L	Log Fc = 1.36092 - .007744t
28C-10L	Log Fc = 1.16599 + .003254t
32C-10L	Log Fc = 1.59701 - .009884t

TABLE 4

TIME AND FOOD CONVERSION EFFICIENCY RELATIONSHIP OF CHANNEL CATFISH AT DIFFERENT EXPERIMENTAL CONDITIONS.

Experimental Condition	Time and Food Conversion Efficiency Relationship
26C-14L	Log FCE = 3.36563 - .02132t
28C-14L	Log FCE = 2.37063 - .00727t
32C-14L	Log FCE = 3.22294 - .01664t
26C-10L	Log FCE = 2.41198 - .00668t
28C-10L	Log FCE = 2.21437 - .01102t
32C-10L	Log FCE = 2.80949 - .001168t

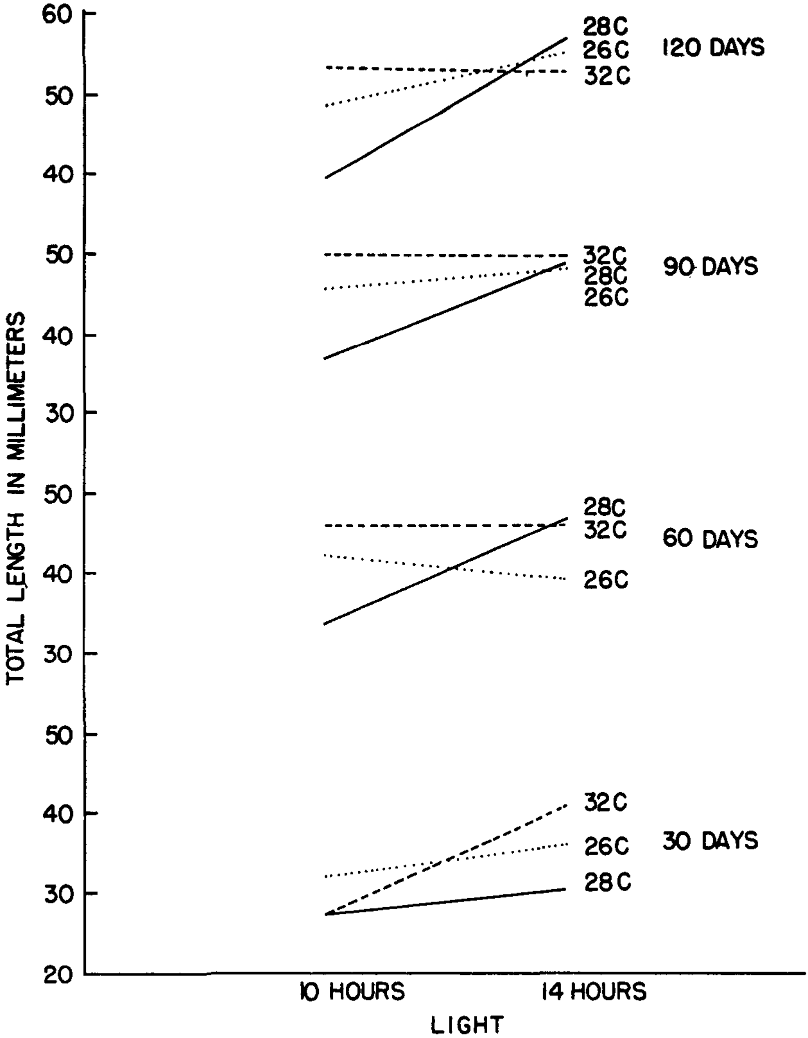

FIGURE 1. Combined effects of temperature and photoperiod on growth in length of channel catfish.

