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RAINBOW TROUT CAGE CULTURE AND BENTHIC PRODUCTION IN EAST-CENTRAL SOUTH DAKOTA DUGOUTS

BY

GLENN DAVID SCHULER

A Thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Wildlife and Fisheries Sciences
(Fisheries Option)

South Dakota State University
1984

RAINBOW TROUT CAGE CULTURE AND BENTHIC PRODUCTION IN EAST-CENTRAL SOUTH DAKOTA DUGOUTS

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.

Thesis Adviser

Department of
Wildlife and Fisheries Sciences

RAINBOW TROUT CAGE CULTURE AND BENTHIC PRODUCTION
IN EAST-CENTRAL SOUTH DAKOTA DUGOUTS

Abstract

GLENN D. SCHULER

Forty-five cages, encompassing 1.0 m^3 of water, distributed between three dugout ponds, were stocked with rainbow trout (*Salmo gairdneri*) fingerlings to determine the feasibility of raising annual fish crops. Growth rates were compared between feeding rate (0, 3, and 5% body weight/day [bwt/day]) and stocking rate (35, 52, and 70 fish/cage). Growth was significantly ($P \leq 0.05$) greater at feeding rates of 3 and 5% bwt/day than 0% bwt/day. The fish fed 0% bwt/day decreased in mean weight by 0.7 g; the weight gain for the 3 and 5% bwt/day feeding rates were 47.2 and 45.2 g, respectively. Significant differences ($P \leq 0.05$) in growth were detected between stocking rates.

Mean survival for the three feeding rates was 98%. Natural food contribution was significantly lower ($P \leq 0.05$) for the 3 and 5% feeding rates, than the 0% bwt/day. Stomachs contained 2.6, 1.3, and 12.8 organisms/stomach for these respective treatments. While cage culture was not commercially feasible due to small harvest size, low stocking rate, and small cage size, trout were large enough for consumption.

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INTRODUCTION

Rainbow trout (Salmo gairdneri) have been cultured with variable success in dugout ponds in eastern South Dakota. Vodehnal (1982) stocked fingerlings in the spring and harvested them in the fall. This culture met with limited success, as survival was only 2.6%. The low survival was attributed to a combination of high water temperatures and low oxygen levels which occurred during July and August. Roell (1983) conducted spring cage culture and reported 98% survival; trout were harvested before critical water temperatures and oxygen levels occurred.

Cage culture has potential since approximately 100,000 dugout ponds have been excavated in South Dakota since the mid 1930s (Vodehnal 1982) and rainbow trout have been shown to survive and grow in dugouts (Vodehnal 1982; Roell 1983). Because of the shallowness and eutrophic waters (DiLauro 1982) the optimal culture period occurs from mid April through late June or early July. Not all dugouts have adequate water depth, but those with a maximum depth of 2.5 m or greater may have potential (Roell 1983). Fish could be produced in dugout ponds for commercial sale, as a family food source, and/or as a recreation for dugout landowners.

Advantages of cage culture include improved environmental control, no predation problems, no interspecific competition for food, fish density regulation, and total recovery of fish (Hahn 1974). In addition, Schmittou (1969) considered close observation of feeding efficiency, general health of the fish, and manipulation of the harvest to fit market requirements to also be important benefits.

Cages also eliminate trout emigration from dugout ponds adjacent to low-laying areas subject to seasonal flooding.

The objectives of this study were: (1) to determine the optimal feeding and stocking rates for cage-reared rainbow trout, (2) to evaluate the contribution of naturally produced food to the caged trout diet, (3) to evalute the economic feasibility of cage rearing rainbow trout on an annual basis, and (4) to determine the macrobenthic numerical abundance, biomass, and faunal composition in two dugouts (one three-years-old and one six-years-old). The objective concerning macroinvertebrate production was a separate objective which was not compared in this paper to trout production.

STUDY AREA

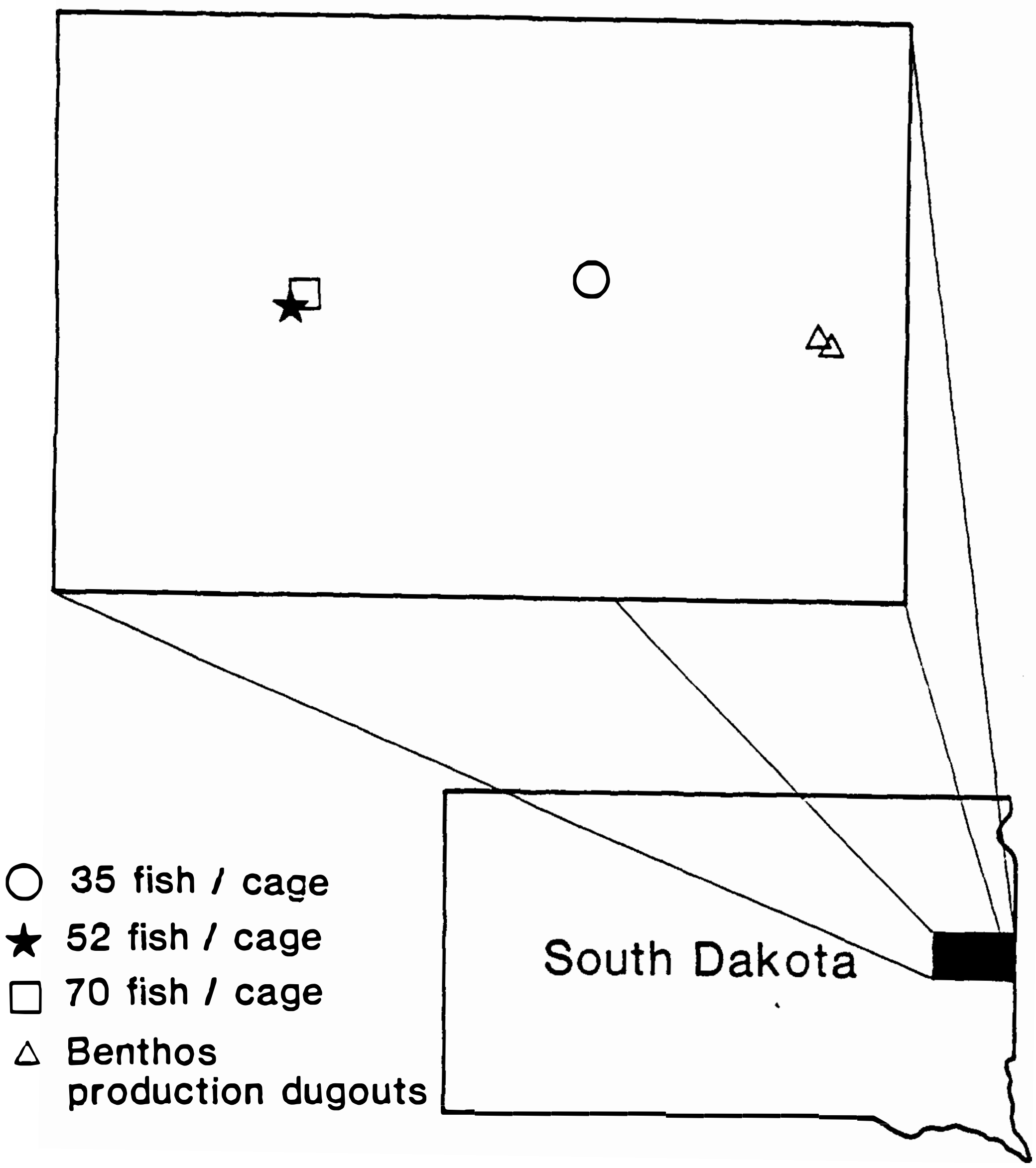
The dugout ponds used in this study were located in Brookings County in east-central South Dakota. Three dugout ponds were used for the trout cage culture portion of the study. Pond selection was based on criteria described by Roell (1983) as favorable for trout growth and survival. Ponds were considered acceptable if (1) maximum depth was at least 3.0 m, and (2) cattle usage was no greater than one cow/hectare for the dugout pasture. Two additional dugout ponds were used for the benthic production portion of the study (Figure 1).

The study area was located in the Coteau des Prairies, a highland region of glacial origin between the Minnesota Red River Lowland and the James River Lowland (Westin and Malo 1978). Landowner names, dugout pond locations, and pond surface areas are provided in Appendix Table 1.

Chernozem soils predominate, and the region is classified as a cool-moist climate. The average temperature for the region is 6.5 C with extremes of -40.5 to 42.7 C (Sphuler et al. 1971). Average annual precipitation is between 48.3 and 48.4 cm (Westin and Malo 1978).

Dugouts are rectangular depressions in an area where runoff water or groundwater seepage can be caught. They vary in size depending upon dugout use, source of water recharge, and construction method. Most dugouts have a surface area between 0.05 and 0.10 hectares (Bue et al. 1964). Bottom widths and lengths are required to be at least 3.0 and 12.1 m, respectively (Soil Conservation Service 1978). In this region, minimum water depth in ponds built for livestock is 3.0 m.

