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Culture of Channel Catfish in East-Central South Dakota Dugout Ponds

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CULTURE OF CHANNEL CATFISH
IN EAST-CENTRAL SOUTH DAKOTA DUGOUT PONDS

BY

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CULTURE OF CHANNEL CATFISH

IN EAST-CENTRAL SOUTH DAKOTA DUGOUT PONDS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Date

CULTURE OF CHANNEL CATFISH

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Abstract

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Twenty dugout ponds in east-central South Dakota were stocked 10 May 1980 with fingerling (mean weight 39.4 g, mean total length 108.4 mm) channel catfish (Ictalurus punctatus) at stocking rates of 309, 618, 1,235, and 1,853 fish/ha. Supplemental food was provided in 16 ponds (four at each stocking rate) at a rate of 4% body weight every other day. Fish in four ponds stocked, one at each of the respective stocking rates were not fed. Eleven of the 16 ponds which received feed were considered fit for analysis at the end of the study period, 27 September 1980. Two of the four ponds which did not receive feed were fit for analysis. Least square means were computed for fish lengths and weights. Final length least square means for the respective stocking rates in ponds receiving food were 274.2, 266.1, 260.6, and 231.2 mm. Final weight least square means for the respective stocking rates were 193.8, 163.3, 166.1, and 105.2 g. Tukey's test revealed no significant ($P \leq 0.05$) differences between the least square mean values for the 1,235/ha rate and the highest respective least mean square values for length, weight, or $K_{(TL)}$. For production purposes, the 1,235/ha stocking rate was determined to be the best of the four rates, yielding 107 kg/ha, and producing an average of 0.84 kg/ha/day. These growth and production values were less than those of similar studies conducted at more southerly latitudes and

were determined to be unprofitable from an aquacultural view. The short growing season and less than optimum water chemistry conditions were believed to have hindered growth. Food habit analysis indicated the catfish were not markedly utilizing the stocked forage base of fathead minnows (*Pimephales promelas*). Taste evaluations by participating pondowners and a taste panel yielded favorable results. In the pondowner test, 93.3% of the respondents rated the flavor as acceptable. The taste panel rated 64% of the fish sampled as good to excellent in taste. Dugout ponds receiving little or no cattle usage were likely to have excess aquatic macrophytes, a probable result of greater water transparency. Assuming 100% collection efficiency, 65.2% of the 489 fish stocked in the 11 usable fed ponds survived. Dugout ponds are capable of supporting channel catfish and also have recreational fisheries potential. These ponds may have commercial potential with channel catfish if a different stocking strategy is followed. The dugout pond may also represent a bait fishery potential with fathead minnows. Future stockings of channel catfish in similar ponds might reach harvestable size if stocked at a larger size (203 - 254 mm total length). Assuming 100% recovery efficiency, 45 of 62 (72.6%) fish left to overwinter in three dugout ponds survived. A new dugout pond was found to be significantly ($P \leq 0.01$) less productive than an older pond. The mean annual zooplankton biomass for the newer pond was 121.6 mg/l while that of the older pond was 245.3 mg/l, both values were representative of eutrophic waters.

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INTRODUCTION

The aquatic ecosystems of eastern South Dakota are very productive (Nickum 1970; Steinberg 1972) and constitute a potential aquacultural resource. It was estimated that over 20,000 dugout ponds exist in the state (Ruwaldt 1975), containing nearly 1,500 surface ha (Bue et al. 1964). The purposes of this study were to: (1) determine the potential of rearing annual crops of channel catfish (*Ictalurus punctatus*) in dugout ponds, (2) evaluate food habits through the examination of the stomachs of harvested fish, (3) evaluate the overwintering success of the channel catfish in dugout ponds, and (4) to compare the relative productivity of a new and an old dugout pond.

In the southern United States the commercial production of channel catfish represents a multi-million dollar industry (Bennett 1970). In 1969, catfish production was about 30 million kg, with the states of Mississippi, Arkansas, and Louisiana accounting for the largest share among the 18 recognized catfish producing states (Bardach et al. 1972). The palatability, desirability, high feed conversion, and existence of market areas (Bardach et al. 1972) are several of the qualities which make the channel catfish a potential fish for culture in South Dakota.

The possibility of winterkill (Hubbs and Trautman 1935; Greenbank 1945) and the short growing season have been the major impediments to the aquacultural utilization of waters in the northern United States. Nickum (1970) noted that winterkill conditions can be expected in South Dakota prairie lakes about once in five to ten years. Two management approaches have been offered to avert the winterkill problem. The first approach is in attempting to artificially prevent the development of winterkill conditions; the second approach circumvents winterkill by accepting its climatological limitations and operating on an annual basis (Johnson 1970). The latter approach is employed in this study.

Large channel catfish fingerlings (average 39.4 g, 108.4 mm) were selected to ameliorate the likelihood of the annual fish crop attaining a harvestable size. The catfish were stocked in 20 ponds at rates of 309, 618, 1,235, and 1,853/surface ha. Four ponds at each rate received a floating pelleted food, constituting 16 fed ponds. One pond at each stocking rate did not receive supplemental food, and were referred to as the unfed ponds. The 16 fed ponds and the four unfed ponds were stocked with a forage base of fathead minnows (*Pimephales promelas*), to supplement the natural food of the ponds.

Two ponds devoid of fish, one newly constructed, were compared to determine relative productivity of an old and a new dugout pond. These ponds are hereafter referred to as the productivity ponds. An evaluation of zooplankton biomass, or standing crop, over a one-year period was used in this determination.

STUDY AREA

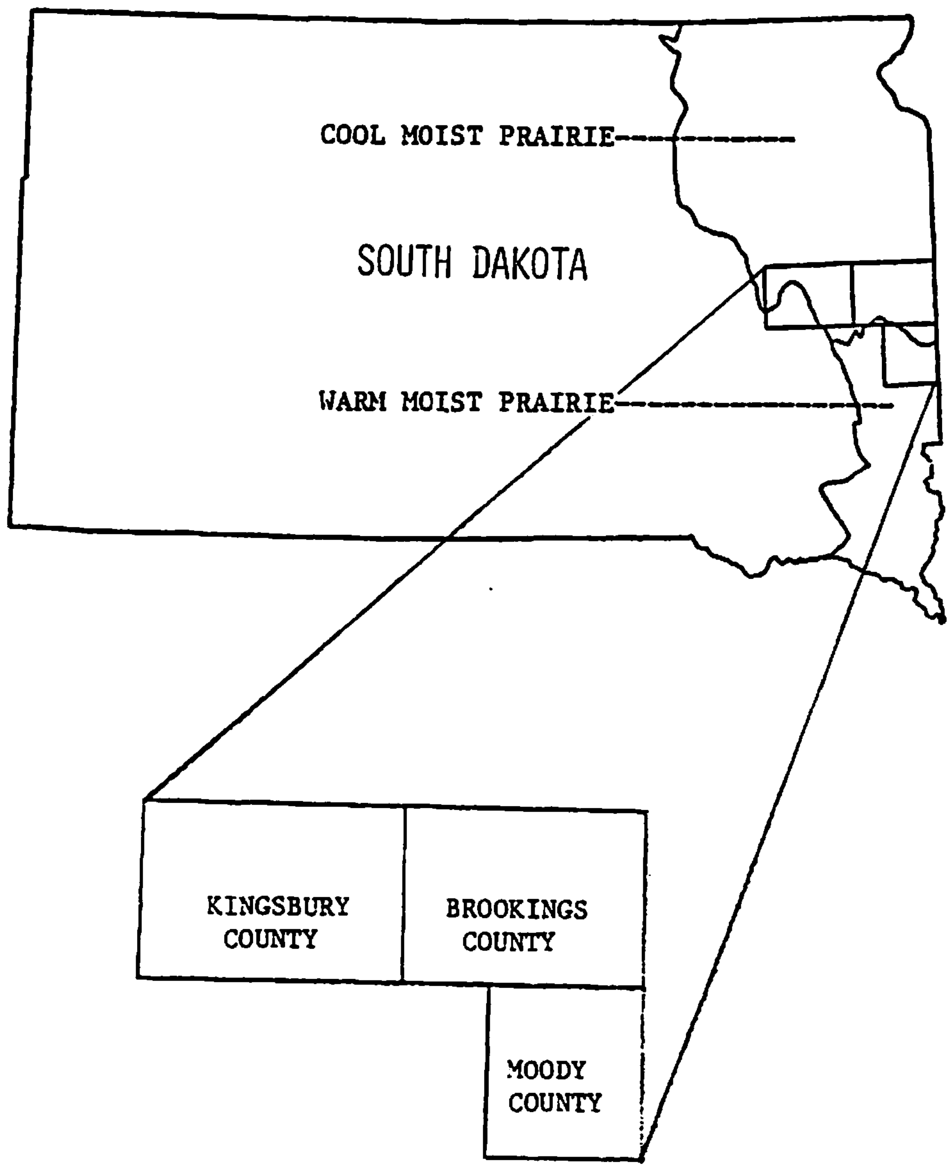
The dugout ponds used in this study were located in Brookings, Kingsbury, and Moody counties in east-central South Dakota (Figure 1). These counties lie on the Coteau des Prairies, a highland area between the Minnesota-Red River Lowland and the James River Lowland. The Coteau slopes gently to the south and west, from 607 m above sea level on the north to about 485 m on the south (Westin and Malo 1978). The location of each dugout used in this study is provided in Appendix Table 1.

Eighteen of the dugouts are located in a subgroup of soils classified as cool moist prairie, or udic borolls (Figure 1). These soils have developed under a cool moist subhumid climate, with an annual precipitation of 48.3 - 58.4 cm and an average air temperature between 5.0 - 7.2 C. The Hersrud and Hobbie ponds lie within the warm moist prairie soil zone (Figure 1) or udic ustolls, of South Dakota. A warm moist climate is associated with the development of these soils, with an annual precipitation of 55.9 - 66.0 cm and an annual mean temperature between 7.2 - 9.4 C (Westin and Malo 1978).

The relatively cool moist climate of the former soil zone has created conditions favoring the accumulation of organic matter. In the latter zone, relatively high temperatures have encouraged considerable biological and chemical activity, so organic matter destruction and release of soil nitrogen are high.

The parent materials of the cool moist prairie soil subgroup include glaciolacustrine sediments, early Wisconsin glacial drift, and

Figure 1. The three county area of South Dakota containing study ponds and the extent of the cool moist prairie and warm moist prairie zones in relation to the three county area used to study the culture of annual crops of channel catfish (*Ictalurus punctatus*) in dugout ponds during 1980.



late Wisconsin glacial drift. The warm moist prairie soil zone parent materials include early Wisconsin drift, late Wisconsin drift, and alluvium (Westin and Malo 1978). Westin and Malo (1978) described both soil groups as being productive. The productivity of soils directly affects the productivity of associated bodies of water (Hickling 1962).

The topography of the Coteau des Prairies is described as rolling. The native vegetation of both described soil subgroups consists of tall grasses. This region, however, has been markedly altered by intensive agricultural development (Westin and Malo 1978).

Most dugouts in the Northern Great Plains and prairie region are in the eastern parts of South Dakota and North Dakota, western Minnesota, and the prairie provinces of Canada. About 185,000 dugouts have been constructed in Manitoba, Saskatchewan, and Alberta, and about 40,000 had been constructed up to 1963 in North and South Dakota, Montana, and western Minnesota (Bue et al. 1964). In 1975 over 20,000 dugouts existed in South Dakota (Ruwaldt 1975).

A dugout pond, or stock watering pit, is a depression dug to a depth of 2.4 m or more in a place where it can catch runoff water or intercept ground water. They vary in size, depending upon the number of livestock to be watered, the method of construction, and the source of water recharge. Typical dimensions approximate 50.0 m in length and 19.7 m in width. Most dugouts have a surface area between 0.05 to 0.10 ha (Bue et al. 1964) and water volumes which approximate 1,233.6 m^3 (personal communication, Dee Watson, Soil Conservation Service). The 20 dugouts which received catfish

(Table 1) averaged 32.6 m in length, 16.5 m in width, and 0.06 ha in surface area. The distribution of the study dugouts appears in Figure 2.

One or both ends of a dugout pond are gently sloped to permit access for cattle, while the sides are generally steep (Bue et al. 1964). The sides are usually constructed with a 2:1 slope, while either one end or, less frequently, both ends have a 4:1 slope. A 2:1 slope infers a 1 m vertical drop for every 2 horizontal meters traversed.

Sixteen of the study dugouts were of the type constructed in intermittent waterways or level ground (Bue et al. 1964). Six of the ponds were of the type constructed in temporary and semipermanent wetland areas (Bue et al. 1964). Ponds of the dam-dugout type (Bue et al. 1964) were not considered in the selection of the ponds. An attempt was made to select ponds not likely to overflow.