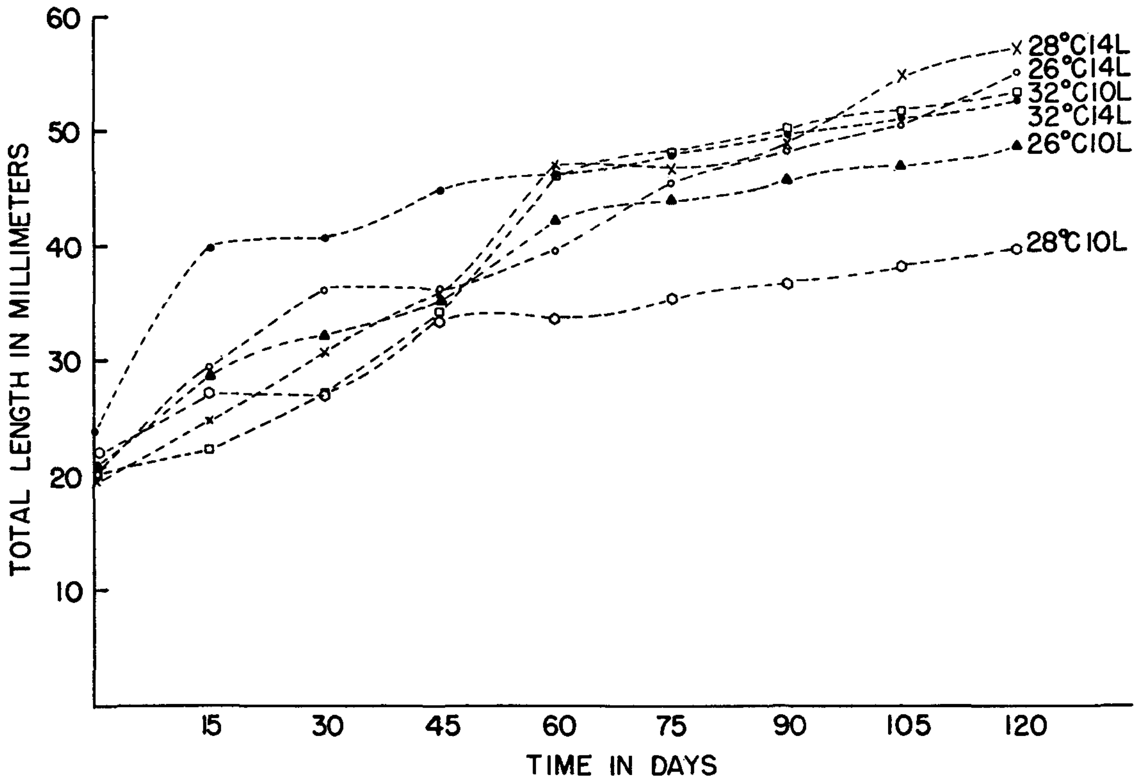

FIGURE 2. Growth in length of channel catfish in different experimental conditions at 15-day intervals.