Figure 1. Distribution of cage and benthos production dugout ponds used to study the culture of rainbow trout (*Salmo gairdneri*) during 1982-83 in Brookings County, South Dakota.



One or both ends of a dugout are more gently sloped to permit access for cattle, while the sides are steeply sloped (Bue et al. 1964). The two side slopes will not be steeper than 2:1 nor flatter than 4:1, while either one or both ends have a 4:1 slope. The excavated material is usually uniformly placed along the long sides of the excavated hole. The material is placed such that its weight will not endanger the stability of the pond sides and where it will not be washed back into the pond by runoff.

MATERIALS AND METHODS

Rainbow Trout Cage Culture

A 3 x 3 x 5 factorial design with three feeding rates, three stocking rates, and five replications was used to determine if significant differences occurred in lengths, weights, and relative weight (W_r) of trout. A significant level of $P \leq 0.05$ was used to detect significant differences. Wege and Anderson (1978) conceived W_r as an index for fish condition. Trout feeding rates (five cages/dugout/feeding rate) tested were 0, 3, and 5% body weight/day (bwt/day). Each stocking rate was randomly assigned to one dugout (35, 52, or 70 fish/cage) and tested. Following the initial analysis of variance of length, weight, and W_r, Waller-Duncan's K-ratio t-test for unequal observations was used if significant differences were detected (Steel and Torrie 1980). This test is applicable to pairwise comparisons of means and used to determine where differences occur among treatments.

Forty-five 0.5 x 1.0 x 2.0 m deep cages were built for the study. Two meter deep cages were needed to allow rainbow trout to select preferred water depth as temperature and oxygen concentrations became stressful.

Frames were constructed of 3.3 cm^2 pine lumber. Frames were held together by 5.5 cm number 10 aluminum wood screws. Black 1.1 cm mesh plastic vexar was fastened to the pine by 1.1 cm galvanized poultry staples. Black 0.3 cm mesh plastic vexar was attached to the top 26.4 cm of the cage in the same manner as the 1.1 cm vexar. The smaller mesh was needed to prevent floating trout chow from drifting out of the cages; 0.3 cm mesh was 13.2 cm above and below the water level (Figure 2).

Cages were covered with 1.1 cm thick plywood lids. Holes were cut in the centers of the covers (20.0 cm^2) to facilitate feeding. Feeding holes were covered with 1.1 cm mesh vexar. Two styrofoam bead blocks (26.4 x 26.4 x 52.8 cm) were fastened at the top of each cage to aid in floatation. Two 4 kg concrete blocks were attached to each cage bottom to maintain proper floatation.

Fifteen cages were placed in the center of each trout dugout pond. Cages were arranged in three rows, five cages per row. The cages in each row were evenly spaced 1.0 m apart and held together with 6 mm nylon rope. Rows were held in place at each end by 6 mm nylon rope attached to two 12 kg concrete blocks placed on the pond bottom. Rows were spaced 1.5 m apart. Random allocation was used in assigning the feeding rates to the cages.

Rainbow trout were obtained from the Cleghorn Springs State Fish Hatchery in Rapid City, South Dakota, on 20 April 1983. Mean total length and weight at time of stocking were 137.9 mm and 26.9 g, respectively. Trout mortality for the first two weeks was assumed to be due to handling stress. Dead trout were counted on 25 April 1983 and 4 May 1983 with the aid of SCUBA gear. Dead trout were placed with live fish held in extra cages.

Feeding began 23 April 1983 and continued daily throughout the study. Fish received Purina Floating Trout Chow, large fingerling size pellets. The food was 37.5% protein and contained all the essential nutrients and vitamins necessary for a complete diet.

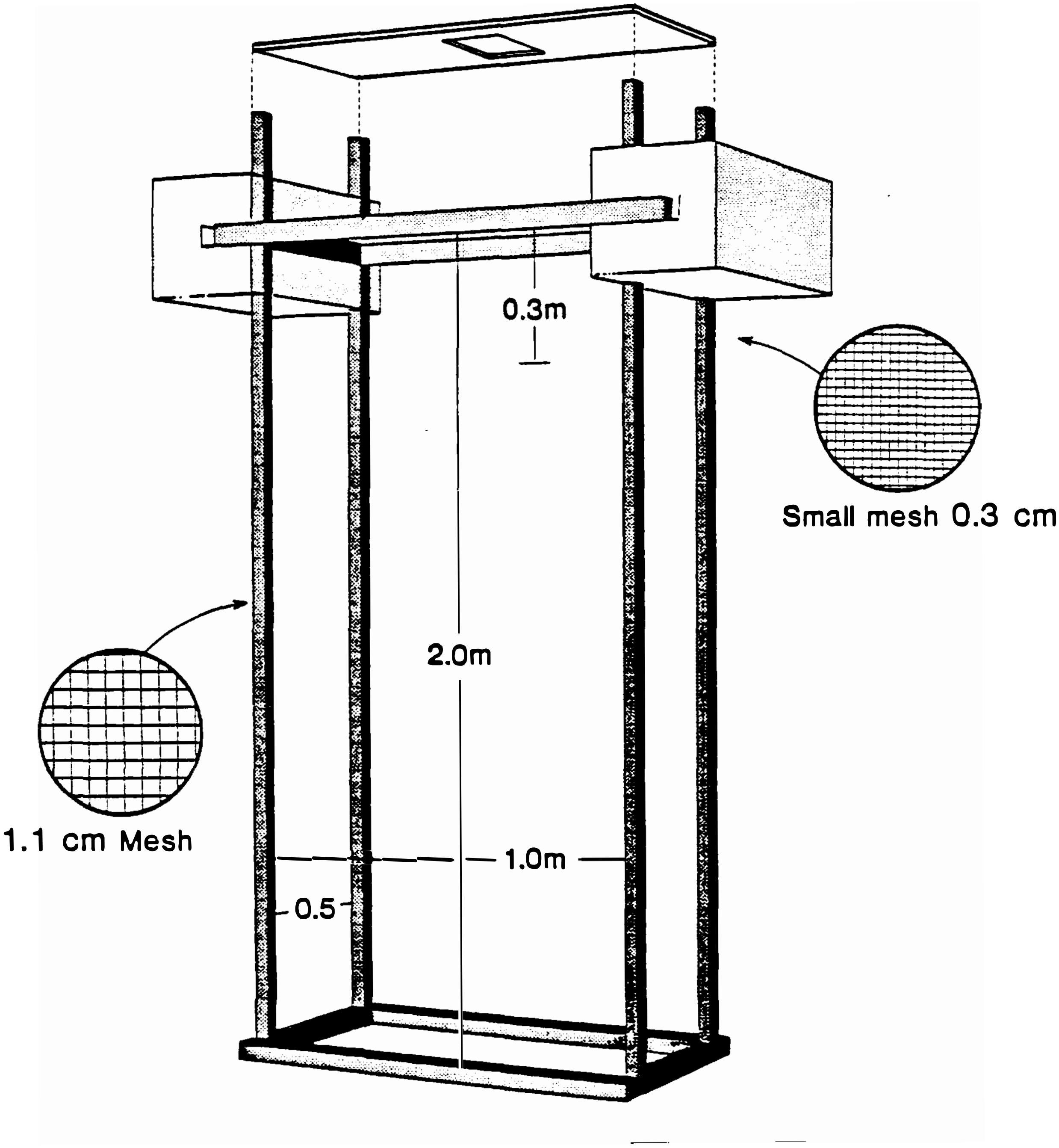


Figure 2. Cage design used to culture rainbow trout (<u>Salmo gairdneri</u>) in dugouts during 1983.

Fish were sampled at 10 - 12 day intervals to monitor growth. A 28% sample (10, 15, and 20 fish from stocking rates of 35, 52, and 70 fish/cage, respectively) of trout was captured with a dip net from one randomly selected cage for each treatment; the fish were weighed and returned to the cage. This sample size was felt to be large enough to accurately monitor trout growth. Daily growth rates were estimated for the sample period and were used to adjust daily feeding allotments until the next sampling date. When a feeding treatment exhibited negative growth, feeding rations were adjusted using the average daily growth for the entire culture period. Prior to the first sample period, daily rations were 0, 3, and 5% bwt/day of the mean stocking weight.

During harvest on 22 - 23 June 1983, all fish were removed by pulling cages to shore and unloading the fish into pails. Final total lengths and weights were taken before trout were dressed. Stomachs of 10 trout were randomly collected from each cage and preserved in 10% formalin for later laboratory analysis of stomach contents. The dressed trout were packed in ice and distributed to landowners and university personnel or were frozen.

Trout stomachs (esophagus to the pylorus) were dissected to determine the contribution of naturally produced food to the caged trout diet. Analysis included the enumeration, identification, and volumetric quantification of the stomach contents. Stomachs with no identifiable items were considered empty.