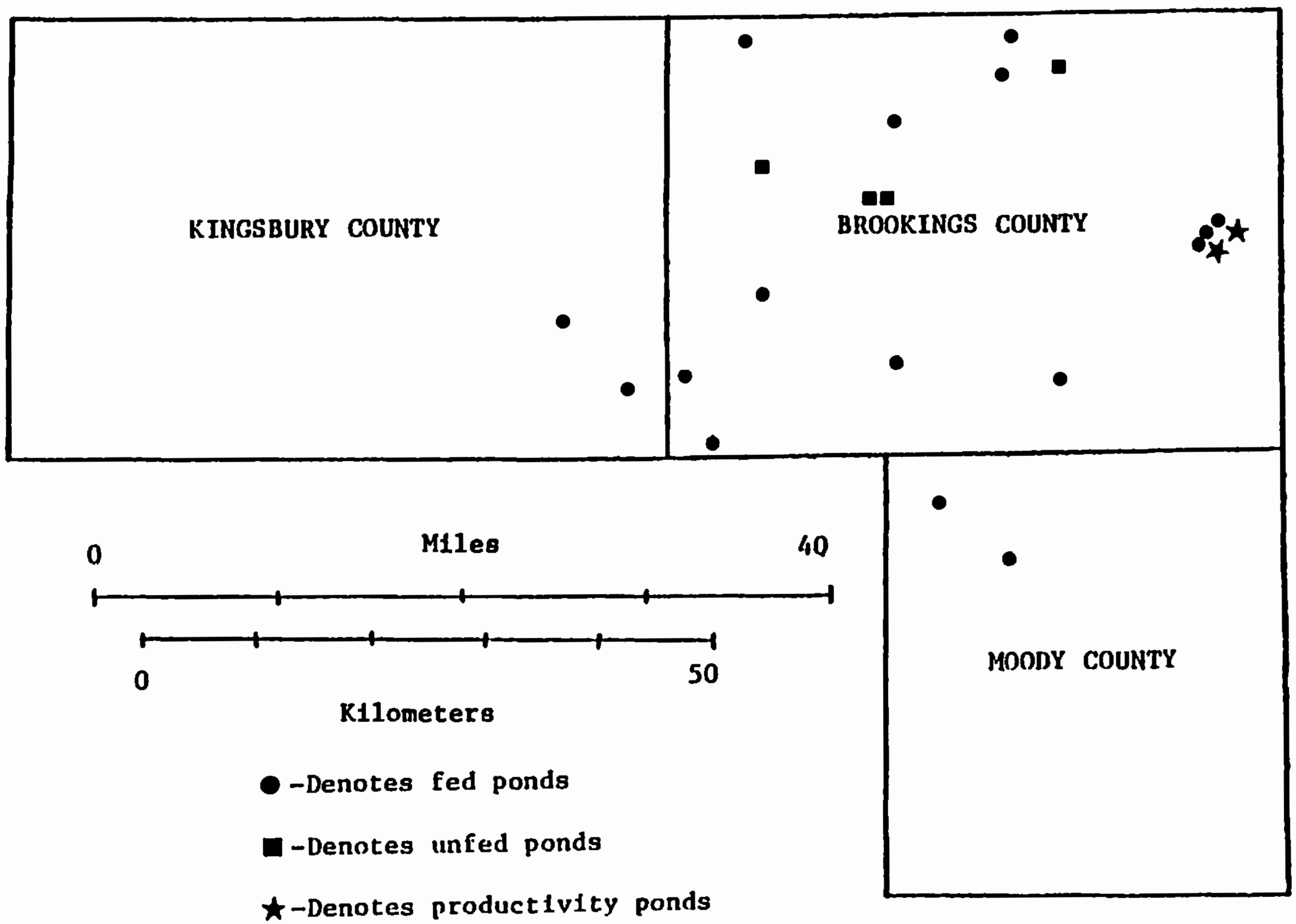
Few ponds supported either submergent or emergent aquatic macrophytes. Coontail (Ceratophyllum demersum) was the dominant submergent in the Matson pond, and Potomogeton pectinatus in the Edie pond. The McKeown and Oppelt ponds, both having three sides fenced for protection from cattle, developed the only evidence of emergent vegetation, with small stands of Typha latifolia present along these protected sides.

Muskrats (Ondatra zibethica) inhabited several dugouts. Lower vertebrate species inhabiting the ponds included larval tiger salamanders (Ambystoma tigrinum), snapping turtles (Chelydra serpentina), painted

Table 1. The stocking rates, types, year constructed, and dimensions of all ponds used to study the culture of annual crops of channel catfish (<u>Ictalurus punctatus</u>) in dugout ponds during 1980.

Pond	Stocking Rate no/ha	Dugout Type	Year Constructed	Length (initial) (m)	Width (m)	Surface Area (ha)
Matson	309	fed	1976	46.9	17.1	0.08
Oleson	309	fed	1976	38.7	18.6	0.07
Hersrud	309	fed	1976	36.0	12.2	0.04
Kurtz	309	fed	1979	25.9	17.7	0.05
Hobbie	618	fed	1976	31.4	17.7	0.06
Cotton	618	fed	1976	25.3	14.0	0.04
Collins	618	fed	1977	39.6	19.2	0.08
Hansen	618	fed	1976	30.5	16.3	0.05
Negstad	1,235	fed	1979	27.4	14.0	0.04
McKeown	1,235	fed	1977	27.4	16.2	0.04
Oppelt	1,235	fed	1977	25.6	13.4	0.03
Foster	1,235	fed	1976	25.0	14.0	0.04
Berg	1,853	fed	1976	30.5	16.5	0.05
Edie	1,853	fed	1976	29.9	19.8	0.06
Thiex	1,853	fed	1977	37.5	17.7	0.07
VandeWeerd	1,853	fed	1977	30.5	16.8	0.05
Christiansen	309	unfed	1977	54.9	23.0	0.15
Kor	618	unfed	1978	35.7	14.6	0.05
Odegaard East	1,235	unfed	1969	27.4	14.0	0.04
Odegaard West	1,853	unfed	1977	29.3	14.0	0.04
Oppelt productivity	-	-	1976	-	-	-
Kurtz productivity	-	-	1980	-	-	-

Figure 2. Distribution of fed, unfed, and productivity research ponds used to study the culture of annual crops of channel catfish (*Ictalurus punctatus*) in dugout ponds during 1980.



turtles (*Chrysemys picta*), and leopard frogs (*Rana pipiens*). Bird species frequenting dugouts included blue-winged teal (*Anas discors*), mallards (*Anas platyrhynchos*), great blue herons (*Ardea herodias*), and double-crested cormorants (*Phalacrocorax auritus*). Invertebrates included crayfish (*Cambarus* spp.) and insects of the orders Odonata, Ephemeroptera, and Trichoptera. Families of other aquatic insect orders represented included Corixidae, Notonectidae, Belostomatidae, Gerridae, Dyticidae, Gyrinidae, Chironomidae, and Culicidae. The crayfish and tiger salamanders were present in every pond, as were most of the aquatic insect groups listed above.

METHODS AND MATERIALS

Fed Ponds

Temporal Limits of Growing Season

Channel catfish fingerlings were stocked in the artificially fed ponds (Figure 2) on 10 May 1980. Fish were removed from the fed ponds 27 September 1980. The temporal limits of the study were chosen with consideration given to both seasonal water temperature and to the impending potential of winterkill. Since water temperatures capable of supporting channel catfish growth exist from May through September in south-central South Dakota ponds (Graham 1966), the study period was designed to coincide with this period.

Stocking Rates

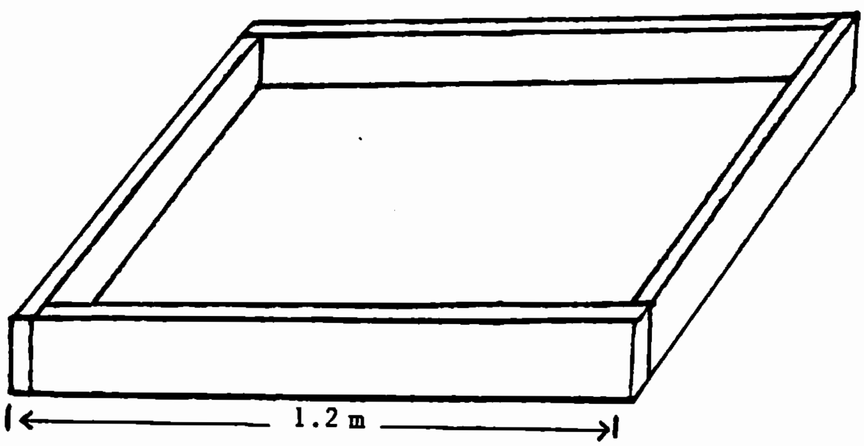
Sixteen ponds were stocked with channel catfish at 309, 618, 1,235, or 1,853 fish/ha (four ponds at each stocking rate). Age group I channel catfish fingerlings (average length 108.4 mm, average weight 39.4 g) were used. The fingerlings were obtained from Willow Lake Fish Hatchery, Hastings, Nebraska. The stocking rates were intermediate between extensive culture (Toole 1951) and intensive culture (Prather 1959, 1961; Bardach et al. 1972; Grizzell et al. 1975). The stocking of large fingerlings to increase the probability of fish attaining a harvestable size has been attempted in the past utilizing other species (Johnson 1970; Sunde et al. 1970).

Supplemental Feeding

Artificial feeding and the stocking of fathead minnows were intended to supplement naturally occurring forage. The fish received a floating pelleted feed at 4% body weight every other day except when (1) mean surface water temperatures were below 15.5 C, (2) dissolved oxygen concentrations were below 3 mg/l, (3) ponds were discarded from the study, and (4) the threat of algal blooms existed. The 4% body weight ration every other day is not equivalent to a 2% daily ration, but will be treated as such for comparative purposes. A 2% daily average rate represents an intermediate feeding rate (Byford 1970; Bardach et al. 1972; Grizzell et al. 1975). Fish were fed COOP Fish Food 32, produced by Farmland Industries, Kansas City, Missouri. This food was composed of 4.8 mm pellets and consisted of not less than 32% protein.

The wind activity in this region necessitated the construction of floating food containment structures (Figure 3), which prevented the beaching of feed. The containment structures were constructed of four 1.2 m sections of 5.1 X 10.2 cm pine lumber. The square area enclosed by these structures was covered with 1.3 cm mesh hardware cloth, which created an area protected from piscivorous birds, but permitted the passage of feed to the water surface. These structures were placed offshore to reduce damage by cattle. The structures were tied to two stakes driven into the bottom in water over a meter in depth. Food was placed in the structures with a long pole to which a plastic container was attached. Fish at each pond were fed at approximately the same time on each feeding day.

Figure 3. The 1.2 m square floating food containment structure constructed of 5.1 X 10.2 cm pine lumber placed in the fed ponds used to study the culture of annual crops of channel catfish (Ictalurus punctatus) in dugout ponds during 1980.



Fathead Minnow Forage Base

Fathead minnow adults approximately 63.5 mm in total length were stocked at the rate of 2,471/ha (Flickinger 1971) in April 1980, to provide a potential forage base for the catfish. Fathead minnows deposit eggs on the underside of various materials (Flickinger 1971), and as little vegetation existed in most dugouts, spawning structures were constructed for each fed pond. These structures consisted of two 1.4 X 1.9 X 182.9 cm pieces of pine lumber to which brush was attached. The two pieces joined in a t-shape, with the vertical portion driven into the pond bottom for anchorage. These structures were placed in water slightly greater than 1 m in depth. This offshore placement was necessary to reduce damage by cattle.

Fish Sampling

Fish were sampled twice monthly from each pond, except in August, when the handling was believed to represent an unacceptable level of stress on the fish. Fish were collected using either a 25.9 m X 2.4 m bag seine with a 19.0 mm mesh, or with a 45.7 m X 2.4 - 4.9 m bag seine with 19.0 mm mesh size. During samplings, three seine hauls per pond were made, unless ten fish were captured before the third haul. In final harvest, hauls were continued until no fish were captured. Total lengths and weights of the fish were recorded and average weights for each stocking rate were used in the computation of feed allotments. For the periods during which insufficient numbers of fish were sampled and during which no sampling occurred, food allotments were estimated using linear regression.

Seining Efficiency

After the final fish seining, the Berg and Matson ponds, both fed ponds, were toxified with Nusyn - Noxfish. This measure was employed as a means of estimating the relative seining efficiency in dugout ponds. The piscicide was applied at 2.0 mg/l, with a hand-held tank sprayer. The operation of an outboard motor circulated the toxicant throughout the pond.

Growth and Production

Growth of the catfish in the present study was recorded in terms of least square mean lengths, weights, and coefficient of condition $K_{(TL)}$ (Carlander 1969). Production data was reported in terms of net production (kg/ha), average weight gain (kg/ha/day), and average daily weight gain per fish in grams. The conversion rate used was S (Swingle 1959), which equals the pounds of feed used divided by the total pounds of fish produced by natural means plus added feeds. Length of growing season refers to number of days water surface temperatures equalled or exceeded 15.5 C.

Preparation of Harvested Fish

During harvest on 26 - 28 September 1980, fish were field dressed, rinsed in clean water, wrapped, and packed on ice. Dressing involved the removal of the skin, head, and viscera.

Food Habit Analysis

The fish were arbitrarily separated into five length-groups of 50 mm increments. Analysis involved the identification, enumeration, and volumetric quantification of the stomach contents. Stomachs with less than 0.1 ml of volume displacement and with no identifiable items present were considered empty. The items were expressed as percent volume of total stomach contents and percent frequency of occurrence for each respective length interval.

Only items in the anterior portion of the digestive tract, from the esophagus to the pylorus, were utilized for food determination. This section of the gastrointestinal tract will hereafter be referred to as the stomach, as in previous food habit studies (McComish 1967; Scalet 1977). In the analysis of stomach contents, stomachs were removed from five fish per pond, where applicable, and preserved in 10% formalin.

Consumer Evaluation of the Channel Catfish

In order to quantitatively determine the quality and palatability of the fish, questionnaires were distributed with fresh frozen fish to the participating pondowners. An additional taste test was conducted by the Nutrition and Food Science Department at South Dakota State University. In this test, color, odor, flavor, texture, and appearance were rated by 11 taste test panelists.

Overwintering of Catfish

Following harvest, a total of 62 catfish were returned to three dugouts to assess catfish winter survival. Forty-six, ten, and six fish were returned to the Thiex, McKeown, and Hobbie ponds, respectively. The fish were recaptured after ice melt, 27 March 1981.

Physical and Chemical Water Quality Characteristics

Physical and chemical water quality characteristics were measured twice monthly throughout the study from 22 May - 19 September 1980, with the exception of secchi disc transparency, which was measured 18-19 September 1980. Water temperatures were recorded from the surface, 0.5, 1.0, 2.0, 3.0 m, and bottom. Salinity, conductivity, and dissolved oxygen concentration were measured at 0.5, 1.0, 2.0, and 3.0 m depths. Conductivity readings were standardized and converted to 25 C (APHA et al. 1971). Dissolved oxygen was determined using the modified Azide-Winkler method (APHA et al. 1975). Water temperatures, salinities, and conductivities were measured with a YSI model 33 S-C-T meter.

The pH, phenolpthalein alkalinity, total alkalinity, and total hardness were recorded from surface water. The two alkalinity readings and the total hardness readings are expressed in mg/l $CaCo_3$. Water samples were taken at various depths with a Kemmerer water bottle. Pond surface areas were computed from direct measurements. An inflatable raft was secured in the middle of the ponds for YSI meter readings, Kemmerer bottle samplings, and maximum depth measurement.

Phenolpthalein alkalinity, total alkalinity, and hardness were measured using a Hach Dr-EL/a kit. The pH measurements were obtained with the Hach pH wide range test kit, model 17-N, with a range of 4 - 10 units. Maximum water depth was measured with a weighted, calibrated line. Secchi disc transparencies were measured using a secchi disc (20.0 cm diameter).