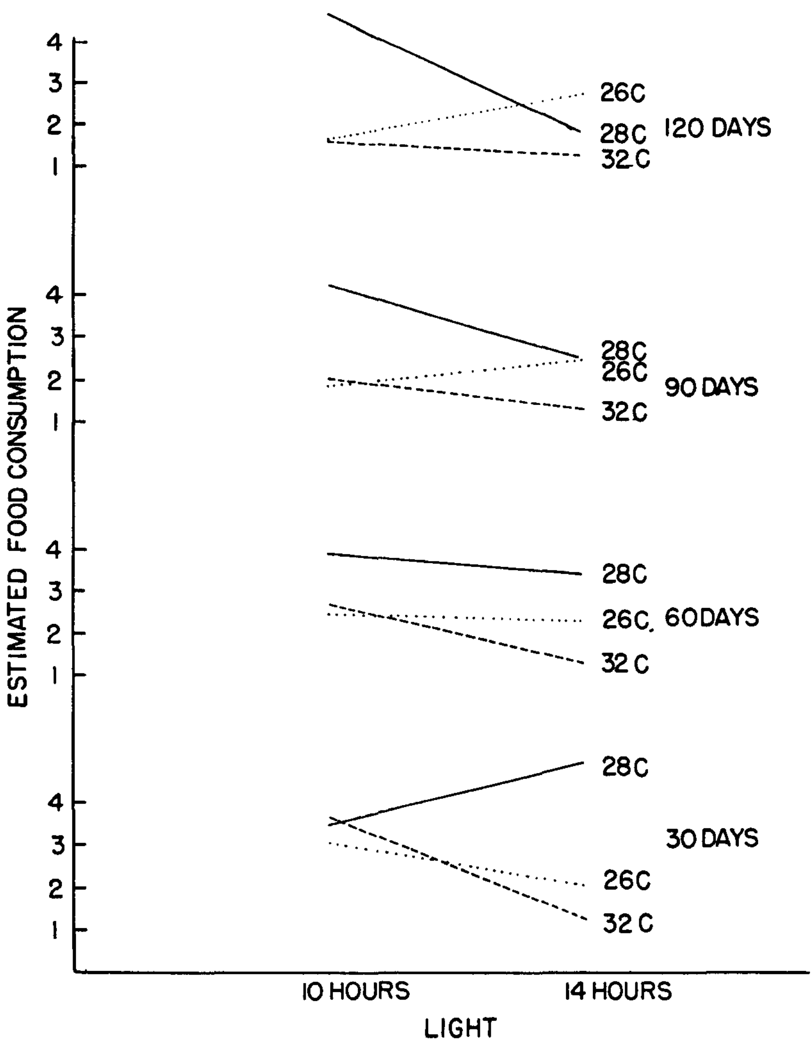

FIGURE 3. Combined effects of temperature and photoperiod on food consumption of channel catfish.

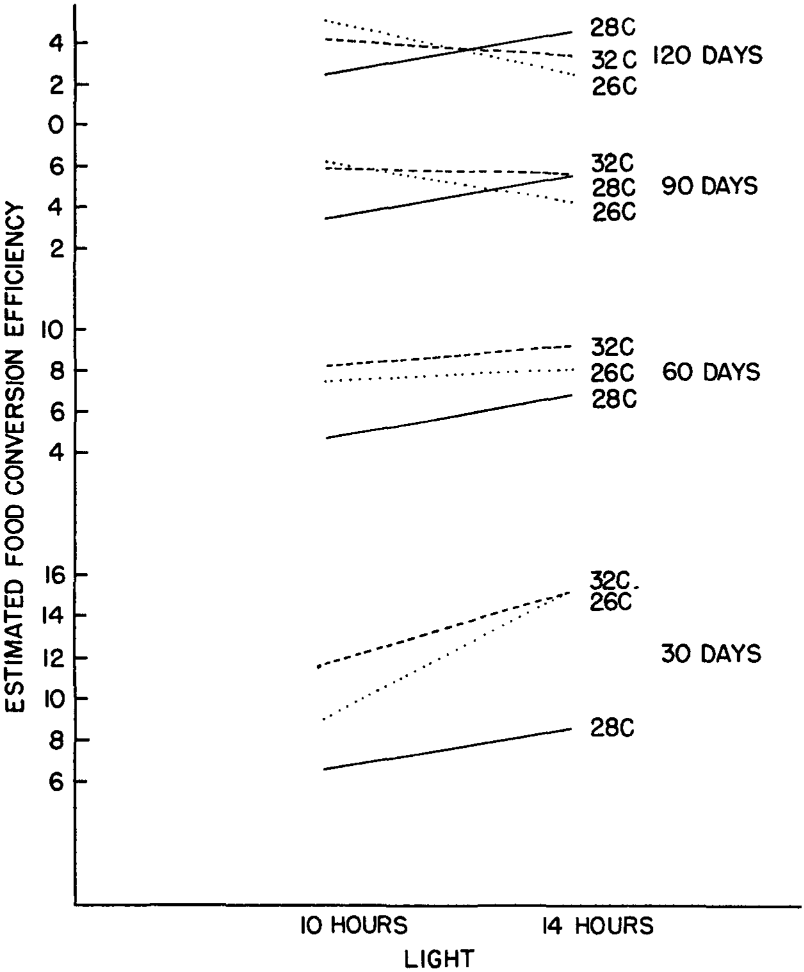

FIGURE 4. Combined effects of temperature and photoperiod on food conversion efficiency of channel catfish.

DISCUSSION

In the present study, it was observed that the growth of channel catfish was influenced by temperature and duration of light. Initially, the fish raised under the 14-hr photoperiod grew better at all the three temperatures than those at the 10-hr photoperiod. With advance in time, the differences in growth of fish at 32 C decreased between the photoperiods, but the growth differences in relation to photoperiods for fish at 28 C became more pronounced. By the termination of the experiments, the fish at 28C-10L were considerably smaller than the rest of the groups; the fish at 28C-14L were slightly larger than those at 32 and 26 C under 10-hr and 14-hr photoperiods.