Chemical and Physical Parameters

Chemical and physical parameters were monitored at approximately two-week intervals in the trout dugout ponds during the study. Sample stations were established in the center of each dugout.

Phenolphthalein alkalinity, total alkalinity, and total hardness were measured using a Hach dr-el/1 kit, from water taken at a 1.0 m depth with a Kemmerer water bottle. Dissolved oxygen samples were taken at surface, 1.0, and 2.0 depths with a Kemmerer water bottle. Oxygen concentrations were determined using the modified Azide-Winkler method (APHA 1975).

Temperature, salinity, and conductivity determinations were made using a YSI Model 33 S-C-T meter. Temperature, salinity, and conductivity readings were taken at surface, 1.0, and 2.0 m depths. Conductivity readings were standardized and converted to 25 C (APHA 1971). A Hach model 17-J test kit was used to measure surface water pH. Secchi disc transparency was also recorded. Water depth was measured using a weighted, calibrated line.

Benthic Productivity Comparison

Benthic productivity was compared between a three-year-old (Kurtz) and a six-year-old (Oppelt) dugout from 23 April 1982 to 23 April 1983. Mid-afternoon samples were taken at approximately two-week intervals during open water periods. During ice cover, samples were taken at four to five week intervals.

A random sampling scheme was used for sampling benthos. Utilizing a random grid technique within each dugout, a total of 288 and 351 sampling stations, 1.0 m^2 in size, was established in the Kurtz and Oppelt dugouts, respectively. The number of sampling stations varied, due to different dugout sizes. Sample stations were not located within 2.5 m of the shore due to dugout dimensions, water level fluctuations, steep slopes, and cattle activity. Three stations per dugout each sample period were selected from a random numbers table (Steel and Torrie 1980). Selected sites were not resampled for at least eight weeks. Benthic macroinvertebrates were sampled with a Ponar dredge (sampling area 289 cm^2).

Benthic organisms were defined as bottom dwelling organisms large enough to be seen by the unaided eye and retained by a U.S. standard number 30 sieve (0.595 mm openings) (EPA 1973; APHA 1975). Samples taken during open water were partially sieved through a 0.5 mm mesh screened bucket immediately after collection in order to reduce sediment volume. Remaining substrate material was washed into jars containing 10% formalin and rose bengal. Rose bengal was used to increase benthos visibility during sorting (Mason and Yevich 1967). During ice cover, samples were placed in 18 liter plastic bags. These samples were processed in the laboratory in the same manner as the open water samples. Samples were preserved in the rose bengal solution for at least 48 hours to ensure complete staining.

Substrate material was resieved through a 1 liter plastic container with 0.5 mm mesh prior to sorting to further reduce sediment volume. Organisms were separated into taxonomic groups, counted, and placed in glass vials containing 70% ethanol. Organisms were identified to the lowest identifiable taxon. Permanent slides of chironomid larvae were made using CMC mounting media. Keys by Smith (1971), Mason (1973), and Simpson and Bode (1980) were used for chironomid larvae identification. Pennak (1978) was used for other organism group identification.

Dry weight was determined to the nearest 1.0 mg using an analytical balance. Organisms were removed from the preservative, placed in previously weighed crucibles, and oven dried at 100 C for 24 hours. Crucibles were removed from the oven, cooled to room temperature in a desiccator, and reweighed.

RESULTS AND DISCUSSION

Rainbow Trout Production

Rainbow Trout Growth

Evaluation of rainbow trout growth, with respect to the three feeding rates and three stocking rates, was based on harvest data (Table 1). Significant ($P \leq 0.05$) differences in length, weight, and W_r occurred between treatments (Tables 2, 3, and 4). The results of Waller-Duncan's K-ratio t-test for length, weight, and W_r indicated that the 0% bwt/day feeding rate was significantly ($P \leq 0.05$) different from the 3 and 5% bwt/day feeding rates, but there was no significant difference between 3 and 5% bwt/day feeding rates (Table 5). Significant differences ($P \leq 0.05$) were also detected by the Waller-Duncan's K-ratio t-test for the three stocking rates (Table 6). A significant stocking rate x feeding rate difference existed in weight, length, and W_r.

Mean individual weight gain per day for the 3 and 5% feeding rates were 0.82 and 0.79 g/day, respectively. The mean individual weight for the 0% bwt/day feeding rate decreased by 0.01 g/day. The Starkenburg south dugout had the highest gain of 0.11, 1.02, and 0.97 g/day for the 0, 3, and 5% feeding rates, respectively. The Schwartz dugout gain was intermediate at 0.90 and 0.87 g/day for the 3 and 5% feeding rates, respectively; the 0% feeding rate exhibited a weight loss of 0.01 g/day. Gain per day was lowest in the Starkenburg north dugout at 0.55 and 0.52 g/day for the 3 and 5% feeding rates, respectively; the 0% feeding treatment had a weight loss of 0.06 g/day (Table 7) Trout had a lower weight gain per day than growth rates

Table 1. The least square mean values for length, weight, and relative weight (W_r) of cage cultured rainbow trout (Salmo gairdneri) during 1983, South Dakota.

Dugout	Feeding rate (% bwt[1]/day)	Average length (mm)	Average weight (g)	(W_r)
Schwartz (35 fish/cage)	0	136.1	21.3	80.3
	3	187.3	80.7	113.1
	5	188.2	79.1	108.2
Starkenburg south (52 fish/cage)	0	149.6	33.7	94.6
	3	188.4	87.8	119.4
	5	186.9	85.0	119.3
Starkenburg north (70 fish/cage)	0	141.3	23.6	76.6
	3	180.4	59.8	93.1
	5	178.7	58.1	92.8

[1] bwt = body weight.

Table 2. Analysis of variance of rainbow trout (*Salmo gairdneri*) total length due to feeding rates in three cage culture dugouts during 1983, South Dakota.

Source	d.f.	SS	MS	F
Stocking rate (SR)	2	28,974	14,487	26.04*
Feeding rate (FR)	2	869,338	434,669	841.68*
SR x FR	4	16,979	4,245	8.22*
Rep (SR)	12	6,676	556	2.92*
FR x Rep (SR)	24	12,394	516	2.71*
Residual	2,254	430,127	191	

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

Table 3. Analysis of variance of rainbow trout (Salmo gairdneri) total weight due to feeding rates in three cage culture dugouts during 1983, South Dakota.

Source	d.f.	SS	MS	F
Stocking rate (SR)	2	210,516	105,258	187.77*
Feeding rate (FR)	2	1,142,629	571,314	981.12*
SR x FR	4	51,948	12,987	22.30*
Rep (SR)	12	6,727	561	2.11*
FR x Rep (SR)	24	13,975	582	2.19*
Residual	2,254	598,967	266	

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

Table 4. Analysis of variance of rainbow trout (Salmo gairdneri) relative weight (W_r) due to feeding rates in three cage culture dugouts during 1983, South Dakota.

Source	d.f.	SS	MS	F
Stocking rate (SR)	2	245,780	122,890	293.29*
Feeding rate (FR)	2	272,025	136,013	254.66*
SR x FR	4	17,891	4,473	8.37*
Rep (SR)	12	5,028	419	5.74*
FR x Rep (SR)	24	12,818	534	7.32*
Residual	2,254	164,469	73	

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

Table 5. Results of Waller-Duncan's K-ratio t-test using least square means for length, weight, and relative weight (W_r), respectively, for the three feeding rates used to study rainbow trout (*Salmo gairdneri*) cage culture during 1983, South Dakota.

Length (mm):	(0% bwt/day)	(5% bwt/day)	(3% bwt/day)
	142.9	183.7	184.7 *
Weight (g):	(0% bwt/day)	(5% bwt/day)	(3% bwt/day)
	26.4	72.1	74.1
W_r:	(0% bwt/day)	(5% bwt/day)	(3% bwt/day)
	83.4	105.3	106.7

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

Table 6. Results of Waller-Duncan's K-ratio t-test using least square means for length, weight, and relative weight (W_r), respectively, for the three stocking rates used to study rainbow trout (*Salmo gairdneri*) cage culture during 1983, South Dakota. All were significant ($P \leq 0.05$).

Length (mm):	(52 fish/cage) 175.0	(35 fish/cage) 170.6	(70 fish/cage) 166.5
Weight (g):	(52 fish/cage) 68.9	(35 fish/cage) 60.4	(70 fish/cage) 46.9
W_r:	(52 fish/cage) 111.1	(35 fish/cage) 100.6	(70 fish/cage) 87.3

Table 7. Production data from rainbow trout (Salmo gairdneri) dugout cage culture during 1983 (present study) compared with growth data from previous studies.