Unfed Ponds

Four unfed ponds (Table 1) were used in the study. Each unfed pond was stocked at one of the four respective stocking rates utilized for the fed ponds. The channel catfish were stocked on the same date as those of the fed ponds. The catfish were harvested from the unfed ponds 28 September 1980. The unfed ponds received no artificial food supplement and no food containment structure. A fathead minnow forage base was provided in the same manner as the fed ponds, with identical spawning structures provided. Fish sampling did not occur between stocking and final harvest in the unfed ponds. Chemical and physical water parameters were not taken from the unfed ponds. Fish from the unfed ponds were prepared for food habit analysis and processed in the same manner as the fed ponds. Processed fish and questionnaires were distributed to the owners of unfed ponds.

Productivity Comparison

Zooplankton were collected from the two productivity ponds (Figure 2) approximately every two weeks in mid-afternoon. Collection occurred over a one year period, from 30 June 1980 to 3 July 1981. On each pond five equally spaced sampling stations were used across a diagonal transect, and two subsamples were taken per station per period. A water core plankton sampler 152 mm in diameter (Applegate et al. 1968), equipped with a no. 10 net was used to collect zooplankton in a vertical water column to within 0.3 m of the bottom. Samples taken closer to the bottom collected sediments.

All zooplankton samples were preserved in the field with Lugol's solution, and later in the laboratory with 5 - 10% formalin. Entire samples were usually counted, but when large numbers of organisms were present, subsamples were taken and counted in a Sedgwick-Rafter counting cell (APHA et al. 1971).

Zooplankton were identified using keys by Brooks (1957), Ward and Whipple (1959), Novotny (1975), and Pennak (1978). Immature cyclopoid copepods were classified as cyclopoid copepodites or cyclopoid nauplii. Additional copepods were identified to genus or species, as were the cladocerans and dipterans.

Insufficient numbers of zooplankton prevented volume displacement dry weight determination (Hall et al. 1970). Calculated dry weights from previous studies (Hall et al. 1970; Wetzel and Likens 1979) were used for dry weight determination. The dry weights for Daphnia spp., Moina spp., and Macrocyclops albidus were estimated using the dry weights of comparative sized plankton from the studies of Hall et al. (1970), and Wetzel and Likens (1979).

The relative productivities of the two productivity ponds were compared and analyzed for significant differences. The comparison was made utilizing periodic mean zooplankton biomasses over the one-year study period for each pond.

Statistical Procedures

To ascertain any significant differences in least square mean lengths, weights, or coefficient of condition (K_{TL}), with respect to stocking rate, several analyses of variance were performed. In each analysis of variance the hypothesis was tested using the mean square for ponds within treatments as an error term.

Tukey's test for unequally replicated means (Steel and Torrie 1980) was applied to the least square mean values for length, weight, and $K_{(TL)}$ at the four respective stocking rates. This test indicated where the significant differences were with respect to individual stocking rates.

A comparison of two sample means for independent samples and unequal variances (Steel and Torrie 1980) was used to determine whether significant differences existed in secchi disc transparency between ponds muddied by cattle and those not muddied by cattle. Least square means for length and weight from the 309 and 618/ha fed ponds suitable for analysis were compared with the respective mean values from unfed ponds at these respective rates, using the same procedure.

Two separate maximum r-square improvement stepwise multiple regression procedures (Helwig and Council 1979) were performed using 22 independent variables to find the multivariate model which best explained the maximum amount of variation in the dependent variables length and weight, respectively. The correlation coefficients between the 22 independent variables and the variables length and weight, respectively, were computed using the CORR procedure of the Statistical Analysis System (Helwig and Council 1979). The stepwise procedure was also used to determine the existence of any linear, quadratic, or cubic relationships between stocking rate and the respective dependent variables length and weight.

To ascertain any significant difference in relative productivity in the two productivity ponds, an analysis of variance was performed using the mean periodic total zooplankton biomasses for each productivity pond. The analysis of variance was then tested using the error mean square as the error term. Twelve separate analysis of variance procedures were performed for both mean annual organism biomass and mean annual organism concentration comparisons. The hypotheses were tested using the ANOVA mean square for pond by date interaction as an error term.

RESULTS AND DISCUSSION

Study Pond Suitability

Eleven of the 16 fed dugouts were suitable for analysis at the end of the study period. Factors determining suitability included sufficient water supply, lack of contamination by other fish species, and the presence of suitable numbers of stocked fish to analyze upon termination of the study. Fed ponds excluded from final analysis included the Collins, Hansen, Foster, VandeWeerd, and Edie dugouts.

The fed ponds of the 309, 618, 1,235, and 1,853/ha rates yielded 41, 19, 95, and 164 fish, respectively,of the 75, 56, 143, and 215 fish stocked, respectively, at these rates. Since several ponds were unsuitable for analysis, least square mean values were used in the evaluation of optimum stocking rates.

The Collins, Hansen, and Foster ponds were flooded over their banks during heavy thunderstorms 24 June 1980. These storms produced between 12.7 and 17.8 cm of rain in a 5 hour period, resulting in flash-flooding. These ponds became continuous with intermittent or permanent streams.

As a result of flooding, other fish species entered the dugouts. Flooding introduced carp (*Cyprinus carpio*), green sunfish (*Lepomis cyanellus*), white suckers (*Catostomus commersoni*), northern pike (*Esox lucius*), and black bullheads (*Ictalurus melas*) into the Collins pond. With the exception of carp, all of the above-mentioned species were found in the Hansen pond following flooding. Green sunfish were found in the Foster dugout.

The VandeWeerd pond experienced a fish kill on 12-13 July 1980. Twenty-nine mortalities were recorded on 12 July, with an additional 14 recorded the following day. It is believed that a blue-green algae bloom contributed to the fish kill.

The Kurtz, Oppelt, and Kor dugouts were also continuous with intermittent streams during flooding but revealed no evidence of contamination with other species and therefore were considered suitable for evaluation. These ponds, however, may have been subject to some loss of channel catfish.

The Edie and Matson dugouts were without cattle in their respective pastures nearly the entire study period. Water transparency in these ponds was much greater than dugouts with cattle; as a result they supported dense stands of submergent aquatic macrophytes. This vegetation hampered sampling efforts, resulting in insufficient numbers of fish collected for analysis. Landowner preference prevented the application of rotenone for final sampling in the Edie pond, while suitable numbers of fish were obtained by toxifying the Matson pond.

Two of the four unfed ponds were deleted from the study. The Odegaard east and Odegaard west ponds had water depths insufficient to support the catfish. The contents of these dugouts were less than 0.3 m in depth, and heavily laden with algae.

Seining Efficiency

Samples collected from the 11 fed ponds fit for analysis during sampling periods were insufficient. This necessitated the use of final fish data in statistical procedures.

Twelve of the 25 stocked catfish were recovered from the heavily vegetated Matson pond, while 12 of the 13 possible survivors were collected with the use of a piscicide. Seining accounted for 50% of the eventual capture, representing a 50.0% capture efficiency. The seining of the Berg dugout produced 63 fish. Seven fish were recovered with the piscicide, therefore a total of 63 out of 70 (90.0%) surviving fish were collected by seining.

The differences in the seining efficiencies between the two ponds may be explained by the presence of submergent macrophytes in the Matson pond, which hindered seining efficiency. No such vegetation problems were encountered in any of the ponds which received exposure to cattle. Unless an efficient alternative method of capture is to be used, ponds receiving no cattle usage should be avoided in future stocking considerations.

Growth

An analysis of variance was performed for each of three dependent growth variables: length, weight, and $K_{(TL)}$. The four stocking rates, 309, 618, 1,235, and 1,853/ha, represented the independent variables in each analysis of variance. Values of length, weight, and $K_{(TL)}$ for each of the 319 harvested fish from the 11 fed ponds were analyzed with respect to the four stocking rates. In each analysis the hypothesis was tested using the mean square for pond within treatment as an error term. Results are presented in Tables 2, 3, and 4. Significant ($P \leq 0.01$) differences in the least square means (Table 5) were evidenced for dependent variables weight, and $K_{(TL)}$, respectively, as stocking rates varied. A significant ($P \leq 0.05$) difference in the least square means for length occurred as stocking rates varied (Table 3).

The results of Tukey's test for unequally replicated means (Steel and Torrie 1980) applied to the least square mean values for length, weight, and $K_{(TL)}$ and are presented in Table 6. The underscored values are not significantly ($P \leq 0.05$) different.

The least square means for length, weight, and coefficient of condition at the 1,235/ha stocking rate did not differ significantly ($P \leq 0.05$) from the highest least square mean values exhibited by the 309/ha stocking rate.

In this study the 1,235/ha stocking rate produced growth parameters comparable to those of the 309/ha stocking rate, which exhibited the highest values. The 1,235/ha rate represents the highest production potential and, therefore, the optimum stocking rate for this experiment.

Comparison of Growth Parameters With Other Studies

Least square mean length, weight, and $K_{(TL)}$ for the 1,235/ha rate were compared with fish of similar sizes or ages, or both, for natural and other waters (Table 7). The catfish of the 1,235/ha rate of the fed ponds in the present study were 260.6 mm, 166.1 g, 0.89 in

Table 2. The results of an analysis of variance for dependent variable weight, using the four stocking rates as treatments for the 11 dugout ponds used to study the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980.

Source	d.f.	SS	MS	F
Treatment	3	279,779.074	93,259.69	10.66 **
Pond (treatment)	7	61,314.960	8,759.28	2.18 *
Residual	308	1,235,734.541		

* Denotes significance ($P \leq 0.05$).

** Denotes significance ($P \leq 0.01$).

Table 3. The results of an analysis of variance for dependent variable length, using the four stocking rates as treatments for the 11 dugout ponds used to study the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980.

Source	d.f.	SS	MS	F
Treatment	3	68,191.525	22,730.508	8.29*
Pond (treatment)	7	19,190.816	2,741.545	2.52*
Residual	308	334,685.893		

* Denotes significance ($P \leq 0.05$).

Table 4. The results of an analysis of variance for dependent variable coefficient of condition ($K_{(TL)}$), using the four stocking rates as treatments for the 11 dugout ponds used to study the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Source	d.f.	SS	MS	F
Treatment	3	0.5623	0.1874	20.60**
Pond (treatment)	7	0.0637	0.0091	1.39
Residual	308	2.0157	0.0065	

** Denotes significance ($P \leq 0.01$).

Table 5. The final least square mean values for weight, length, and coefficient of condition ($K_{(TL)}$) by stocking rate (treatment) and by pond, respectively, for the 11 dugout ponds used to study the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Treatment	No. Fish	Weight LS Mean (g)	Length LS Mean (mm)	$K_{(TL)}$ LS Mean
309	41	193.8	274.2	0.91
618	19	163.3	266.1	0.82
1,235	95	166.1	260.6	0.89
1,853	164	105.2	231.1	0.79

Pond	Treatment (ha)	Weight LS Mean (g)	Length LS Mean (mm)	$K_{(TL)}$ LS Mean
Kurtz	309	208.5	289.5	0.85
Matson	309	170.1	258.7	0.94
Oleson	309	195.4	269.8	0.93
Hersrud	309	201.1	278.7	0.91
Cotton	618	119.3	245.7	0.80
Hobbie	618	207.2	286.5	0.83
McKeown	1,235	168.4	262.9	0.86
Oppelt	1,235	138.3	244.9	0.91
Negstad	1,235	191.6	273.8	0.89
Berg	1,853	109.8	235.2	0.79
Thiex	1,853	100.6	227.1	0.80

Table 6. The results of Tukey's test using least square means for weight, length, and coefficient of condition ($K_{(TL)}$), respectively, for the four respective stocking rates from the 11 dugout ponds used to study the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980.

Weight (g):	(1,853/ha) 105.3	(618/ha) 163.3	(1,235/ha) 166.1	(309/ha) 193.8
Length (mm):	(1,853/ha) 231.253	(1,235/ha) 260.6	(618/ha) 266.1	(309/ha) 274.2
Coefficient of condition (K_{TL}):	(1,853/ha) 0.79	(618/ha) 0.82	(1,235/ha) 0.89	(309/ha) 0.91

* Underscored values denote no significant ($P \leq 0.05$) difference.

Table 7. The growth data from the three 1,235/ha stocking rate of fed dugout ponds fit for analysis used to study the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980 (present study) compared with growth data from previous studies.

Location and Source	Age of Fish at Harvest	Age of Fish when Stocked	Feeding Rate % Body Weight/Day	Mean Weight When Stocked (g)	Mean Length at Harvest (mm)	Mean Weight at Harvest (g)	$K_{(TL)}$ at Harvest	Habitat Type
Fort Randall Reservoir, South Dakota (Shields 1955)	-	-	0.0	-	177.8 - 381.0	-	0.68	Natural
Pool 9, Upper Mississippi River, Lansing, Iowa (Appelget and Smith 1951)	-	-	0.0	-	263.9	136.1	0.74	Natural
Ponds 4, 6, and 20 Jackson County, Illinois (Bulow 1967)	II	I	3.0	18.1	414.4	802.0	1.13	Strip-mine culture ponds
Stuttgart, Arkansas (Stephenson 1964)	I	I	3.0	5.9	296.6	245.6	1.63	Culture ponds

Table 7. (Continued)

Location and Source	Age of Fish at Harvest	Age of Fish When Stocked	Feeding Rate % Body Weight/Day	Mean Weight When Stocked (g)	Mean Length at Harvest (mm)	Mean Weight at Harvest (g)	$K_{(TL)}$ at Harvest	Habitat Type
Lawrence, Kansas (Simco and Cross 1966)	I	I	0.0	5.9	-	108.9	-	Culture ponds
North-eastern South Dakota (Wheeler 1979)	I	I	7.6	5.70	232.0	109.0	0.87	Cage culture in heated reservoir
East-central South Dakota* (present study)	I	I	2.0	39.41	260.6	166.1	0.89	Dugout ponds

* Values represent the 1,235/ha stocking rate.

least square mean length, weight, and $K_{(TL)}$, respectively. Catfish of comparable length from natural waters in South Dakota (Shields 1955) and Iowa (Appelget and Smith 1951) were lower in $K_{(TL)}$ than the 1,235/ha rate catfish (Table 7) and lower in $K_{(TL)}$ than the values for the three remaining stocking rates of the present study (Table 5).

Cultured channel catfish in Arkansas (Stephenson 1964) and in southern Illinois (Bulow 1967) were greater in length, weight, and $K_{(TL)}$ values than those of the present study (Table 7). Respective lengths of growing seasons for these two studies and the present study are 140, 289, and 128 days. Growing season refers to days in which water surface temperatures are 15.5 C or greater. The Arkansas and Illinois catfish received a greater daily supplemental ration than those of the present study (Table 7).