West (1966) studied the effects of controlled temperatures on growth of channel catfish, and observed maximum growth at an optimum temperature between 29 and 30 C. The present study indicates that the optimum temperature for maximum growth of channel catfish depends on photoperiod. Under 14-hr photoperiod, maximum growth was at 28 C, but under 10-hr photoperiod maximum growth occurred at 32 C.

Past studies on growth involving light revealed conflicting results. Brown (1946) demonstrated an inverse relationship between light and growth of brown trout; Eisler (1957) and Tryon (1943) found direct relationship in their studies on chinook salmon and cutthroat trout, respectively. Gross et al. (1965) reported that green sunfish grew better in 16-hr than in 8-hr constant daylength. They further stated that increasing daylength had a stimulating effect on growth while decreasing daylength inhibited growth. The channel catfish of our study showed a direct relationship between photoperiod and growth at 26 and 28 C, and the observed direct relationship was more pronounced for the fish raised at 28 C. For fish at 32 C there was a direct relationship between photoperiod and growth in the earlier time periods, but from 60 days on light had no affect on growth.

Brown (1957) stated that the growth of fishes was influenced by the quality and quantity of food, physico-chemical conditions, overcrowding and space. In this study quality of the food was the same, quantity of food was "unrestricted", and the physico-chemical conditions in each of the experimental conditions for dissolved oxygen, free carbon dioxide, and pH taken at 15-day intervals were within the prescribed ranges for warm water fishes (FWCPA, 1968). There was no over-crowding since the fish were equally distributed in all the experimental conditions and the space (size of the tank) was the same for all the groups. Therefore, the differences in growth of the experimental channel catfish were due to the combined effects of temperature and photoperiod.

It was observed that the combined effects of temperature and photoperiod on food consumption of channel catfish varied with time. The inverse relationship between food consumption and photoperiod for the fish at 32 C existed up to 90 days, but by the last 15-day period photoperiods had no effect on food consumption. The initial inverse relationship between food consumption and light for fish at 26 C changed to a direct relationship after 60 days. The direct food consumption-photoperiod relationship that was present at 30 days for fish at 28 C changed to an inverse relationship by 60 days and became more pronounced with time.

Baldwin (1956) found that brook trout consumed the greatest amount of food at 13 C and the food consumption was low above and below this temperature. Kinne (1960) and West (1966) noted an increase in food intake with increasing temperature for desert pupfish and channel catfish, respectively. Gross et al. (1965) found that green sunfish consumed more food during longer daylengths than in shorter daylengths. Considering the average food consumption per 15-day period under 14-hr photoperiod, the channel catfish at 28 C consumed the greatest amount of food (3.45 g), while the fish at 26 and 32 C consumed 2.33 and 1.33 g, respectively. Under 10-hr photoperiod, food consumption for the fish at 28 C was the greatest (4.03 g) whereas the fish at 32 and 26 C consumed 2.60 and 2.39 g, respectively. Under both the light conditions, the food consumption of channel catfish was greatest at 28 C and decreased above and below this temperature as was the case with brook trout (Baldwin, 1956). These findings were in contradiction with those of West (1966). West's experiments were conducted for a period of 68 days and the fish were measured at 4-day intervals. Frequent handling of fish may have resulted in increased activity in relation to temperature and thus an increase in food intake. In this study, for channel catfish at 28 and 32 C the food consumption was higher in shorter light duration than in longer light duration. However, the food intake for fish at 26 C was the same under both the light conditions. It was evident that the influence of light on food consumption was dependent on temperature and that differences in food consumption in relation to photoperiods become more pronounced with increase in temperature.