Source	Stocking size (grams)	Harvest size (grams)	Length culture period (days)	Average weight gain/ fish/day (grams)	Conversion rate	Survival (%)	Production (kg/m^3)	% daily weight gain
Present study Schwartz 3%	27	81	60[a]	0.90	1.8	100.0	1.9	3.33
Present study Schwartz 5%	27	79	60	0.87	3.2	99.4	1.8	3.22
Present study Starkenburg S 3%	27	88	60	1.02	1.6	100.0	3.2	3.78
Present study Starkenburg S 5%	27	85	60	0.97	2.5	99.2	3.0	3.59
Present study Starkenburg N 3%	27	60	60	0.55	1.5	94.0	2.2	2.03
Present study Starkenburg N 5%	27	58	60	0.52	2.6	93.4	2.0	1.92
Buck et al. 1972	94	185	74	1.20	4.0	65.5	81.0	1.27
Collins 1972	85	340	115	2.20	1.5	96.1	30.3	2.58
Hahn 1974	4	75	126	0.56	3.2	59.6	8.4	14.00

Table 7. (Continued)

Source	Stocking size (grams)	Harvest size (grams)	Length culture period (days)	Average weight gain/ fish/day (grams)	Conversion rate	Survival (%)	Production (kg/m^3)	% daily weight gain
Kilambi et al. 1977	150	297	138	1.10	2.6	99.0	65.3	0.73
Roell 1983 (2% bwt/day)	35	89	47[b]	1.16	1.0	98.3	1.9	3.31
Roell 1983 (4% bwt/day)	35	102	47	1.44	1.8	96.6	2.3	4.11
Tatum 1973	94	338	120	2.00	3.9	77.2	64.7	2.12
Whitaker and Martin 1974	8	153	122	1.19	1.5	54.0	-	14.87
Whitaker and Martin 1974	14	200	130	1.43	1.5	54.0	-	10.21

[a] Fed 60 of 63 days in dugout.

[b] Fed 47 of 55 days in dugout.

reported by Buck et al. (1972), Collins (1972), Tatum (1973), Kilambi et al. (1977), and Roell (1983) (Table 7). This slower growth appeared to be at least partially due to the small stocking size of 26.9 g. Roell (1983) stocked 35.0 g fingerlings and reported weight gains of 1.16 and 1.44 g/day at a feed ration of 2 and 4% bwt/day, respectively. Whitaker and Martin (1974) found daily weight gain to be greater for 14 g fingerlings (Table 7).

Percent daily weight gain for the Schwartz and Starkenburg south dugouts, 3 and 5% feeding treatments, showed gains to be greater than those reported by Buck et al. (1972), Collins (1972), Tatum (1973), and Kilambi et al. (1977). Daily gain for the Starkenburg north dugout 3 and 5% feeding rates, were lower than these respective studies. Daily gains reported by Hahn (1974) and Whitaker and Martin (1974) exceeded the present study; daily weight gain can be greater as stocking size increases (Whitaker and Martin 1974).

Mean conversion rates for the 3 and 5% feeders were 1.65 and 2.79, respectively. Feed conversion values for the 3% feeders in the Schwartz, Starkenburg south, and Starkenburg north dugouts were 1.8, 1.6, and 1.5, respectively. Feed conversion for the 5% treatments were 3.2, 2.5, and 2.6 for the Schwartz, Starkenburg south, and Starkenburg north dugouts, respectively. The mean 3% feeding rate food conversion was more favorable than those documented by Buck et al. (1972), Tatum (1973), Hahn (1974), and Kilambi et al. (1977) (Table 7). More desirable conversion rates were reported by Collins (1972), Whitaker and Martin (1974), and Roell (1983). The low mean conversion rate of 1.65 for the 3% feeding rate and no significant differences in harvest weight, length, and W_r between 3 and 5% feeding rates indicated the 3% rate to be most favorable. Roell (1983) considered a 2% allotment to be an inadequate diet and a 4% ration to be slightly excessive.

The 0% bwt/day fed fishes showed either a slight increase or weight loss. This would be expected since they were not fed and natural food was limited, due to the fish being confined to the cages.

Mean net production for the 3 and 5% feeding rates was 2.3 kg/m^3 with a range of 1.8 - 3.2 kg/m^3 (Table 7). The present study net production was surpassed by Buck et al. (1972), Collins (1972), Hahn (1974), Kilambi et al. (1977), Tatum (1973), and Whitaker and Martin (1974) (Table 7), with values ranging from 8.4 - 81.0 kg/m^3. Small stocking size, low stocking rate, and short culture period were factors contributing to the low production.

Stocking densities for the present study were lower than reported by Buck et al. (1972), Collins (1972), Tatum (1973), Whitaker and Martin (1974), and Kilambi et al. (1977). Collins (1972) reported that trout raised at densities of 260, 390, and 455/m^3 showed no differences in weight gain. Kilambi et al. (1977) found neither growth nor feed conversion to be affected by densities of 183 and 301/m^3. For dugout cage culture, stocking rates may possibly be increased if fewer 1 m^3 cages were placed in the dugout. The present study maximum stocking rate of 70/cage, with 15 cages, resulted in a density of 17,500 trout/hectare. Studies by Halverson et al. (1980) and Roell (1983), were conducted at a density of 8,650 trout/hectare. Careful consideration must be given to the dugout size, stocking rate, and cage size and number so as not to surpass the dugout carrying capacity. Overstocking may result in ammonia excesses and/or oxygen deficits resulting in poor growth and survival.

Due to the small stocking size and short culture period, trout were unable to attain a minimum marketable-size of 173 g (Whitaker and Martin 1974). With a mean harvest size of 83.1 g for the 3 and 5% feeding treatments in the Schwartz and Starkenburg south dugouts, trout were large enough to be considered of marginally edible size for landowners. If 40 - 80 g trout could be stocked and cultured for a feeding period of 60 days, an edible size and possibly a marketable-sized trout might be produced. If growth was similar to the present study, with a feeding rate of 3% bwt/day and a feed conversion rate of 1.65, 40 - 59 g trout fingerlings would attain an edible size of 116 - 170 g. If 60 - 80 g trout were stocked, fish would reach a marketable size of 173 - 232 g.

Growth within each dugout appeared to be influenced by Secchi disc visibility. From 23 April to 14 May, Secchi disc readings in all dugouts equaled or exceeded 0.6 m (Appendix Table 3). Mean trout growth for this period was 0.98 g/day for all 3 and 5% bwt/day feeding treatments (Figures 3, 4, and 5). Growth for this period was greatest in the Starkenburg north dugout at 1.04 g/day.

From 14 May to 17 May water clarity decreased in the Starkenburg north dugout from a Secchi disc reading of 0.9 to 0.3 m. This decrease in water clarity may have been due to the introduction of cattle into the surrounding pasture on 16 May. The cattle introduction corresponded with an increase in suspended silt in the surrounding