Fish from a cage culture experiment in a South Dakota power plant cooling reservoir (Wheeler 1979) were lower in all three growth parameters than the fish of the present study (Table 7). The dugout catfish were larger when stocked, but received a lower ration and had a shorter growing season than the caged catfish.

Channel catfish in Kansas ponds (Simco and Cross 1966) experienced a longer growing season but received no artificial food. Stocked at a rate identical to the 1,235/ha rate dugout fish, the Kansas fish were lower in mean weight at harvest (Table 7). It is likely that the natural productivity of the dugout ponds, the supplemental food ration provided, or these two variables in concert resulted in the greater weight of the catfish in the present study.

Production Comparison With Other Studies

The catfish of the 1,235/ha rate of the present study experienced a conversion rate (S) and a net production of 2.52 and 107 kg/ha, respectively. The three ponds of the 1,235/ha rate produced 0.84 kg/ha/day, while the average daily weight gain per fish was 1.29 g. These catfish were lower in all production values than the respective values of the Alabama (Swingle 1959), Illinois (Bulow 1967), and Arkansas (Stephenson 1964) catfish (Table 8). The fish of the present study did surpass the South Dakota caged catfish (Wheeler 1979) and the Kansas catfish (Simco and Cross 1966) in respective average daily weight gain per fish, but were higher in S (Table 8). Net production of the Kansas catfish (Simco and Cross 1966) and average daily weight gain in kg/ha were lower than the respective values of the present study (Table 8). The higher production values in the Alabama, Illinois, and Kansas studies may be a reflection of the length of the respective growing seasons and greater food ration (Table 8). A more desirable conversion rate was evidenced in the South Dakota cage culture experiment (Table 8).

The net production and the average weight gain/ha, respectively, are useful values but are more a reflection of survival and possibly capture success than the average daily weight gain per fish. For example, if the 138 fish stocked at 1,235/ha in the present study had been recovered, the net production per ha would have been 203 kg, rather than 107 kg, and the average daily weight gain would have been 1.59 kg/ha, rather than 0.84 kg/ha. The average daily weight gain per

Table 8. The production data from the three 1,235/ha stocking rate fed dugout ponds fit for analysis used to study the culture of annual crops of channel catfish (<u>Ictalurus punctatus</u>) during 1980 (present study) compared with growth data from previous studies.

Location and Source	Stocking Rate No/ha	Length (days) Growing Season[a]	Conversion Rate S[b]	Feeding Rate Body Weight/ Day	Net Production kg/ha	Average Weight Gain kg/ha/Day	Average Weight Gain Per Fish/Day (g)
Auburn, Alabama (Swingle 1959)	2,471	273	2.30	3.0	434	1.6	1.7
Jackson County, Illinois Ponds 4, 6, and 20 (Bulow 1967)	4,942	289[c]	1.36	3.0	2,473	8.6	2.7
Stuttgart, Arkansas (Stephenson 1964)	3,706	140	1.63	3.0	831	5.9	1.7
Lawrence, Kansas (Simco and Cross 1966)	1,235	180	-	-	103	0.6	0.6
North-eastern South Dakota (Wheeler 1979)[d]	-	147	1.46	7.6	-	-	0.7
South Dakota, Present study	1,235	128	2.52	2.0	107	0.8	1.3

[a] Refers to days with water surface temperature > 15.5 C.

[b] (Swingle 1959).

[c] Represents 1.5 growing seasons.

[d] Cage culture experiment.

fish may represent a more valid estimate of the actual weight gains of the fish. It is possible, however, that a reduction in standing crop resulted in an increase in food availability for each fish.

It is evident from the relatively high respective average daily weight gain per fish in the Alabama, Illinois, and Arkansas studies (Table 8) that the channel catfish is capable of better growth at higher densities than evidenced by the 1,235/ha rate fed fish of the present study. From this data it is apparent that crowding was not a limiting factor in the growth of the fish.

Simco and Cross (1966) found a decrease in growth rate, but no significant differences among weight gains in an experiment in which catfish were fed 2.0, 3.5, 5.0, and 7.0% daily rations. Since the difference between feeding rates in the pond culture studies cited in Table 8 and the present study were 1.0% it is likely that the effect of this difference was neglible with regard to the mean daily weight gain.

Optimum Growth Temperatures

The length of the growing season requires yet further clarification. Channel catfish exhibit little growth below 15.5 C (Byford 1970) and slow growth between 15.5 C to 21.0 C. Regular feeding of catfish occurs when water temperature exceeds 21 C (Swingle 1959) and growth ameliorates from 21.0 C to 29.5 C (Bardach et al. 1972). Optimum growth temperature occurs between 25 to 30 C (West 1966; Bulow 1967; Shrable et al. 1969; Andrews and Stickney 1972). The present study included 29 days when surface temperatures equaled or exceeded 25 C, while the southern Illinois catfish experienced 62 days of temperatures in this range (Bulow 1967). Kansas pond surface temperatures equaled or exceeded 25 C for approximately 107 days (Simco and Cross 1966). It is reasonable to assume that the Arkansas (Stephenson 1964) and Alabama (Swingle 1959) ponds (Table 8), located at yet more southerly latitudes, experienced equal or longer periods with water surface temperatures within this optimum range. Gray (1969) indicated that under optimum conditions channel catfish may double their weight each month. The Arkansas fish, stocked at 5.9 g and harvested at 245.6 g, 140 days later, more than doubled in weight monthly. It is likely that these fish experienced optimum temperatures for nearly four months. It is reasonable to assume that the Alabama fish encountered long periods in the optimum temperature range, since they nearly doubled in weight monthly. The water temperatures in South Dakota, with respect to optimum growth conditions, were growth restrictive.

Feeding Activity of Fish

The catfish of the present study were not observed surface feeding on the supplemental ration throughout the entire study. Only infrequently after stocking were the fish observed accepting the floating pellets. During the first five days of feeding, winds swept the floating feed to shore. Food containment structures were constructed to maintain the availability of the floating food. Approximately 10 days after stocking, these structures were placed in the ponds. It is possible that during the first 10 days the catfish, which had been trained to accept floating pellets, had this conditioned feeding response disrupted.

Fish were observed feeding at very few ponds and infrequently following the emplacement of the food containment structures. It is possible that the catfish may have been utilizing the feed after it sank to the bottom. Although the food containment structures may not have contributed to the successful surface feeding of the catfish, they did prevent the washing of food to shore by wind action. They allowed the feed to sink to the bottom in open water, making it available to underwater consumption by catfish.

Harlan and Speaker (1969) stated that in extremely turbid water catfish feed less extensively. Disease, low dissolved oxygen (Byford 1970), and low secchi disc transparency (Bennett 1970) are several factors which may exert a negative influence on feeding of fishes. The fish, when examined during sampling, appeared in good condition, with no noticeable signs of disease present. On several days from late June through early August, several ponds were not fed during times of possible stress. The Oleson pond, in particular, was not fed for several days when high temperatures and low oxygen concentrations were prevalent.

Secchi disc transparency measurements were taken 18-19 September 1980, for the 16 fed ponds. The 16 fed dugouts averaged 0.35 m secchi disc transparency (Table 9). Seven of these 16 dugouts were being used by cattle on the dates tested. These seven dugouts averaged 0.13 m in secchi disc transparency as opposed to 0.51 m of the nine dugouts without cattle. Using the comparison of two sample means for independent samples and unequal variances, a significant ($P \leq 0.05$) difference in secchi disc transparency means was found between the

Table 9. The secchi disc transparency values (19-20 September 1980) for the 16 fed dugout ponds used to study the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980, and the results of a pairwise comparison of the means of ponds which experienced cattle use and those which did not.

Pond	Secchi disc transparency (M)	Cattle using pond
Cotton	0.2	No
Berg	0.2	No
Matson	1.1	No
Negstad	0.4	No
Oleson	0.1	Yes
Hersrud	0.1	Yes
Hobbie	0.1	Yes
Thiex	0.6	No
Oppelt	0.4	No
McKeown	0.4	No
Kurtz	0.2	Yes
Foster[a]	0.1	Yes
VandeWeerd[a]	0.1	Yes
Edie[a]	1.1	No
Hansen[a]	0.2	Yes
Collins[a]	0.2	No
Christiansen[b]	-	Yes
Kor[b]	-	No

[a] Deleted from study

[b] Unfed ponds

Table 9. (Continued)

Comparison of Means

	Mean value	t' value	effective d.f.
Ponds without cattle use	0.5111	3.1626*	8.3770 ≈ 8
Ponds with cattle use	0.1286		

* Denotes signficance ($P \leq 0.05$)

ponds with cattle and those without cattle (Table 9). A positive correlation existed between increasing secchi disc transparency and increasing catch rate success for fish with surface fly rod lures (Bennett 1970). Although fly fishing success may not be the ultimate measure of surface feeding activity, this may indicate that surface feeding can be negatively affected by low water transparency. This is not meant to imply that channel catfish are predominantly surface feeders. Low transparency is, rather, a factor which may have interferred with the visual acuity of the fish inasmuch as the floating feed is concerned.

Wheeler (1979) suggested that wave action may have diminished the surface feeding response of his channel catfish. The near constant wind in this region was sufficient to create waves 15 - 20 cm in height on the dugouts, although 8 - 10 cm waves were more typical.

The unfed ponds at the 1,235/ha and 1,853/ha rates were unfit for analysis. The only unfed ponds available for comparison of growth with the fed ponds were the 309/ha and 618/ha unfed dugouts. Such a comparison may indicate whether the feed was being significantly utilized by the fish. The least square mean values for length and weight for both the 309/ha and 618/ha rates exceeded the respective mean values for the unfed ponds. A comparison of the least square means of the fed ponds for length and weight versus the respective mean values from the unfed ponds appears in Table 10. A significant ($P \leq 0.05$) difference existed between the respective weight means of the 309/ha fed and unfed ponds. No significant difference existed between the respective weight means of the 618/ha fed and unfed ponds. There were

Table 10. The mean lengths and weights of fed and unfed dugout ponds for the respective 309 and 618/ surface ha stocking rates used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980, and the results of the pairwise comparison of means at both rates.

	Length (mm)	S^2 Length	Weight (g)	S^2 Weight	n
Christianson mean (309/ha unfed)[a]	269.9	532.703	165.7	2,389.718	46
309/ha least square mean[b]	274.2	846.502	193.8	4,087.944	41
Kor mean (618/ha unfed)[a]	245.9	357.091	131.7	1,479.818	11
618/ha least square mean[b]	266.1	1,468.608	163.3	8,906.672	19

[a] Ponds not fed, but received fathead minnows at 2,471/ha.

[b] Ponds fed 2% per day and received fathead minnows at 2,471/ha.

Table 10. (Continued)

		Mean Value	t' Value	Effective d.f.
Weight	Christiansen (309/ha unfed)	165.7	2.28*	75
	Fed ponds 309/ha	193.8		
	Kor (618/ha unfed)	131.7		
	Fed ponds 618/ha	163.3	1.29 NS	26
Length	Christiansen (309/ha unfed)	269.9		
	Fed ponds 309/ha	274.2	0.76 NS	76
	Kor (618/ha unfed)	245.9		
	Fed ponds 618 ha	266.1	1.93 NS	28

* Significant ($P \leq 0.05$)

NS Not significant ($P \geq 0.05$)

no significant differences between length means for both the 309/ha rate and the 618/ha rate fed and unfed ponds, respectively. Significant differences in growth values would be expected at the higher stocking rate as well, especially if competition for food was a contributing factor in the significant difference in weights at the 309/ha rate. The lack of significant differences in length at both the 309 and 618 /ha rates and in weight at the 309/ha rate may indicate the lack of competition for food. The two unfed ponds may have received stockings below their respective natural carrying capacities. The existence of only one unfed pond at each of the two above-mentioned rates may not represent a valid comparison, but was the only data available.

Variables Affecting Growth

Physical and chemcial factors were possibly operative in affecting growth of the channel catfish. No significant ($P \leq 0.05$) cubic or quadratic relationships were found, but a significant ($P \leq 0.05$) linear relationship existed for both length and weight, with respective r^2 values of 0.5261 and 0.5125.

Separate maximum r-square improvement stepwise multiple linear regression was performed using 22 independent variables to find the multivariate model which best explained the maximum amount of variation in the dependent variables length and weight, respectively. The independent variables used are listed in the methods and materials section of this paper. The 3.0 m readings for temperature, salinity, conductivity, and dissolved oxygen concentration are deleted. This omission improved the number of missing observations from 61 missing out of a total of 88 observations, to 15 observations missing. The fact that few ponds were 3.0 m deep or more, accounts for the 46 missing observation difference. Similarly, not all ponds were 2.0 m deep or deeper for the entire study period, explaining the remaining 15 missing observations.

For dependent variable length, the best significant ($P \leq 0.05$) 14 variable model yielded an r^2 value of 0.7615. The variables of the best 14 variable model, alpha and beta values, and the r^2 value for the maximum r-square improvement procedure are presented in Table 11.

For dependent variable weight, the best 14 variable model in the maximum r-square improvement stepwise multiple linear regression procedure yielded a significant ($P \leq 0.05$) r^2 value of 0.7691. The variables of the best 14 variable model for weight, the alpha and beta values, and the accompanying r^2 value are displayed in Table 12.

Correlation relationships of the physical and chemical parameters with length and weight were determined. The r values and appropriate r^2 values for each particular significant ($P \leq 0.01$) relationship are presented in Table 13.

The variables stocking rate, temperature, and Julian date would be expected to reflect negative, positive, and positive correlation, respectively, with fish growth measurements. In both maximum r-square improvement stepwise multiple regression procedures (Tables 11 and 12) stocking rate and temperature were significant variables in the regression models. The correlation with stocking rate for length, $r = -0.7251$, and for weight, $r = -0.7150$, were also significant ($P \leq 0.05$) (Table 13). Bottom temperature exerted positive r values

Table 11. The variables of the best 14 variable model which significantly ($P \leq 0.05$) affected length of fish computed using a maximum r-square improvement multiple regression procedure for the 11 dugouts used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Variable	Beta
Stocking rate	- 0.0823
Time in 1/4 hours since sunrise	0.3160
Surface temperature	- 2.0571
0.5 m temperature	2.9734
1.0 m temperature	- 3.6828
2.0 m temperature	3.5278
0.5 m salinity	-21.4014
0.5 m conductivity	- 0.0890
2.0 m conductivity	0.0775
0.5 m dissolved oxygen	3.7973
1.0 m dissolved oxygen	- 2.6092
2.0 m dissolved oxygen	- 1.4682
Phenolpthalein alkalinity	- 0.5568
Total hardness	0.0345
Alpha = 270.1771	

For best 14 variable model, $r^2 = 0.7615$

Table 12. The variables of the best 14 variable model which significantly ($P \leq 0.05$) affected weight of fish, computed using a maximum r-square improvement multiple regression procedure, for the 11 dugouts used for analysis in the study of the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980.