Regarding food conversion efficiency, there was a direct relationship between conversion efficiency and photoperiod up to 60 days for the fish at all the temperatures, but from there on the relationship became inverse for the fish at 26 and 32 C. Kinne (1960) reported that for desert pupfish the conversion efficiency decreased with increasing temperature. West (1966) noted the most efficient food conversion coefficient at 29 C and lower coefficients above and below this temperature. Gross et al. (1965) found that food conversion efficiency for green sunfish was higher in longer daylengths than in shorter daylengths. Based on data for the entire period of the present study, the average food conversion efficiency per 15-day period for channel catfish under 14-hr photoperiod was higher at 32 C (9.56) followed by fish at 26 (8.84) and 28 C (6.75). Under 10-hr photoperiod the fish at 32 C had the most efficient conversion (8.16), while the fish at 26 and 28 C had the food conversion efficiencies of 7.29 and 4.66, respectively. That is, the channel catfish of this study showed lower food conversion efficiency at 28 C, and was higher above and below this temperature. For any temperature, the conversion efficiency was higher in longer photoperiods than in shorter photoperiods, and these findings agree with those of Gross et al. (1965).

Optimum conditions for raising channel catfish should be evaluated in terms of inerrelationships among growth, food consumption, and food conversion efficiency with respect to temperature and photoperiod. The channel catfish at 32C-14L consumed less food than the other groups. The fish at 32C-10L consumed more food than those at 32C-14L, but this was lower than those at 28C-10 & 14L, and food consumption was almost the same as those at 26 C under both the light conditions. Regarding food conversion, the fish at 32 C under both the 10-hr and 14-hr photoperiods had greater conversion efficiencies than the fish at other temperature-photoperiod combinations. The fish at 32C-14L had greater conversion efficiency than those at 32C-10L. The lengths reached by the fish at 32 C, by the termination of the experiments, were not significantly different from those at 26 C under both the photoperiods and those at 28C-14L. Since the fish at 32C-14L consumed least amount of food with greatest food conversion efficiency and reached the same size as the other groups with larger food intake, it was apparent that these fish required less food for maintenance. Thus the 32C-14L combination was the optimum condition for the channel catfish. Although the mortalities of fish in the experimental conditions were not statistically significant (x^2 + 9.5, d.f. + 5), the fish at 32C-14L had the lowest total percentage mortality. It is important to point out, that the temperature-photoperiod combination of 28C-10L was unsuitable for channel catfish.

ACKNOWLEDGMENTS

This work was partially supported by funds provided by the office of Water Resources Research, Department of the Interior, as authorized under the Water Resources Act of 1964, PL 88-379, as amended by PL 89-404.

The authors wish to thank Dr. David A. Becker for his comments on the manuscript.

LITERATURE CITED

Baldwin, N. S. 1956. Food consumption and growth of brook trout at different temperatures. Trans. Amer. Fish. Soc. 86: 323-328.

Brown, M. W. 1946. The growth of brown trout *(Salmo trutta* Linn.*)* III. The effect of temperature on the growth of two year-old trout. J. Expt. Biol. 22: 145-155.

_________. 1957. The Physiology of Fishes. Volume I. Academi Press Inc., Publishers, New York. 447 p.

Eisler, T. 1957. The influence of light on the early growth of Chinook Salmon. Growth, 21: 197-203.

Felin, F. E. (1951). Growth characteristics of the poeciliid fish, *Platypoecilus maculatus.* Copeia, (1): 15-28.

FWPCA. 1968. Water quality criteria. Federal Water Pollution Control Administration, Washington, D. C. 234 p.

Gibson, M. B. and B. Hirst. 1955. The effect of salinity and temperature on the pre-adult growth of guppies. Copeia, (3): 241-243.

Gross, W. L., E. W. Roelofs and P. O. Fromm. 1965. Influence of photoperiod on growth of green sun-fish Lepomis cyanellus. J. Fish. Res. Board. Canada 22(6): 1379-1386.

Kinne, O. 1960. Growth, food intake, and food conversion in a euryplastic fish exposed to different temperatures and salinities. Physiol. Zool. 33: 288-317.

Strawn, Kirk. 1961. Growth of largemouth bass fry at various temperatures. Trans. Amer. Fish. Soc. 90(3): 334-335.

Tryon, C. A. Jr. 1943. The effect of covering hatchery troughs on growth of cutthroat trout *(Salmo clarkii).* Trans. Am. Fish. Soc. 72: 145-49.

West, B. W. 1966. Growth, food conversion, food consumption and survival at various temperatures of the channel catfish *Ictalurus punctatus* (Rafinesque). M. S. Thesis, Graduate School, University of Arkansas 65 p.