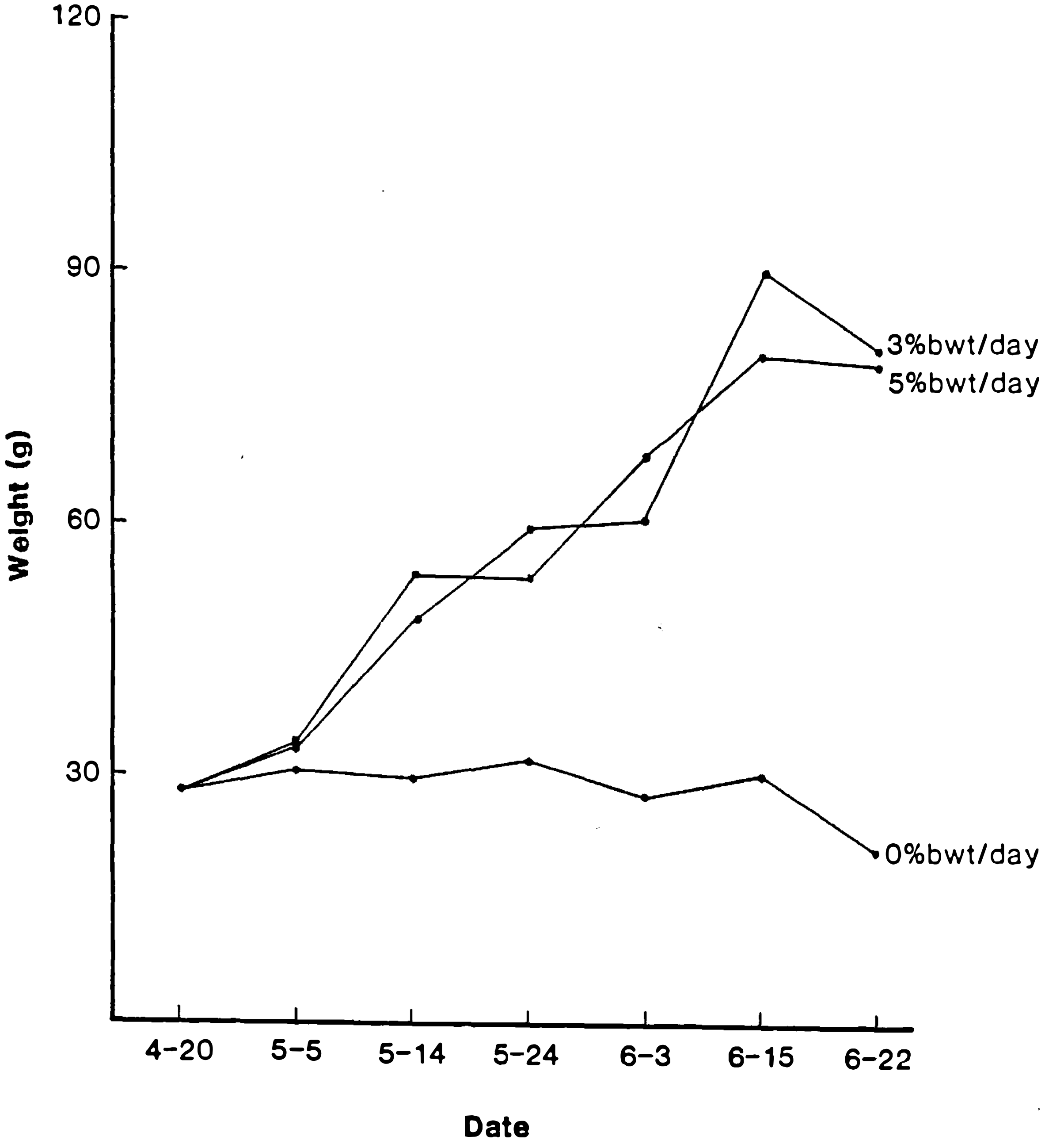


Figure 3. Mean weight (g) of rainbow trout (Salmo gairdneri) at various feeding rates for culture period in Schwartz dugout pond.

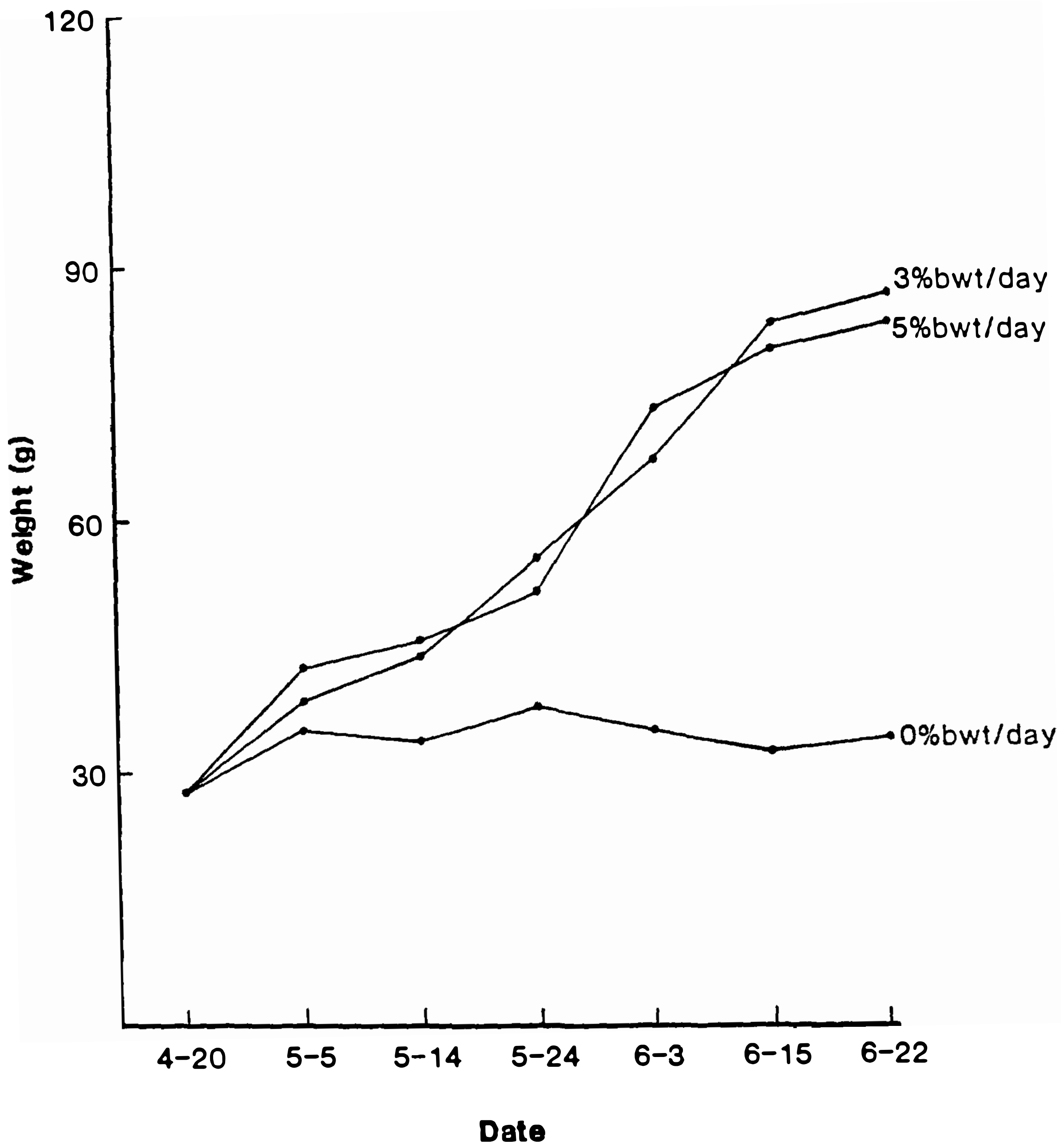


Figure 4. Mean weight (g) of rainbow trout (Salmo gairdneri) at various feeding rates for culture period in Starkenburg south dugout pond.

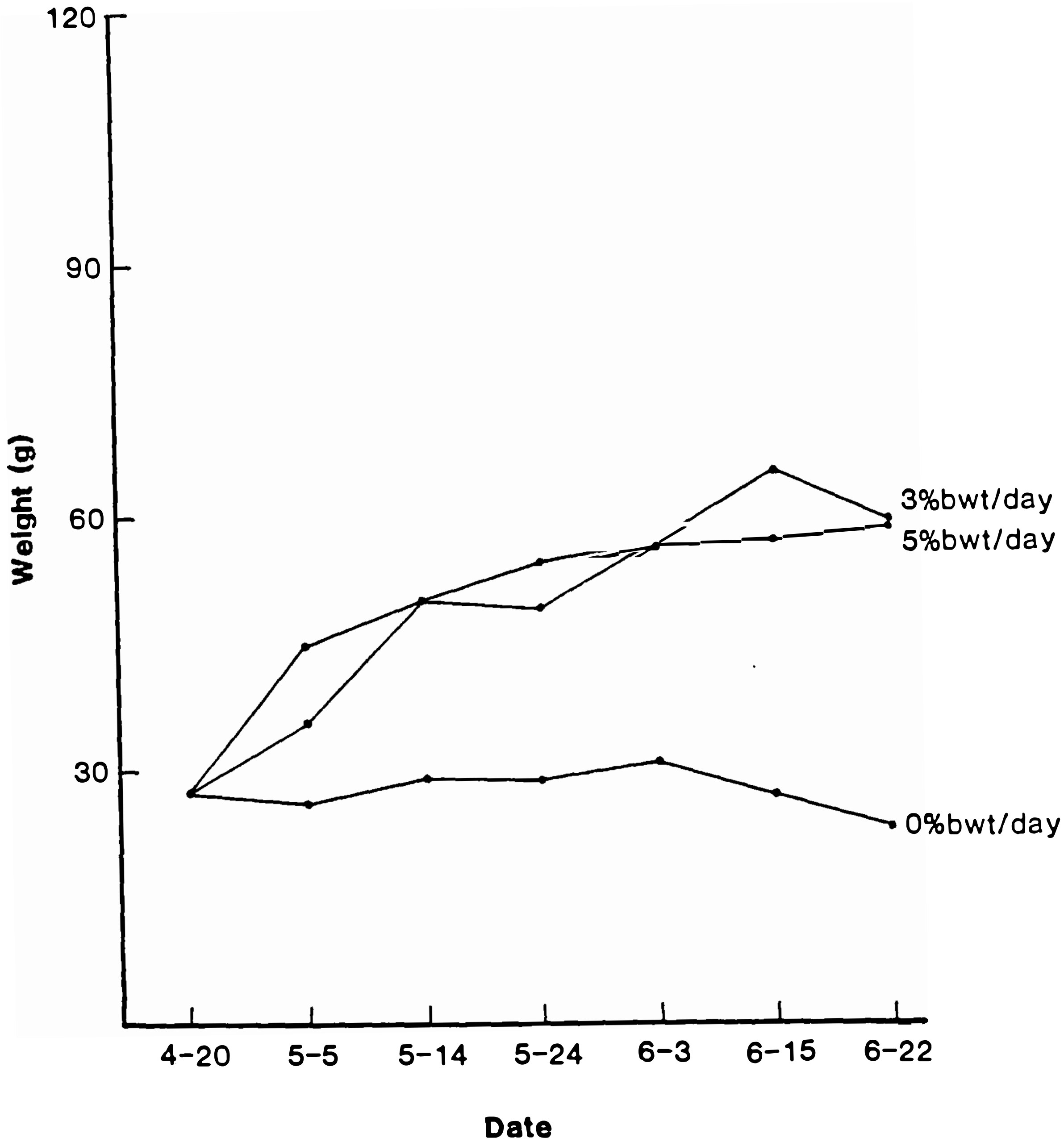


Figure 5. Mean weight (g) of rainbow trout (Salmo gairdneri) at various feeding rates for culture period in Starkenburg north dugout pond.