Variable	Beta
Stocking rate	- 0.1617
Time in 1/4 hours since sunrise	0.4932
Surface temperature	- 3.8518
0.5 m temperature	6.9216
1.0 m temperature	- 8.7581
2.0 m temperature	6.8630
0.5 m salinity	-39.9432
0.5 m conductivity	- 0.1773
2.0 m conductivity	0.1528
0.5 m dissolved oxygen	6.5357
1.0 m dissolved oxygen	- 5.8103
2.0 m dissolved oxygen	- 2.6286
Phenolpthalein alkalinity	- 0.9445
Total hardness	0.0752
Alpha = 199.4140	

For best 14 variable model, $r^2 = 0.7691$

Table 13. Significant ($P \leq 0.05$) correlation coefficients for variables length and weight and accompanying coefficients of determination of the fish harvested from the 11 dugouts used for analysis in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Independent Variable	Length r	r^2
Stocking rate	- 0.7251	0.5258
Bottom temperature	0.2990	0.0895
0.5 m salinity	- 0.3439	0.1182
1.0 m salinity	- 0.3344	0.1118
2.0 m salinity	- 0.3329	0.1108

Independent Variable	Weight r	r^2
Stocking rate	- 0.7150	0.5112
Bottom temperature	0.3146	0.0990
0.5 m salinity	- 0.3293	0.1084
1.0 m salinity	- 0.3188	0.1016
2.0 m salinity	- 0.3164	0.1001

of 0.2990 and 0.3146 for length and weight, respectively, indicating that the fish may have remained in close association with the bottom. The temperature ranges in which channel catfish growth occurs has been discussed at length, and the positive correlation coefficients are reflections of the relationship between temperature and growth. Mean periodic temperatures at various depths and overall means for the study period are presented in Table 14.

Physical and Chemical Water Characteristics

The mean pH for the 11 fed ponds was 9.15 (Table 15). In five of the eight sampling periods the minimum pH values were greater than the maximum value (8.5) for the range in which channel catfish suffer no ill effects (Table 15). The mean pH value for each period exceeded 8.5 (Table 15). The pH values obtained, although not found to significantly effect growth, were consistently above the optimum range for channel catfish, 6.3 to 7.5 (Bardach et al. 1972). They reported that the fish suffered no ill effects in the 5.0 to 8.5 range, and that a pH value over 9.5 is likely to be lethal. In no case was any pH value for any period within the optimum range for channel catfish. In six of the eight sampling periods the maximum pH value exceeded the 9.5 value (Table 15); a potentially lethal limit for this species. The Hobbie, Matson, McKeown, Cotton, Berg, and Hersrud ponds all exceeded this potentially lethal limit in at least one sampling. The maximum range of the pH meter readings was 10.0. The maximum pH values of 10.0 (Table 15) may therefore represent values of 10.0 or greater. These possibly conservative pH estimates may have effected the deletion of pH

Table 14. Mean temperatures (in C) with maximum and minimum values, from various depths per period, and overall mean temperature for the 11 fed dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
1	05/22/80	Surface	21.6	19.1	24.8
		0.5	21.0	19.0	24.0
		1.0	19.7	17.3	21.0
		2.0	15.0	12.0	18.8
		3.0	13.7	12.0	17.5
		Bottom	13.0	11.2	16.9
2	06/20/80	Surface	25.6	20.8	30.1
		0.5	21.4	17.1	26.8
		1.0	20.1	15.5	24.0
		2.0	18.9	16.1	21.9
		3.0	16.9	14.6	18.9
		Bottom	16.9	12.8	21.3
3	07/07/80	Surface	27.5	22.8	32.4
		0.5	25.5	22.5	28.5
		1.0	23.3	18.6	27.0
		2.0	20.8	17.3	25.0
		3.0	18.6	15.1	23.5
		Bottom	18.3	12.2	25.5
4	07/22/80	Surface	23.3	21.0	27.3
		0.5	22.3	20.8	24.9
		1.0	21.3	19.5	24.1
		2.0	20.3	16.9	23.2
		3.0	19.1	14.8	23.5
		Bottom	19.0	13.0	23.0
5	08/06/80	Surface	23.3	20.9	25.5
		0.5	23.3	20.8	25.8
		1.0	22.0	20.5	23.9
		2.0	20.3	17.1	22.5
		3.0	19.5	15.6	20.8
		Bottom	19.4	15.3	22.7

Table 14. (Continued)

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
6	08/22/80	Surface	20.9	16.1	24.4
		0.5	19.9	16.0	23.6
		1.0	19.4	15.9	21.6
		2.0	18.2	13.9	20.9
		3.0	16.3	13.8	19.8
		Bottom	17.3	13.5	20.5
7	09/05/80	Surface	21.3	11.8	25.5
		0.5	18.7	12.4	22.2
		1.0	17.9	13.2	20.2
		2.0	17.5	13.9	20.0
		3.0	18.1	16.8	20.2
		Bottom	16.7	8.8	20.2
8	09/19/80	Surface	15.6	13.9	19.0
		0.5	15.0	13.8	16.1
		1.0	14.7	13.9	15.6
		2.0	14.6	14.0	15.1
		3.0	-	-	-
		Bottom	14.8	14.0	15.8
Mean 05/22 to 09/19/80		Surface	22.4	11.8	32.4
		0.5	20.9	12.4	28.5
		1.0	19.8	13.2	27.0
		2.0	18.2	12.0	25.0
		3.0	17.5	12.0	23.5
		Bottom	17.0	8.8	25.5

Table 15. Mean pH and maximum depth (m) values per period, with periodic maximum and minimum values and overall means for the 11 fed dugout ponds used in the study of culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Period	Date	Value	Mean	Minimum Value	Maximum Value
1	05/22/80	pH*	9.12	8.90	≥ 10.00
		Depth	2.45	2.10	3.65
2	06/20/80	pH*	8.88	7.80	9.80
		Depth	2.86	1.80	3.85
3	07/07/80	pH*	9.13	8.00	≥ 10.00
		Depth	3.12	1.60	3.90
4	07/22/80	pH*	9.28	8.80	≥ 10.00
		Depth	2.87	0.95	3.50
5	08/06/80	pH*	9.31	8.80	≥ 10.00
		Depth	2.65	0.85	3.33
6	08/22/80	pH*	9.39	8.70	≥ 10.00
		Depth	2.47	1.06	3.33
7	09/05/80	pH*	9.22	9.00	9.50
		Depth	2.57	0.92	3.26
8	09/19/80	pH*	8.88	8.50	9.50
		Depth	2.16	0.80	2.90
Mean 05/22 to 09/19/80		pH*	9.15	7.80	≥ 10.00
		Depth	2.87	0.80	3.90

* Maximum measurement of pH meter is 10.0, so values of 10.00 represent pH ≥ 10.0.

from factors significantly affecting growth in the statistical computations. Byford (1970) stated that pH is difficult to measure because of diurnal fluctuations. He suggested the use of total water hardness as a more reliable test.

The mean total hardness for the 11 fed ponds fit for analysis was 459.2 mg/l (Table 16). Total hardness means for every sampling period (Table 16) are well in excess of the optimum hardness range (20.0 - 120.0 mg/l) for channel catfish (Byford 1970), indicating that the fish may have been subjected to stress. In only three cases were the minimum values within the optimum total hardness range. These exceptions were the Oppelt, Matson, and Cotton ponds.

The mean total alkalinity for the 11 fed ponds was 181.4 mg/l (Table 16). Mean total alkalinity values for each sampling period were within the optimum range of Bardach et al. (1972) for channel catfish (30.0 - 200.0 mg/l). The maximum total alkalinity values for each sampling period exceeded the maximum limit for the optimal range without exception. Ponds exceeding this maximum value at least once included the Cotton, Berg, Negstad, Hersrud, Oppelt, and Hobbie dugouts.

Mean periodic conductivities for the 11 fed ponds analyzed appear in Table 17. High salinity and conductivity values are often directly related. Work concerning deleterious conductivity values for this species would be useful.

The mean dissolved oxygen values for the 11 fed ponds at depths of 0.5 m and 1.0 m for each period (Table 18) exceeded the minimum value (5.0 mg/l) above which channel catfish grow well (Byford 1970). With the exception of one sampling period, the 2.0 m mean readings for

Table 16. Mean phenolpthalein alkalinity (mg/l), total alkalinity (mg/l), and hardness (mg/l) means per period, and overall means for the 11 fed dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Period	Date	Value	Mean	Minimum Value	Maximum Value
1	05/22/80	Phenol. alk.	4.6	0.0	25.0
		Total alk.	198.6	140.0	270.0
		Total hardness	467.5	90.0	1,170.0
2	06/20/80	Phenol. alk.	6.7	0.0	30.0
		Total alk.	169.2	60.0	240.0
		Total hardness	436.2	60.0	1,580.0
3	07/07/80	Phenol. alk.	6.2	0.0	30.0
		Total alk.	177.9	110.0	310.0
		Total hardness	460.4	125.0	1,460.0
4	07/22/80	Phenol. alk.	8.3	0.0	50.0
		Total alk.	170.0	120.0	230.0
		Total hardness	480.8	130.0	1,540.0
5	08/06/80	Phenol. alk.	10.4	0.0	50.0
		Total alk.	194.2	150.0	290.0
		Total hardness	484.2	140.0	1,430.0
6	08/22/80	Phenol. alk.	11.7	0.0	70.0
		Total alk.	174.2	130.0	240.0
		Total hardness	482.9	125.0	1,530.0
7	09/05/80	Phenol. alk.	7.9	0.0	40.0
		Total alk.	169.2	130.0	250.0
		Total hardness	466.4	130.0	1,500.0
8	09/19/80	Phenol. alk.	3.6	0.0	33.0
		Total alk.	198.1	130.0	270.0
		Total hardness	395.8	130.0	1,100.0
Mean 05/22 to 09/19/80		Phenol. alk.	7.4	0.0	70.0
		Total alk.	181.4	60.0	290.0
		Total hardness	459.2	60.0	1,580.0

Table 17. Mean conductivities with maximum and minimum values at each respective depth per period, with overall means at each depth (in μmhos, standardized and converted to 25 C) for the 11 dugout ponds used in the study of the culture of annual crops of channel catfish (Ictalurus punctatus) during 1980.

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
1	05/22/80	0.5	604.17	233.00	1,046.00
		1.0	629.67	243.00	1,131.00
		2.0	636.25	242.00	1,134.00
		3.0	518.00	244.00	769.00
2	06/20/80	0.5	828.92	124.00	2,573.00
		1.0	839.08	120.00	2,591.00
		2.0	897.67	288.00	2,622.00
		3.0	647.40	328.00	1,032.00
3	07/07/80	0.5	832.33	257.00	2,509.00
		1.0	857.33	268.00	2,540.00
		2.0	835.45	286.00	2,560.00
		3.0	834.14	357.00	2,415.00
4	07/22/80	0.5	845.25	272.00	2,479.00
		1.0	829.00	292.00	2,489.00
		2.0	857.27	294.00	2,541.00
		3.0	517.20	353.00	796.00
5	08/06/80	0.5	894.83	302.00	2,646.00
		1.0	872.54	305.00	2,636.00
		2.0	901.45	320.00	2,707.00
		3.0	628.00	543.00	818.00
6	08/22/80	0.5	864.25	291.00	2,530.00
		1.0	868.75	289.00	2,525.00
		2.0	903.18	308.00	2,518.00
		3.0	864.80	517.00	1,966.00
7	09/05/80	0.5	927.17	288.00	2,572.00
		1.0	897.73	294.00	2,552.00
		2.0	939.64	334.00	2,530.00
		3.0	675.67	589.00	748.00

Table 17. (Continued)

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
8	09/19/80	0.5	1,498.83	541.00	3,000.00
		1.0	1,427.73	504.00	3,074.00
		2.0	1,438.80	493.00	3,074.00
		3.0	-	-	-
Means 05/22 to 09/19/80		0.5	911.97	124.00	3,000.00
		1.0	898.21	120.00	3,074.00
		2.0	916.88	242.00	3,074.00
		3.0	684.76	244.00	2,415.00

Table 18. Mean dissolved oxygen concentrations (mg/l) with maximum and minimum values at each respective depth per period, respectively, with overall means at each depth for the 11 dugout ponds used in the study of the culture of annual crops of channel catfish (<u>Ictalurus punctatus</u>) during 1980.

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
1	05/22/80	0.5	8.4	7.0	10.0
		1.0	8.9	6.0	15.0
		2.0	5.7	3.0	10.0
		3.0	4.0	1.0	6.0
2	06/20/80	0.5	7.3	3.0	15.8
		1.0	7.3	2.8	12.6
		2.0	5.7	0.0	9.6
		3.0	1.5	0.0	3.4
3	07/07/80	0.5	6.4	1.2	10.2
		1.0	6.7	2.0	10.8
		2.0	4.6	0.8	9.4
		3.0	2.0	0.4	3.2
4	07/22/80	0.5	7.9	1.6	12.8
		1.0	8.2	1.6	16.4
		2.0	8.4	1.2	9.4
		3.0	3.6	0.0	8.6
5	08/06/80	0.5	7.9	5.6	11.8
		1.0	7.7	5.2	11.6
		2.0	5.3	1.4	8.8
		3.0	2.3	1.2	3.6
6	08/22/80	0.5	8.1	3.6	14.2
		1.0	7.3	4.8	10.6
		2.0	5.3	0.0	7.8
		3.0	4.9	3.4	7.0
7	09/05/80	0.5	7.7	5.8	9.8
		1.0	7.3	5.2	9.2
		2.0	5.3	2.2	8.2
		3.0	3.9	2.0	6.8

Table 18. (Continued)

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
8	09/19/80	0.5	8.5	6.4	10.4
		1.0	7.8	5.8	9.6
		2.0	7.2	5.8	8.8
		3.0	-	-	-
Mean 05/22 to 09/19/80		0.5	7.8	1.2	15.8
		1.0	7.6	1.6	16.4
		2.0	5.7	0.0	10.0
		3.0	3.0	0.0	8.6

each period exceeded 5.0 mg/l (Table 18). The mean dissolved oxygen values for the 3.0 m depth were below 5.0 mg/l every period with one exception (Table 18). The periodic minimum values (Table 18) indicated that from late June through August some ponds, at all depths, were within the range (< 3.0 mg/l) considered stressful to channel catfish (Simco and Cross 1966; Byford 1970). The Oleson and Hobbie ponds experienced this dissolved oxygen stress at all depths and were fed only occasionally during this period, when dissolved oxygen concentrations were in excess of 3.0 mg/l. Simco and Cross (1966), however, found that ponds which experienced morning dissolved oxygen levels less than 2.0 mg/l yielded satisfactory growth of channel catfish. This indicated that diurnal oxygen fluctuations may explain such growth. They found that when dissolved oxygen concentrations remained below 4.0 mg/l for several weeks, inhibition of growth of channel catfish was evidenced in ponds. Moss and Scott (1961) reported that critical dissolved oxygen levels were usually less than 1 mg/l, but increased slightly with rising temperature. Some ponds experienced stressful dissolved oxygen concentrations, but every pond was found to have at least one stratum of water with a minimum of 1.0 mg/l during sampling.