watershed during a period of receding water levels. DiLauro (1982) found water clarity to be significantly ($P \leq 0.05$) lower in dugouts exposed to pasturing cattle. This low water clarity continued for the remainder of the study, (Secchi disk visibility of 0.3 - 0.4) and corresponded with a reduced mean growth rate for the 3 and 5% bwt/day treatments of 0.24 g/day (Figure 5). Singler (1981) reported steelhead trout growth to be slower in turbid water. It is uncertain why the Starkenburg south dugout water clarity remained at 1.4 to 1.7 m after 16 May as cattle exposure to the Starkenburg dugouts was equal. Soil differences and/or denser terrestrial vegetation in the Starkenburg south dugout watershed are possible explanations.

The Schwartz and Starkenburg south dugouts mean growth rate for the same feeding rates during this period was 0.93 g/day (Figures 3 and 4). Since rainbow trout are obligate visual feeders (Ware 1972), the low water clarity in the Starkenburg north dugout would have reduced the ability of trout to efficiently locate and consume food.

Rainbow trout mean survival rates for the Schwartz, Starkenburg south, and Starkenburg north dugouts were 99.6, 99.5, and 95.1%, respectively. Survival was comparable to the value of 98.0% reported by Roell (1983); other survival rates are in Table 7. The slightly lower survival in the Starkenburg north dugout may be attributed to the high silt turbidity. Hahn (1974) found that a significant ($P \leq 0.0005$) correlation existed between high turbidity and rainbow trout mortality.

Rainbow Trout Feeding Behavior

Feeding with floating trout chow commenced 23 April, three days after stocking, and continued daily until 21 June for a total of 60 days. Fish were first observed taking sinking pellets on the second feeding day; approximately 25% of each feed allotment would sink within five minutes. By the fourth feeding day, trout were observed consuming prepared food in all cages fed.

Trout in the 3% bwt/day treatment fed more voraciously than the 5% bwt/day trout, frequently forcing water out through the feeding holes as they consumed floating feed. The 5% bwt/day trout rarely forced out water; they usually consumed pellets as they sank.

The 3% bwt/day trout in the Schwartz and Starkenburg south dugouts usually consumed all floating pellets prior to the next feeding. In contrast, small amounts of floating feed were usually seen in the 5% bwt/day cages prior to a feeding.

In the Starkenburg north dugout, trout in both feeding treatments consumed all the feed until the decrease in water clarity. Following the reduction in water clarity, feeding became subdued. Trout from both the 3 and 5% bwt/day feeding treatments never consumed the entire feed allotment during the low water clarity in this dugout.

Physiochemical Evaluation

The mean dissolved oxygen concentrations at surface, 1.0, and 2.0 m for the culture period were 9.3, 8.5, and 7.5 mg/liter, respectively. Dissolved oxygen ranges at surface, 1.0, and 2.0 m for the culture period were 7.8 - 11.2, 5.4 - 10.4, and 0.6 - 10.2 mg/liter, respectively (Appendix Table 3). Oxygen levels were not considered adequate for trout growth and survival if concentrations fell below 6.0 mg/liter (Barica 1975). On two occasions oxygen fell below this level. The Starkenburg north dugout had low oxygen at 2.0 m on 3 June and the Schwartz dugout had low oxygen concentrations occur at 1.0 and 2.0 m depths on 18 June. On these occasions trout did not appear to be stressed as feeding occurred.

Temperatures were adequate for trout growth and survival from 20 April to 21 June. Mean temperatures for this period at surface, 1.0, and 2.0 m were 13.6, 13.0, and 11.8 C (Appendix Table 3). These mean temperatures fell below the value of 15 C reported by Buck et al. (1972) as the optimum temperature for growth and feed conversion for caged rainbow trout. Temperature ranges at surface, 1.0, and 2.0 m for the culture period were 3.2 - 29.0, 3.2 - 26.5, and 3.2 - 23.1 C, respectively (Appendix Table 3).

Fish were harvested on 21 - 22 June, after surface temperatures reached or exceeded the lethal temperature of 27 C (Cherry et al. 1977). Mean temperatures on 21 June at surface, 1.0, and 2.0 m were 27.3, 24.0, and 21.6 C, respectively.

Oxygen and temperature profiles were taken on 23 June following harvest. All dugouts had lethal and sublethal temperatures at surface and 1.0 m, respectively. Dissolved oxygen concentrations were adequate at the surface and 1.0 m, but were at lethal levels for all dugouts at 2.0 m (Appendix Table 3).

Mean Secchi disc readings during the culture period for the Schwartz, Starkenburg south, and Starkenburg north dugouts were 1.5, 1.3, and 0.5 m, respectively. Water clarity probably accounted for the differences in growth between dugouts.

All other chemical and physical parameters monitored were adequate for trout survival and growth. During the culture period pH levels ranged from 8.1 - 8.3 for all dugouts. Witschi and Ziebell (1979) reported survival of rainbow trout fingerlings was 100% when stocked in ponds with a pH of 8.5

Conductivity levels ranged from 240 - 680 µmhos/cm with an average of 436 µmhos/cm. Clodfelter (1982) found rainbow trout to survive in South Dakota ponds with conductivities of 150 - 1,856 µmhos/cm.

Salinity readings ranged from 0.1 - 0.5 parts per thousand with a mean of 0.3 parts per thousand. Tatum (1973) reported rainbow trout growth rates of 0.7 - 1.2 g/day for trout cage cultured in brackish water with a salinity of 20 parts per thousand.

The total hardness and alkalinity levels in all dugouts were above the 20 mg/liter (Boyd 1974) considered necessary for optimal fish production. Total hardness levels ranged from 184 - 444 mg/liter with a mean of 328 mg/liter. Total alkalinity levels ranged from 148 - 264 mg/liter with an average of 218 mg/liter.

Maximum depth declined in all dugouts during the study period (Appendix Table 3). The greatest depths in the Schwartz, Starkenburg south, and Starkenburg north dugouts were 3.2, 3.0, and 4.0 m, respectively, occurring on 18 April. Minimum depths for these respective dugouts were 2.7, 2.9, and 3.6 m, occurring on 18 June.

These depths still allowed cages to maintain proper floatation above the dugout bottoms.

Stomach Contents

Stomach contents of 450 trout were analyzed following harvest to obtain an estimate of the contribution of natural food to trout diets (Table 8). Stomachs contained a total of 2,381 food organisms with a total volume of 23.6 ml. Conchostracods were the most numerically abundant food item accounting for 63.9% of all organisms consumed; aquatic insects were second totaling 33.9%.

Trout stomachs from the Schwartz dugout contained 182 organisms with a total volume of 1.9 ml (Table 9). Chironomidae comprised the most numerically abundant (65.4%) taxon in the trout stomachs, amphipods ranked second (17.6%), and anisopterans third (8.5%). Food items were most abundant in the non-fed fish, accounting for 89.8% of all organisms consumed. Food item frequency of occurrence for the 0, 3, and 5% bwt/day feeding rates were 3.16, 0.22, and 0.26 items/stomach, respectively (Table 9).

Trout stomachs from the Starkenburg south dugout contained 2,169 organisms with a total volume of 21.0 ml (Table 9). Conchostracods were the most numerically abundant (70.2%) organisms in the trout diet, chironomids ranked second (14.1%), and corixids third (12.7%). Macroinvertebrates were consumed more frequently by the non-fed fish; 75.1% of the organisms were consumed by this group. Natural food item frequency of occurrence for the 0, 3, and 5% bwt/day feeding rates were 32.56, 7.48, and 3.60 items/stomach, respectively (Table 8).

Table 8. Mean number and volume of aquatic organisms from cage-reared rainbow trout (Salmo gairdneri) stomachs, for three dugouts during 1983, South Dakota.

Dugout	Feeding rate	Mean number	Mean volume (ml)
Schwartz (35 fish/cage)	0	3.16	0.0318
	3	0.22	0.0022
	5	0.26	0.0024
Starkenburg south (52 fish/cage)	0	32.56	0.3222
	3	7.48	0.0690
	5	3.60	0.0316
Starkenburg north (70 fish/cage)	0	0.50	0.0196
	3	0.06	0.0010
	5	0.04	0.0004

Table 9. Stomach contents of rainbow trout (Salmo gairdneri) from cage culture, expressed as mean number of organisms per stomach, for three dugout ponds, during 1983, South Dakota.