Salinity values for the 11 fed ponds fit for analysis ranged from 0.0 to 1,200.0 mg/l (0.0 to 1.200 $^{o}/oo$), with overall means near 80.0 mg/l (0.08 $^{o}/oo$) over the entire period (Table 19). The salinity, or total dissolved solids, was negatively correlated with growth in terms of both length and weight in this study (Table 13). Wetzel (1975) stated that in the past salinity and total dissolved solids were treated as the same value. Simco and Cross (1966) reported a high positive

Table 19. Mean salinities (in $^{o}/oo$), with maximum and minimum values at each respective depth per period, with overall means at each depth for the 11 dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
1	05/22/80	0.5	0.115	0.0	1.100
		1.0	0.123	0.0	1.200
		2.0	0.127	0.0	1.200
		3.0	0.310	0.0	1.200
2	06/20/80	0.5	0.112	0.0	1.200
		1.0	0.112	0.0	1.200
		2.0	0.114	0.0	1.200
		3.0	0.005	0.0	0.020
3	07/07/80	0.5	0.142	0.0	0.900
		1.0	0.151	0.0	1.000
		2.0	0.173	0.0	1.000
		3.0	0.171	0.0	1.200
4	07/22/80	0.5	0.018	0.0	0.090
		1.0	0.016	0.0	0.090
		2.0	0.016	0.0	0.090
		3.0	0.000	0.0	0.000
5	08/06/80	0.5	0.064	0.0	0.600
		1.0	0.055	0.0	0.600
		2.0	0.055	0.0	0.600
		3.0	0.000	0.0	0.000
6	08/22/80	0.5	0.068	0.0	0.700
		1.0	0.076	0.0	0.800
		2.0	0.084	0.0	0.800
		3.0	0.140	0.0	0.700
7	09/05/80	0.5	0.020	0.0	0.120
		1.0	0.019	0.0	0.110
		2.0	0.019	0.0	0.110
		3.0	0.007	0.0	0.010

Table 19. (Continued)

Period	Date	Depth (m)	Mean	Minimum Value	Maximum Value
8	09/19/80	0.5	0.056	0.0	0.150
		1.0	0.049	0.0	0.150
		2.0	0.050	0.0	0.150
		3.0	-	-	-
Mean 05/22 to 09/19/80		0.5	0.075	0.0	1.200
		1.0	0.077	0.0	1.200
		2.0	0.081	0.0	1.200
		3.0	0.094	0.0	1.200

correlation between growth in terms of weight and total dissolved solids with values in the 200 - 500 mg/l (0.200 - 0.500 ^{o}/oo) range in channel catfish ponds. They hypothesized that the increasing ration of supplemental feed probably contributed to the total dissolved solids. The low negative correlation coefficients (Table 13) between salinity at three depths and both length and weight could not be explained.

From the preceding review of chemical and physical pond conditions, it is clear that all of the fed ponds in this study experienced at least one growth limiting condition during the study. Total hardness values were constantly within the zone of stress. Total alkalinity, dissolved oxygen concentrations, and mean temperatures were frequently outside of the respective ranges of values considered necessary for optimum growth. The mean pH was constantly within the range considered deletarious to channel catfish, and maximum values frequently exceeded a pH of 9.5, considered in the lethal range.

The above characteristics, possible predation by other pond fauna, possible unreported fishing, and inefficient capture methods may have contributed to the loss, or apparent loss, of fish throughout the study.

Future Stocking Recommendations

It is the contention of the author that if fish were stocked at a larger fingerling size at the 1,235/ha stocking rate and fed twice daily for more efficient food usage and optimal growth (Andrews and Page 1975), at a 3% body weight/day ration, an annual crop should reach a harvestable size. The interpretation of harvestable size varies between

136.1 to 226.8 g (Regier 1963), 226.8 g (Swingle 1950; Davis 1959), 340.2 to 567.0 g (Hatcher 1971), 453.6 g (Bardach et al. 1972), and 453.6 to 680.4 g (Bennett 1970). Hereafter harvestable size will refer to fish 226.8 g or larger in weight. The age of the fish stocked and the associated larger size lessened the growth needed to attain harvestable size, as channel catfish exhibit their greatest growth rates in their second year (Appleget and Smith 1951).

If catfish of 203.2 mm were stocked and experienced the same average daily growth as that experienced by the 1,235/ha rate fish of the present study, finishing weights would exceed 231.4 g or slightly greater than usable size. Channel catfish of 203.2 mm average 50.8 g, and catfish 254.0 mm in length average 148.8 g (Grizzell et al. 1975). If catfish of 254.0 mm were stocked and experienced the same daily weight gains per fish, they would weigh 329.4 g. At these larger sizes the catfish would be more apt to utilize the fathead minnow forage base. At 170 mm, the channel catfish is just beginning to make the transition from an insectivorous to a piscivorous diet (Jearld 1970).

Food Habits

Stomach contents of 66 fish were analyzed following harvest. The major food group, in terms of total frequency of occurrence (95.6%), was insects, primarily aquatic insects. They comprised 57.3, 45.7, and 40.4% of the total volume of food items for the 125 - 174 mm, 225 - 274 mm, and the 275 - 324 mm intervals, respectively, constituting the greatest volume percentage of identifiable organisms in any of these intervals (Table 20). Decapods comprised 60.3% of the total

Table 20. Stomach contents of channel catfish collected 27-28 September, expressed as percent volume and percent frequency of occurrence (in parentheses) for the fed and unfed dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Item	Fish Length-Groups (mm)				
	125 - 174	175 - 224	225 - 274	275 - 324	325 - 374
Belostomatidae	-	-	-	3.0 (0.2)	-
Corixidae	-	-	1.6 (0.5)	7.2 (26.7)	1.6 (1.8)
Notonectidae	-	-	22.2 (3.5)	17.1 (21.6)	1.8 (1.8)
Gyrinidae	-	-	T[a] (T)[a]	-	-
Non-identifiable Coleoptera	-	-	4.0 (0.4)	3.0 (3.1)	-
Chironomidae	57.3 (98.6)	T[a] (90.0)	14.0 (90.2)	3.9 (39.4)	8.5 (84.2)
Chaoborinae	-	-	2.1 (1.3)	0.7 (2.3)	-
Ephemeroptera	T[a] (1.4)	-	T[a] (T)	T[a] (1.0)	T[a] (1.8)
Trichoptera	-	T[a] (10.0)	-	-	-
Odonata	-	-	1.4 (0.7)	0.5 (0.2)	-
Terrestrial Orthoptera	-	-	0.4 (T)[a]	2.0 (0.5)	-
Insects (Total)	57.3 (100.0)	U[b] (100.0)	45.7 (96.6)	40.4 (95.0)	11.9 (89.6)

Table 20. (Continued)

Item	Fish Length-Groups (mm)				
	125 - 174	175 - 224	225 - 274	275 - 324	325 - 374
Pimephales promelas	-	-	1.5 (T)[a]	2.2 (0.2)	-
Decapoda	-	-	-	5.0 (0.2)	60.3 (3.5)
Hirudinea	-	-	3.2 (2.6)	0.6 (2.4)	2.0 (7.0)
Nematomorpha	-	-	1.6 (0.2)	-	-
Amphipoda	-	-	T[a] (T)[a]	0.3 (1.3)	-
Cladocera	-	-	T[a] (0.3)	T[a] (1.1)	-
Non-identifiable	42.7 (U)[b]	-	47.8 (U)[b]	54.3 (U)[b]	25.9 (U)[b]
Stomachs with food*	1	3	27	22	5
Stomachs empty*	0	2	3	3	0

[a] T - Denotes a trace, or less than 1 %

[b] U - Denotes an undeterminable amount

* Stomachs with less than 0.10 ml of volume displacement and with no identifiable organisms were considered empty.

percent volume of the 325 - 374 mm interval. Utilization of fathead minnows was evidenced in only two length-groups, 225 - 274 mm and 275 - 324 mm, respectively. Minnows constituted 1.5 and 2.2% volume of these respective length-groups, while the respective percent frequencies were a trace and 0.2%.

As length increased, there was a diminishing utilization of insect food items in terms of both percent volume and percent frequency of occurrence. These results parallel those of Jearld (1970). There was an increase in both percent volume and percent frequency for decapods from the 275 - 324 mm to the 325 - 374 mm intervals in the present study. Perry (1969) found increasing percent volumes and occurrences of large crustacea in channel catfish of the 377 - 474 mm range.

Fathead minnows were only present in the stomachs of larger catfish. From the 225 - 274 mm interval to the 275 - 324 mm interval the use of fathead minnows was evidenced in the present study. Low returns of fish in the higher length-groups may have caused the apparent lack of fathead minnows in the stomachs of the larger length-groups. Non-identifiable items comprised from 0.0 to 54.3% volume of the stomach contents of the five length-groups.

Carlander (1969) stated that channel catfish less than 100 mm feed primarily on benthic arthropods, but when greater than 100 mm they were usually omnivorous or piscivorous. Channel catfish have been considered piscivorous at 375 mm (Williamson and Smitherman 1976), 377 mm (Perry 1969), and at 355 mm (Busbee 1968). In terms of percent volume, channel catfish stomachs contained 69.4% fish in the 290 - 329 mm interval, representing a 24.0% frequency of occurrence (Jearld 1970).

With the possible exception of the upper portion of the 325 - 374 mm length interval, the channel catfish of this study were below the lengths generally considered as piscivorous. The fathead minnows were available as they spawned successfully in each pond and were in evidence throughout the study. Busbee (1968) found that no size-class analyzed contained a predominance of any one food item. He emphasized that the fish in the length intervals regarded as piscivorous were utilizing a wide variety of food types, indicating that food consumption may be more dependent on the availability of, rather than a preference for, food items. Perry (1969) indicated that diets of channel catfish less than 377 mm in total length consisted primarily of small insects, amphipods, algae, and undetermined organic material. He further stated that beyond this length, in addition to the former food items, fish and larger crustaceans comprised a portion of the diet.

Consumer Evaluation of the Channel Catfish

Of 19 pondowners provided fish, 16 responded (Table 21). In the flavor-desirability, texture-desirability, and the overall satisfaction categories, 100.0% of the responses were in the three highest categories. In the appearance-desirability category, 93.3% of the responses were in the three highest categories. In the flavor description 93.3% of the respondents rated the catfish acceptable. In the consumer preference 93.7% of the respondents would eat this catfish at least occasionally, while 62.5% would eat it more often.

Table 21. Percentages of pondowner-consumer responses in various categories, with the numbers of responses (in parentheses) for the fish collected from fed and unfed dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

	Flavor-desirability	Appearance-desirability	Texture-desirability	Overall satisfaction
Like extremely	50.0 (8)	53.3 (8)	40.0 (6)	43.8 (7)
Like strongly	31.2 (5)	26.7 (4)	40.0 (6)	31.2 (5)
Like moderately	18.8 (3)	20.0 (3)	20.0 (3)	25.0 (4)
Like slightly	-	6.7 (1)	-	-
Dislike slightly	-	-	-	-
Dislike moderately	-	-	-	-
Dislike strongly	-	-	-	-
Dislike extremely	-	-	-	-

Flavor Description

Acceptable	93.3	(14)	Rancid	-
Too fishy	3.3	(0.05)[a]	Salty	-
Too bland	-		Bitter	-
Musty	3.3	(0.05)[a]	Yeast-like	-
Medicinal	-		Other off-flavor	-

Table 21. (Continued)

Consumer Preference		
I would eat this every opportunity I had	25.0	(4)
I would eat this quite often	12.5	(2)
I would eat this frequently	25.0	(4)
I like this and would eat it occasionally	31.2	(5)
I have no preference	6.2	(1)
I don't like this, but would eat it occasionally	-	
I would rarely eat this	-	
I would eat this only if there were no other food available	-	
Force would be needed to make me eat this	-	

How Fish Was Prepared		
Baked	-	
Broiled	6.2	(1)
Fried	87.5	(4)
Deep-fried	6.2	(1)
Grilled	-	
Other (explain)	-	

Texture Description		
Firm and flaky	78.6	(11)
Tough	-	
Mushy	21.4	(3)
Mealy	-	
String-like	-	

[a] One respondent described flavor using two rating categories.

In the texture description, 78.6% of the respondents found the texture firm and flaky. Most of the responding pondowners (87.5%) fried the catfish, and it was seasoned according to individual preference.

A taste test involving a test panel was conducted by the Department of Nutrition and Food Science, South Dakota State University. In this taste test each of the 11 panelists sampled a portion of broiled, unseasoned catfish from each of three randomly selected ponds, and described five characteristics (Table 22).

In the color category, 69.7% of the fish sampled was rated good to very good, while 90.9% was judged above fair. In the odor category 69.7% of the fish sampled was above fair. In the flavor description, 63.6% of the fish tasted was good to excellent, while 75.7% of the fish was rated above fair. In the texture description, 63.7% of the fish sampled were found to be good to excellent, while 86.4% was rated above fair. In the appearance category, the test panel described 71.9% of the fish tested as good to excellent, and 90.7% above fair.

These results suggest that the channel catfish from the dugout ponds were palatable and desirable. Many pondowners offered additional positive comments and inquired about participating in further pond stockings with channel catfish.

Overwintering of Fish

A total of 62 fish were returned to three randomly selected dugout ponds after the 1980 fall harvest in order to evaluate overwinter survival. The three ponds were seined following final ice melt on 27 March 1981. Thirty-eight of the 46 fish left in the Thiex dugout

Table 22. Percentages of fish categorically rated by a taste panel, with numbers of panel responses (in parentheses) per respective category, for the fish collected from fed and unfed dugout ponds used in the study of the culture of annual crops of channel catfish (*Ictalurus punctatus*) during 1980.