Food item	Schwartz			Starkenburg S			Starkenburg N		
	Feed rate (% bwt[1]/day)			Feed rate (% bwt[1]/day)			Feed rate (% bwt[1]/day)		
	0	3	5	0	3	5	0	3	5
Nematoda	-	-	-	0.12	0.04	-	-	-	-
Conchostraca	-	-	-	22.20	5.74	2.50	-	-	-
Amphipoda	0.46	0.06	0.10	-	-	-	-	-	-
Hydracarina	-	-	-	0.02	-	-	-	-	-
Dytiscidae	0.06	-	-	0.20	0.02	0.04	-	-	-
Haliplidae	0.02	-	-	0.26	-	-	-	-	-
Chaoborinae	0.08	-	-	0.02	0.04	0.04	-	-	-
Chironomidae	2.10	0.16	0.12	5.00	0.82	0.28	-	-	-
Baetidae	0.04	-	0.04	0.50	0.02	0.02	-	-	-
Corixidae	0.02	-	-	4.04	0.74	0.72	0.46	0.06	0.04
Notonectidae	-	-	-	0.08	-	-	-	-	-
Pleidae	0.04	-	-	-	-	-	-	-	-

Table 9. (Continued)

	Schwartz			Starkenburg S			Starkenburg N		
	Feed rate (% bwt[1]/day)			Feed rate (% bwt[1]/day)			Feed rate (% bwt[1]/day)		
Food item	0	3	5	0	3	5	0	3	5
Anisoptera	0.30	-	-	-	-	-	-	-	-
Physidae	0.02	-	-	0.04	0.06	-	-	-	-
Planorbidae	0.02	-	-	0.08	-	-	-	-	-
Pimephales promelas	-	-	-	-	-	-	0.04	-	-

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[1] bwt = bodyweight/day.

Natural food consumption in the Starkenburg north dugout was low (Table 9). Stomachs contained 30 organisms with a total volume of 0.7 ml. Corixids were the most numerically abundant (93.3%) taxon found. Fathead minnows (Pimephales promelas) were the only other organism consumed totaling 6.7% by number. Food items were most common in the non-fed fish, accounting for 83.3% of all consumed organisms. Food item frequency of occurrence for the 0, 3, and 5% bwt/day feeding rates were 0.50, 0.06, and 0.04 items/stomach, respectively.

The contribution of natural food items by number and volume were significantly ($P \leq 0.05$) different between dugouts, feeding rates, and feeding rates within dugouts. The mean consumption rates for the 0, 3, and 5% bwt/day treatments by number were 12.71, 2.59, and 1.28 items/stomach, respectively. Mean stomach content volumes for these respective feeding rates were 1.205, 0.241, and 0.118 ml/stomach.

A Waller-Duncan's K-ratio t-test for stomach content natural food item number and volume showed the non-fed treatment to be significantly ($P \leq 0.05$) greater than the 3 and 5% bwt/day treatments (Table 10). This test also revealed the natural food consumption rate, by number and volume, to be significantly ($P \leq 0.05$) greater in the Starkenburg south dugout than the Schwartz and Starkenburg north dugouts (Table 11). The low consumption rate by the 3 and 5% bwt/day feed treatments indicated that natural foods probably represented a minor portion to the diet.

Table 10. The results of Waller-Duncan's K-ratio t-test for mean number and mean volume of natural food items in cage cultured rainbow trout (*Salmo gairdneri*) for three respective feeding rates during 1983, South Dakota.

Number:	(0% bwt[a]/day)	(3% bwt[a]/day)	(5% bwt[a]/day)
	12.7	2.59	1.28
			*
Volume:	(0% bwt[a]/day)	(3% bwt[a]/day)	(5% bwt[a]/day)
	12.05	2.41	1.18

[a] bwt = body weight/day.

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

Table 11. Results of Waller-Duncan's K-ratio t-test for mean number and mean volume of natural food items in cage cultured rainbow trout (*Salmo gairdneri*) for the three respective dugouts during 1983, South Dakota.

Number:	Starkenburg S 15.16	Schwartz 1.21	Starkenburg N 0.21*
Volume:	Starkenburg S 14.00	Schwartz 1.25	Starkenburg N 0.39

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

Palatability

Trout palatability was not quantified by a taste panel, but personal communications with landowners and university personnel who consumed trout were favorable. All individuals considered the flavor as acceptable. One landowner consumed trout three to four times per week for approximately six weeks. The only criticism was the small trout size.

Economic Evaluation

The economics of a hypothetical dugout cage culture operation was developed for rainbow trout reared in 9.82 m^3 (1.22 x 3.66 x 2.2 m deep) floating cages. Rectangular shaped cages with a high surface-volume ratio were used to reduce the potential of water circulation problems from occurring at the cage center (Roell 1983). Cages were constructed with 12.7 mm mesh plastic netting. Roell (1983) reported plastic netting to be more durable and less prone to fouling from debris than nylon netting.

With proper care, cages constructed with plastic mesh should last at least five years. Cages used in the present study were in their second year of use and exhibited no plastic mesh wear.

Initial fingerling weight was assumed to be 66 g (178 mm). A final harvest marketable weight of 190 g round weight (live weight) was projected from a feeding ration of 3% bwt/day, with a feed conversion rate of 1.65, such as in this study. The culture period was assumed to be 60 days. The cost estimate of the fingerlings ($35/100) was obtained from Trout Aire fish hatchery, St. Paul, Minnesota. The transport charge was $1.00/mile one way, with a delivery capacity of 818 kg (12,400 fingerlings), delivery distance is 350 miles.

A stocking rate of 100 fish/m^3 (one cage/dugout) was used for this evaluation. This stocking rate results in a density of approximately 14,900 trout/hectare (0.06 hectare dugout), a density between the Starkenburg south and north dugouts.

The estimated costs (Table 12) per weight of fish reared (dressed weight) reveal the impact of cage cost if it is all included in first year figures. Cage cost would be relatively insignificant if it is prorated over several years.

With current wholesale fresh trout prices at $5.03 - $5.69/kg ($2.29 - $2.59/lb) (Capitol City Fish, personal communication), a successful operation may be possible if cage cost is prorated over a period of five years. The production cost of rainbow trout would be $4.26/kg ($1.93/lb) resulting in a profit of $0.77 - $1.43/kg ($0.36 - $0.66).

While rainbow trout cage-rearing is biologically feasible, economic success is uncertain. Hopefully continued research will provide landowners with the necessary data to enable rainbow trout to be cage-reared by dugout owners for a food and/or income source.

Table 12. Estimated costs of a hypothetical cage-rearing operation for rainbow trout (Salmo gairdneri) in a 9.82 m^3 rectangular cage within an eastern South Dakota dugout pond.

Item	Cost
Fingerlings (66 g each)	
$35 per hundred Stock at 100/m^3 = 893 fish[1]	$ 313
Feed	
183 kg @ $0.88/kg	161
Cage (plastic netting)	248
Transportation[2]	25
Total	$ 747
Total (cage cost prorated)[3]	$ 549
Harvest	
893 fish at 147 g (dressed)[4] each Less 2% mortality = 875 fish Cost per kilogram	$ 5.80/kg (2.63/lb)
Cost (cage cost prorated) per kilogram	$ 4.26/kg (1.93/lb)

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[1] 8.93 m^3 of cage is submersed.

[2] Cost at capacity load.

[3] Prorated over five years.

[4] Dressed weight approximately 75% round weight.

RAINBOW TROUT PRODUCTION CONCLUSION

Cage-reared rainbow trout exhibited favorable growth and survival at feeding rates of 3 and 5% bwt/day. An optimal stocking rate (as it effects growth rate) was not, however, determined. Differences in dugout water chemistry in the ponds studied appeared to be a factor affecting growth rate. The low contribution of naturally produced food items consumed by the 3 and 5% bwt/day feeding rates, indicated natural food items probably represented a minor portion of the diet. In addition if natural food represented a major portion of the diet, non-fed fish would have experienced weight gain.

While trout did not obtain a marketable size, fish were large enough for consumption. A hypothetical cage culture utilizing a feeding rate of 3% bwt/day and a feed conversion rate of 1.65, indicated that cage culture may be profitable if stocking size and stocking rate were increased and larger cages were used.

Benthic Production

An annual cycle of benthic macroinvertebrates in two dugouts, Kurtz (three-year-old) and Oppelt (six-year-old) (Appendix Table 1), was investigated to determine benthic production and fauna. Benthic communities can be used as indicators of aquatic system productivity and water quality (Tebo 1955; Anderson and Hooper 1956; Hayne and Ball 1956; Carr and Hiltunen 1965; Cole and Underhill 1965; Mrachek and Bachman 1967).