Responses	Color		Odor		Flavor		Texture		Appearance	
Excellent	-		3.0	(1)	15.2	(5)	15.2	(5)	9.4	(3)
Very good	36.4	(12)	12.1	(4)	30.3	(10)	22.7	(7.5)[a]	28.1	(9)
Good	33.3	(11)	27.3	(9)	18.1	(6)	25.8	(8.5)[a]	34.4	(11)
Below good - Above fair	21.2	(7)	27.3	(9)	12.1	(4)	22.7	(7.5)[a]	18.8	(6)
Fair	6.1	(2)	21.2	(7)	18.1	(6)	9.1	(3)	6.2	(2)
Below Fair - Above Poor	3.0	(1)	-		6.1	(2)	1.5	(0.5)[a]	3.1	(1)
Poor	-		9.1	(3)	-		3.0	(1)	-	
Very poor	-		-		-		-		-	
Extremely poor	-		-		-		-		-	
Total	33		33		33		33		32[b]	

[a] Two respondents described texture using two rating categories.

[b] One respondent failed to answer in this category.

pond were recovered; while three dead fish were collected on shore. Three of the six catfish overwintering in the Hobbie dugout were recovered while four of the ten overwintering catfish in the McKeown dugout were recovered.

Overwinter survival, assuming 100% recovery efficiency was 72.6%, indicating that the three ponds were suitable for the survival of channel catfish during the 1980-81 winter. The ponds were covered with ice periodically during the winter, as at least two total thaws were observed during the winter of 1980-81. Little, if any, snow covered the ice that winter. Open water or ice with little snow cover are both known to reduce the potential of winterkill (Patriarche and Merna 1970).

It might be noted that several fish collected from the Thiex and Hobbie ponds exhibited possible disease symptoms. White to hemorrhagic cysts were present in the skin between caudal fin rays. The mouths and barbels of some of these fish were inflammed, with portions of the upper barbels completely eroded in some fish. The cause of these symptoms was not determined.

Although the majority of fish survived the winter, the risks involved in overwintering the fish in dugouts may be prohibitive from an economic viewpoint. The acceptance of the aquacultural limitations imposed by winterkill through the management of annual crops of channel catfish in dugouts appears most feasible. If, however, fish do not attain harvestable size in the first season, overwintering may be necessary.

Costs

The 1,235/ha stocking rate of this study was the optimum rate. The costs for this rate were analyzed. At this rate, 143 catfish were stocked in the three analyzed ponds, 95 of which were recovered at harvest. The total cost for the catfish at $0.385 each was $55.06. The total feed cost for these catfish amounted to $12.59. As 36.2% of the live weight was lost in the decapitation, skinning, and evisceration of the channel catfish (Bulow 1967), the 16,439.8 g gross harvest of channel catfish of the 1,235/ha stocking rate represented 10,488.6 g of processed frozen catfish. The market value of frozen catfish in 1980 was $3.81/kg (Stellmacher 1981); the frozen catfish net worth amounted to $40.00. The cost of the 143 stocked catfish and the supplemental feed, combined, totaled $67.65. This represents a $27.65 net loss, not considering the cost of the fathead minnows, the feeding and spawning structures, and the labor involved.

In this initial experiment with channel catfish in east-central South Dakota dugouts, the results were not aquaculturally profitable. The ponds did, however, exhibit the capability of supporting channel catfish. These ponds hold recrational fisheries potential, and may yet represent commercial potential for the channel catfish.

Fathead minnows reproduced successfully in every pond. The dugout pond may have a potential bait fishery application.

Relative Pond Productivity

A dugout pond constructed in the spring 1980 (Kurtz pond) and a pond excavated in 1976 (Oppelt pond) were compared to determine differences in relative productivity, with zooplankton biomass used as a means of comparison. The use of zooplankton biomass to determine differences in the relative productivity of bodies of water is well documented (Rawson 1942, 1960, 1961; Koshinsky 1965; Sparrow 1966; Applegate and Mullan 1967; Johnson 1971; Anderson and Green 1975, 1976).

The mean annual zooplankton biomass for the older pond was 245.3 mg/l, while that of the newly constructed pond was 121.6 mg/l. These respective values may be converted to 245,302.8 mg/m^3 and 121,590.3 mg/m^3. These values far exceed those of Rawson (1942), Sparrow (1966), and Applegate and Mullan (1967) and may be considered as zooplankton biomasses representative of highly eutrophic waters.

For a comparison of the total biomass of each of the two ponds and a determination of their relative productivity, mean periodic total zooplankton biomasses for each pond (Table 23) were used in an analysis of variance procedure to ascertain any significant differences in the mean values (Table 24).

The Oppelt productivity pond was significantly ($P \leq 0.01$) greater in mean biomass than the Kurtz productivity pond throughout the 26 sampling periods. A significant ($P \leq 0.01$) difference in zooplankton biomass between dates was also evidenced.

Further analysis to determine any differences in the dependent variables mean periodic biomass/l and mean periodic concentration/l between ponds, between dates, and pond-date interaction was computed using an ANOVA for each dependent variable per zooplankton item. The biomasses and concentrations from the 260 samples from each pond, representing one year of sampling, were used in the computations. For each respective ANOVA, tests of hypotheses using the ANOVA mean square

Table 23. The periodic mean total zooplankton biomasses for an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, over a one year period during 1980-81.

Date	Period	Old (Oppelt)	New (Kurtz)
06/30/80	1	137.896	11.730
07/14/80	2	164.509	335.804
07/30/80	3	567.742	578.144
08/13/80	4	816.199	565.625
08/29/80	5	416.573	619.957
09/12/80	6	172.852	177.047
10/01/80	7	376.467	85.328
10/21/80	8	233.684	61.744
10/31/80	9	216.193	10.517
11/14/80	10	92.114	8.419
11/28/80	11	295.746	10.729
12/19/80	12	242.949	22.319
12/26/80	13	582.391	35.144
01/09/81	14	315.220	99.622
01/23/81	15	353.552	36.844
02/13/81	16	598.897	48.401
02/20/81	17	62.051	57.107
03/06/81	18	92.031	7.423
03/20/81	19	53.870	1.207
04/04/81	20	87.616	85.908
04/18/81	21	17.924	3.864
05/08/81	22	59.587	36.104
05/22/81	23	26.338	19.482
06/05/81	24	63.647	38.087
06/22/81	25	48.143	57.704
07/03/81	26	283.683	54.617

Table 24. The results of an analysis of variance procedure indicating significant ($P \leq 0.01$) differences in zooplankton biomass over a one year period between an older and a recently constructed dugout pond during 1980 and 1981.

Source	d.f.	SS	MS	F
Pond	1	198,962.422	198,962.422	11.79**
Period	25	1,542,253.948	61,690.156	3.66**
Residual	25	421,829.358	16,873.174	

** Denotes significance ($P \leq 0.01$).

for sample (pond within date) as an error term detected significant differences. The results of the 12 separate ANOVA tests for both mean periodic organism biomass and mean periodic organism concentration are found in Tables 25 and 26. The periodic values for each zooplankton item in terms of both mean biomass and mean concentration for each pond over the entire year are presented in Table 27. The respective annual mean values for each zooplankton item collected during the study are found in Appendix Tables 2 - 13.

Table 25 and Appendix Table 2 indicated that the Daphnia spp. mean annual biomass value for the new pond was significantly ($P \leq 0.05$) higher than that of the older pond. This was the only planktor from the new pond determined to be significantly ($P \leq 0.05$) greater in biomass than the same organism in the older pond.

The respective mean annual biomass values for Moina spp., cyclopoid copepodites, cyclopoid nauplii, Cyclops vernalis, and Chaoborus spp. in the older pond were significantly ($P \leq 0.01$) higher than the respective mean annual biomass values from the new pond (Table 25).

In each case where significant ($P \leq 0.05$ or $P \leq 0.01$) differences were found in respective mean annual biomasses between ponds, there also existed significant ($P \leq 0.01$) differences in biomass between dates, as well as significant ($P \leq 0.01$) interaction between ponds and dates (Table 25).

Table 25. The results of 12 identical but separate ANOVA procedures for dependent variable mean biomass (mg/l) for each zooplankton item collected over a one year period with regard to independent variables pond, date, and pond within date, respectively, for an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81.

Organism	Pond	Date	Pond Within Date
Daphnia spp.	*	**	**
Moina spp.	**	**	**
Chydorus sphaericus	NS	NS	NS
Bosmina longirostris	NS	NS	NS
Cyclopoid copepodites	**	**	**
Cyclopoid nauplii	**	**	**
Cyclops vernalis	**	**	**
Eucyclops agilis	NS	**	NS
Macrocyclops albidus	NS	**	*
Mesocyclops edax	NS	**	*
Diaptomus spp.	NS	NS	NS
Chaoborus spp.	**	**	**

* Denotes significance ($P \leq 0.05$)

** Denotes significance ($P \leq 0.01$)

NS = No significance ($P \geq 0.05$)

Table 26. The results of 12 identical but separate ANOVA procedures for dependent variable concentration (number/l) for each zooplankton item collected over a one year period with regard to independent variables pond, date, and pond within date, respectively, for an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81.

Organism	Pond	Date	Pond Within Date
Daphnia spp.	*	**	**
Moina spp.	**	**	**
Chydorus sphaericus	NS	NS	NS
Bosmina longirostris	NS	NS	NS
Cyclopoid copepodites	**	**	**
Cyclopoid nauplii	**	**	**
Cyclops vernalis	**	**	**
Eucyclops agilis	NS	**	NS
Macrocyclops albidus	NS	**	**
Mesocyclops edax	NS	**	*
Diaptomus spp.	NS	NS	NS
Chaoborus spp	**	**	**

* Denotes significance ($P \leq 0.05$)

** Denotes significance ($P \leq 0.01$)

NS = No significance ($P \geq 0.05$)

Table 27. Annual mean concentration (number/l) and biomass (mg/l), respectively, for each of the 12 zooplankton items collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81.

	Old (Oppelt)		New (Kurtz)	
Zooplankton item	number/l	mg/l	number/l	mg/l
Daphnia spp.	2.8106	22.3343	6.5242	50.3522
Moina spp.	6.8374	28.7142	0.0735	0.3087
Chydorus sphaericus	0.0001	0.0002	0.0000	0.0000
Bosmina longirostris	0.0003	0.0005	0.0050	0.0090
Cyclopoid copepodites	11.1940	34.2741	4.3916	12.7017
Cyclopoid nauplii	1.2450	0.0170	0.3511	0.0031
Cyclops vernalis	1.4734	12.6469	0.5642	4.8518
Eucyclops agilis	0.1093	0.8751	0.0589	0.4735
Macrocyclops albidus	0.6682	9.7348	0.2469	3.7592
Mesocyclops edax	0.0872	0.8725	0.0245	0.2768
Diaptomus spp.	0.0082	0.0489	0.0018	0.0106
Chaoborus spp.	1.0225	152.0075	0.2712	40.5133

The *Daphnia* spp. mean annual concentration for the new pond was significantly ($P \leq 0.05$) higher than the respective older pond value. This value represented the only mean annual concentration of the new pond which significantly ($P \leq 0.05$) exceeded a respective value in the older pond.

The respective mean annual concentration values for *Moina* spp., cyclopoid copepodites, cyclopoid nauplii, *Cyclops vernalis*, and *Chaoborus* spp. in the older pond were significantly ($P \leq 0.01$) greater than the respective values of the new pond.

In each case where significance ($P \leq 0.05$ or $P \leq 0.01$) was found in respective mean annual concentrations between ponds, there also existed significant ($P \leq 0.01$) differences in concentrations between dates, as well as significant ($P \leq 0.01$) interaction between ponds and dates affecting concentrations.

The older pond was determined to have a significantly ($P \leq 0.01$) greater mean annual biomass than the new dugout. The older pond had a longer exposure to cattle use and this may have resulted in significantly greater relative productivity. The accompanying deposition of excrement within the pond and its drainage basin had increased the nutrient content of the water. As cattle tend to congregate in or near these ponds several times daily during the warm summer months, the older pond had benefited from several years of enrichment. The new pond was more a reflection of the basic natural fertility of the water and surrounding soils. It is likely that similar differences would occur between older and recently constructed dugout ponds elsewhere. It is possible that the soil productivities of the respective pond basins may have differed for other reasons.

If such a relationship exists between all older and newly constructed dugout ponds it may have important fisheries management implications, particularly if the fathead minnow is the forage fish of choice. Since the fathead minnow is considered to be mainly planktivorous in its food habits (Moore 1932), the relative productivities of the ponds may have an impact on the fathead minnow forage base. If growth and production of the forage base declines, consequent reductions in the growth and production of the game fish of choice would be expected.

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APPENDIX

Appendix Table 1. The respective location of the fed, unfed, and productivity dugout ponds in the three county study area used to study the culture of annual crops of channel catfish (<u>Ictalurus punctatus</u>) during 1980-81 in east-central South Dakota.

Pond	County	Range	Township	1/4 of 1/4 Section	1/4 Section	Section
Matson	Kingsbury	R53W	T110N	-	NW	30
Oleson	Brookings	R52W	T109N	-	NW	33
Hersrud	Moody	R50W	T108N	-	SE	16
Kurtz	Brookings	R47W	T111N	SE	SW	31
Hobbie	Moody	R49W	T108N	-	SW	32
Cotton	Brookings	R52W	T110N	-	NW	24
Collins	Brookings	R49W	T109N	-	NW	9
Hansen	Brookings	R49W	T112N	-	NW	19
Negstad	Brookings	R52W	T109N	-	NE	7
McKeown	Brookings	R48W	T110N	-	SW	1
Oppelt	Brookings	R48W	T110N	NW	NW	1
Foster	Brookings	R49W	T112N	-	NE	7
Berg	Kingsbury	R53W	T109N	-	NW	15
Edie	Brookings	R50W	T112N	-	SW	32
Thiex	Brookings	R50W	T109N	-	SW	6
VandeWeerd	Brookings	R52W	T112N	-	NE	11
Christianson	Brookings	R52W	T111N	-	NW	24
Kor	Brookings	R49W	T112N	-	SW	14
Odegaard East	Brookings	R52W	T111N	-	SE	25
Odegaard West	Brookings	R52W	T111N	-	SE	25
Oppelt productivity	Brookings	R48W	T110N	SE	NW	1
Kurtz productivity	Brookings	R47W	T111N	SW	SW	31

Appendix Table 2. The periodic mean concentration (number/l) and biomass (mg/l) for Daphnia spp. collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/ l	mg/l
06/30/80	0.0438	0.3493	0.0029	0.0230
07/14/80	0.0	0.0	0.1720	1.3749
07/30/80	1.5347	8.8789	46.9741	375.7934
08/13/80	21.0947	168.7596	52.2387	417.9104
08/29/80	34.2526	273.5066	68.7664	503.7970
09/12/80	7.6059	60.8471	1.3686	9.4336
10/01/80	7.5407	60.3270	0.0142	0.1139
10/21/80	0.0315	0.2515	0.0321	0.2565
10/31/80	0.0084	0.0668	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0	0.0
12/19/80	0.0036	0.0290	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0125	0.0720
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0029	0.0230
04/04/81	0.0109	0.0873	0.0	0.0
04/18/81	0.0049	0.0393	0.0164	0.1303
05/08/81	0.0	0.0	0.0078	0.0623
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0184	0.1456
06/22/81	0.0	0.0	0.0029	0.0230
07/03/81	0.9439	7.5513	0.0	0.0

Appendix Table 3. The periodic mean concentrations (number/l) and biomass (mg/l) for Moina spp. collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0024	0.0100	0.0128	0.0536
07/14/80	54.1842	227.5744	0.0884	0.3715
07/30/80	82.4932	346.4691	0.0212	0.0891
08/13/80	41.0637	172.4671	1.7888	7.5130
08/29/80	0.0	0.0	0.0	0.0
09/12/80	0.0	0.0	0.0	0.0
10/01/80	0.0	0.0	0.0	0.0
10/21/80	0.0	0.0	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0083	0.0351	0.0	0.0
12/19/80	0.0036	0.0152	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0	0.0	0.0	0.0
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.0	0.0	0.0	0.0

Appendix Table 4. The periodic mean concentrations (number/l) and biomass (mg/l) for Chydorus sphaericus collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0029	0.0057	0.0	0.0
07/14/80	0.0	0.0	0.0	0.0
07/30/80	0.0	0.0	0.0	0.0
08/13/80	0.0	0.0	0.0	0.0
08/29/80	0.0	0.0	0.0	0.0
09/12/80	0.0	0.0	0.0	0.0
10/01/80	0.0	0.0	0.0	0.0
10/21/80	0.0	0.0	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0	0.0
12/19/80	0.0	0.0	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0	0.0	0.0	0.0
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.0	0.0	0.0	0.0

Appendix Table 5. The periodic mean concentrations (number/l) and biomass (mg/l) for Bosmina longirostris collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0	0.0	0.0046	0.0083
07/14/80	0.0	0.0	0.0	0.0
07/30/80	0.0	0.0	0.0	0.0
08/13/80	0.0	0.0	0.0	0.0
08/29/80	0.0	0.0	0.0	0.0
09/12/80	0.0	0.0	0.1226	0.2207
10/01/80	0.0	0.0	0.0	0.0
10/21/80	0.0077	0.0138	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0029	0.0052
12/19/80	0.0	0.0	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0	0.0	0.0	0.0
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.0	0.0	0.0	0.0

Appendix Table 6. The periodic mean concentrations (number/l) and biomass (mg/l) for cyclopoid copepodites collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	46.9620	140.8858	0.5962	1.8749
07/14/80	3.1872	9.5613	47.2599	130.6734
07/30/80	39.7149	119.1447	13.9199	41.7600
08/13/80	101.4782	304.4350	1.4019	3.6058
08/29/80	3.5040	10.5117	1.4178	4.2059
09/12/80	3.3679	10.1039	29.6973	89.0918
10/01/80	2.7051	8.1154	10.6941	32.0823
10/21/80	0.1414	0.3186	1.3811	4.1435
10/31/80	0.0678	0.2034	0.4870	1.5965
11/14/80	0.0089	0.0267	0.2195	0.6235
11/28/80	0.0151	0.0453	0.2031	0.6093
12/19/80	0.0077	0.0230	0.0170	0.0508
12/26/80	0.0307	0.0919	0.0400	0.1199
01/09/81	0.0230	0.0690	0.0054	0.0162
91/23/81	0.0	0.0	0.0083	0.0248
02/13/81	0.0077	0.0230	0.0123	0.0367
02/20/81	0.0	0.0	0.0039	0.0116
03/06/81	0.0042	0.0125	0.0058	0.0172
03/20/81	0.0147	0.0442	0.0039	0.0116
04/04/81	0.2106	0.6289	0.0611	0.1834
04/18/81	1.5741	4.7220	0.1792	0.5374
05/08/81	13.8170	41.5582	2.0002	6.0004
05/22/81	2.4911	7.4727	0.9023	2.2576
06/05/81	10.2610	30.7825	2.4239	7.2717
06/22/81	13.4358	40.3074	0.7398	1.9317
07/03/81	48.0143	162.0395	0.5025	1.5080

Appendix Table 7. The periodic mean concentrations (number/l) and biomass (mg/l) for cyclopoid nauplii collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	4.4333	0.0444	0.1481	0.0016
07/14/80	2.8723	0.0305	0.8612	0.0087
07/30/80	5.6667	0.0565	0.7359	0.0073
08/13/80	6.5375	0.0596	0.4628	0.0046
08/29/80	1.0863	0.0216	0.3329	0.0065
09/12/80	0.2174	0.0042	0.6283	0.0125
10/01/80	0.3704	0.0073	0.6818	0.0136
10/21/80	0.0693	0.0014	0.3708	0.0074
10/31/80	0.0750	0.0015	4.1971	0.0036
11/14/80	0.0060	0.0001	0.0591	0.0020
11/28/80	0.0	0.0	0.0167	0.0004
12/19/80	0.0	0.0	0.0029	0.0001
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0039	0.0001
03/20/81	0.0180	0.0056	0.0097	0.0003
04/04/81	0.1259	0.0025	0.0221	0.0005
04/18/81	0.2232	0.0044	0.0554	0.0009
05/08/81	2.0595	0.0412	0.2242	0.0045
05/22/81	0.2383	0.0046	0.0230	0.0005
06/05/81	4.3972	0.0880	0.1156	0.0022
06/22/81	2.7497	0.0550	0.0872	0.0016
07/03/81	1.2237	0.0123	0.0902	0.0001

Appendix Table 8. The periodic mean concentrations (number/l) and biomass (mg/l) for Cyclops vernalis collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dkaota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.1541	1.3255	0.0108	0.0931
07/14/80	4.2405	36.4681	3.2576	28.0161
07/30/80	7.3096	62.8617	5.6440	48.5376
08/13/80	10.4461	89.8364	3.3684	28.9675
08/29/80	0.3922	3.3722	0.1830	1.5746
09/12/80	0.6029	5.1855	1.2009	10.3273
10/01/80	0.0911	0.7838	0.5662	4.8696
10/21/80	0.0328	0.2817	0.1052	0.9042
10/31/80	0.0	0.0	0.0265	0.2279
11/14/80	0.0042	0.0359	0.0343	0.2953
11/28/80	0.0049	0.0423	0.0184	0.1587
12/19/80	0.1610	0.1377	0.0	0.0
12/26/80	0.0077	0.0659	0.0	0.0
01/09/81	0.0384	0.3295	0.0	0.0
01/23/81	0.0077	0.0659	0.0	0.0
02/13/81	0.0	0.0	0.0102	0.0871
02/20/81	0.0060	0.0516	0.0081	0.0693
03/06/81	0.0	0.0	0.0039	0.0334
03/20/81	0.0278	0.2393	0.0	0.0
04/04/81	0.0264	0.2266	0.0099	0.0855
04/18/81	0.0531	0.3905	0.0077	0.0659
05/08/81	1.0406	8.9492	0.0390	0.3350
05/22/81	1.0112	8.2836	0.0234	0.2008
06/05/81	0.2378	2.0455	0.1098	0.9450
06/22/81	1.0379	8.9268	0.0	0.0
07/03/81	11.5197	98.9142	0.0412	0.3541

Appendix Table 9. The periodic mean concentrations (number/l) and biomass (mg/l) for Eucyclops agilis collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0	0.0	0.0	0.0
07/14/80	0.4073	3.2579	0.6210	4.9676
07/30/80	0.1966	1.5729	0.2160	1.7277
08/13/80	0.8267	6.6134	0.2181	1.7446
08/29/80	0.0192	0.1539	0.0	0.0
09/12/80	0.2191	1.7527	0.0	0.0
10/01/80	0.0974	0.7792	0.0	0.0
10/21/80	0.0	0.0	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0042	0.0334	0.0229	0.1833
12/19/80	0.0077	0.0613	0.0049	0.0393
12/26/80	0.0153	0.1226	0.0109	0.0871
01/09/81	0.0153	0.1226	0.0042	0.0334
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0036	0.0290
02/20/81	0.0	0.0	0.0123	0.0978
03/06/81	0.0153	0.1226	0.0097	0.0770
03/20/81	0.0131	0.1046	0.0273	0.2191
04/04/81	0.0278	0.2225	0.0153	0.1227
04/18/81	0.0167	0.1336	0.0	0.0
05/08/81	0.7790	6.2313	0.0029	0.0230
05/22/81	0.0617	0.5088	0.3630	2.9603
06/05/81	0.1200	0.9598	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.0	0.0	0.0	0.0

Appendix Table 10. The periodic mean concentrations (number/l) and biomass (mg/l) for Macrocyclops albidus collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0	0.0	0.0	0.0
07/14/80	0.3014	4.5203	0.0	0.0
07/30/80	0.5752	8.6286	0.3496	5.2434
08/13/80	5.0650	75.9764	0.5258	7.8860
08/29/80	7.2925	104.5366	0.2357	3.5360
09/12/80	2.4018	36.0286	3.2723	49.0943
10/01/80	1.2536	16.1767	1.6671	26.4451
10/21/80	0.0515	0.7711	0.2433	3.6497
10/31/80	0.0106	0.1591	0.0352	0.5264
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0	0.0
12/19/80	0.0	0.0	0.0049	0.0738
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0077	0.1149	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0766	1.1494	0.0057	0.0862
05/22/81	0.0383	0.5747	0.0415	0.6228
06/05/81	0.0600	0.8998	0.0383	0.5747
06/22/81	0.0600	0.8898	0.0	0.0
07/03/81	0.1779	2.6690	0.0	0.0

Appendix Table 11. The periodic mean concentrations (number/l) and biomass (mg/l) for Mesocyclops edax collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0	0.0	0.0036	0.0363
07/14/80	0.0	0.0	0.1292	1.2921
07/30/80	0.8835	8.8352	0.1306	1.3058
08/13/80	1.3850	13.8506	0.2067	2.0670
08/29/80	0.0	0.0	0.0	0.0
09/12/80	0.0	0.0	0.0	0.0
10/01/80	0.0	0.0	0.1663	2.4952
10/21/80	0.0	0.0	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0	0.0
12/19/80	0.0	0.0	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0	0.0	0.0	0.0
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.0	0.0	0.0	0.0

Appendix Table 12. The periodic mean concentrations (number/l) and biomass (mg/l) for Diaptomus spp. collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.0	0.0	0.0	0.0
07/14/80	0.0	0.0	0.0	0.0
07/30/80	0.0	0.0	0.0	0.0
08/13/80	0.0	0.0	0.0	0.0
08/29/80	0.0	0.0	0.0	0.0
09/12/80	0.0	0.0	0.0460	0.2760
10/01/80	0.0	0.0	0.0	0.0
10/21/80	0.0	0.0	0.0	0.0
10/31/80	0.0	0.0	0.0	0.0
11/14/80	0.0	0.0	0.0	0.0
11/28/80	0.0	0.0	0.0	0.0
12/19/80	0.0	0.0	0.0	0.0
12/26/80	0.0	0.0	0.0	0.0
01/09/81	0.0	0.0	0.0	0.0
01/23/81	0.0	0.0	0.0	0.0
02/13/81	0.0	0.0	0.0	0.0
02/20/81	0.0	0.0	0.0	0.0
03/06/81	0.0	0.0	0.0	0.0
03/20/81	0.0	0.0	0.0	0.0
04/04/81	0.0	0.0	0.0	0.0
04/18/81	0.0	0.0	0.0	0.0
05/08/81	0.0	0.0	0.0	0.0
05/22/81	0.0	0.0	0.0	0.0
06/05/81	0.0	0.0	0.0	0.0
06/22/81	0.0	0.0	0.0	0.0
07/03/81	0.2121	1.2725	0.0	0.0

Appendix Table 13. The periodic mean concentrations (number/l) and biomass (mg/l) for Chaoborus spp. collected over a one year period from an old (Oppelt) and a newly constructed (Kurtz) dugout pond, both devoid of fish, during 1980-81 in east-central South Dakota.

	Old (Oppelt)		New (Kurtz)	
Date	number/l	mg/l	number/l	mg/l
06/30/80	0.9966	149.5198	0.0554	8.3292
07/14/80	0.8506	120.9705	1.0046	150.6994
07/30/80	0.5187	66.2711	0.3790	56.8543
08/13/80	0.7091	106.3658	0.9963	149.4540
08/29/80	0.7531	112.0795	0.6324	94.8535
09/12/80	0.4501	67.5181	0.1482	19.3933
10/01/80	1.6458	246.8962	0.1119	16.7782
10/21/80	1.4110	211.6550	0.3122	46.8273
10/31/80	1.2031	180.4471	0.0508	7.6121
11/14/80	0.6001	83.3752	0.0622	9.3288
11/28/80	1.9100	283.4933	0.0607	9.1079
12/19/80	1.5112	226.6861	0.1436	20.6027
12/26/80	3.5491	532.3664	0.2180	32.6951
01/09/81	2.1121	316.7828	0.2806	42.0988
01/23/81	2.1589	316.9244	0.2372	35.5665
02/13/81	3.8313	574.6904	0.2898	43.4738
02/20/81	0.3949	59.2562	0.3397	50.9588
03/06/81	0.5849	87.7397	0.0490	7.3520
03/20/81	0.3266	48.9920	0.0058	0.8618
04/04/81	0.5727	85.9025	0.5174	77.6206
04/18/81	0.0842	12.6450	0.0252	3.3421
05/08/81	0.0366	5.4864	0.1908	28.5975
05/22/81	0.0809	12.1356	0.1178	17.6817
06/05/81	0.1529	22.9314	0.2145	32.1835
06/22/81	0.0346	5.1900	0.2728	40.9363
07/03/81	0.1058	15.8756	0.3344	50.1376