The mean annual biomass of benthos in the Kurtz and Oppelt dugouts were 3,274 and 1,320 mg/m^2, respectively. Biomass peaked at the Kurtz and Oppelt dugouts on 4 November 1982 and 4 June 1982, respectively (Figures 6 and 7). The mean numerical abundance in the Kurtz and Oppelt dugouts were 5,275 and 1,570/m^2, respectively. Benthic macroinvertebrate numbers peaked in both dugouts on 4 June 1982.

Mean annual invertebrate biomass and numerical abundance in the Kurtz dugout was significantly ($P \leq 0.05$) greater than in the Oppelt dugout (Tables 13 and 14). Significant differences ($P \leq 0.05$) were also observed between sample dates for biomass and numerical abundance.

Kurtz Dugout Benthic Community

The Kurtz dugout fauna was dominated by chironomids and aquatic worms (class Oligochaetae). Chironomids and oligochaetes averaged 48 and 44%, respectively, of the total biomass found in the Kurtz dugout. These taxa comprised 35 and 62%, respectively, of the total Kurtz benthic fauna by number.

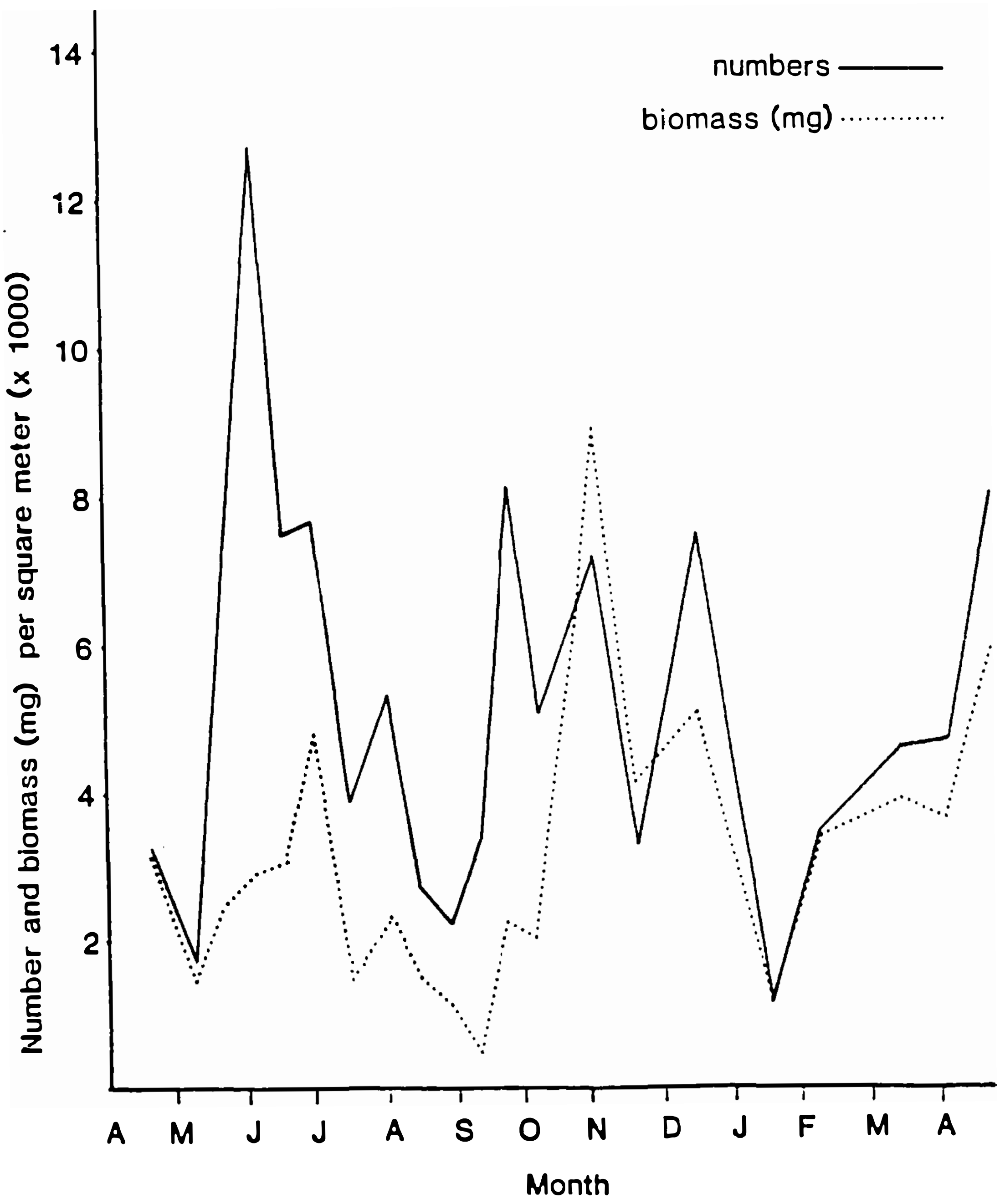

Figure 6. Abundance and biomass of benthic macroinvertebrates in a three-year-old (Kurtz) South Dakota dugout pond during 1982-83.

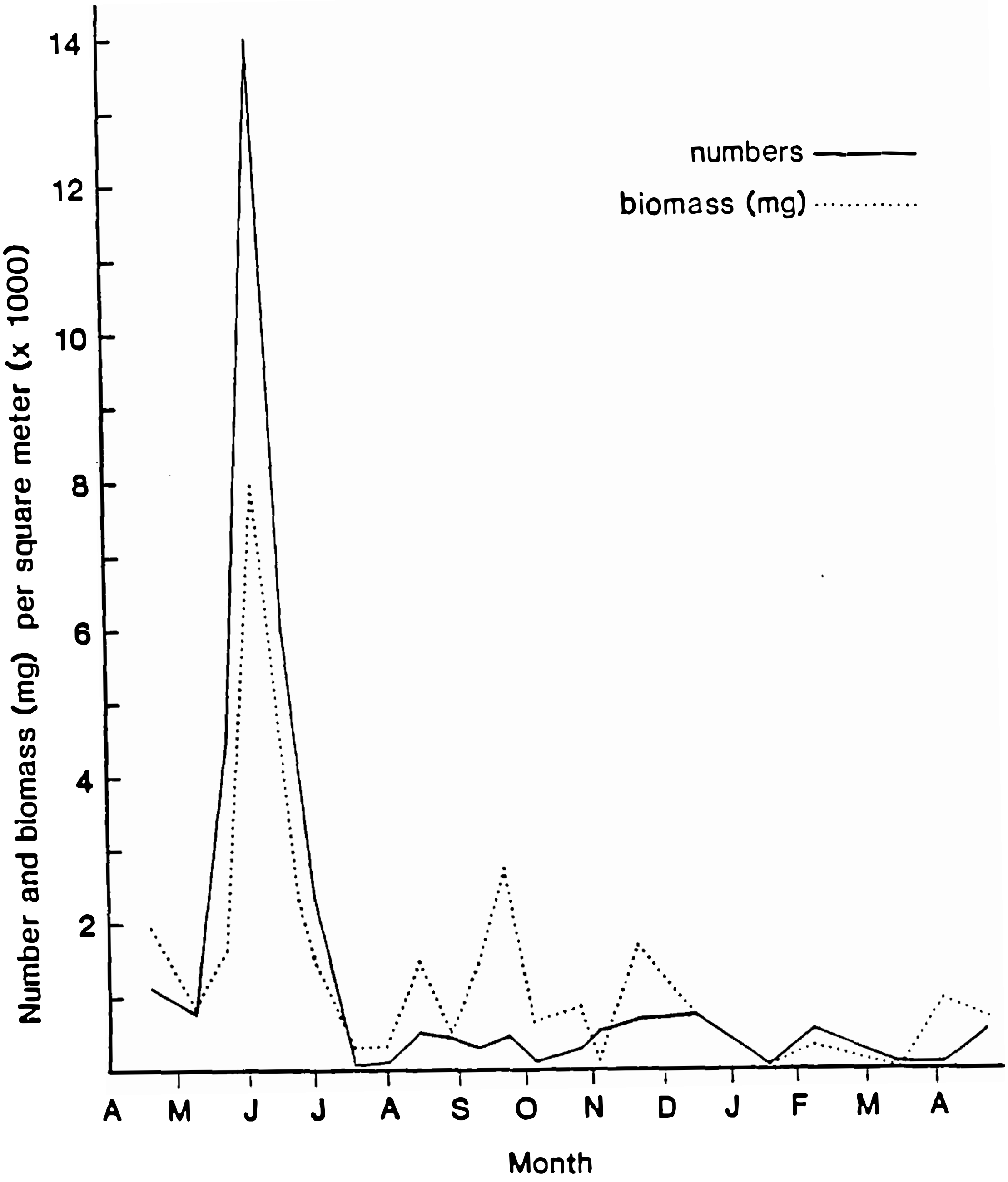

Figure 7. Abundance and biomass of benthic macroinvertebrates in a six-year-old (Oppelt) South Dakota dugout pond during 1982-83.

Table 13. The analysis of variance procedure showing significant differences in macrobenthic biomass between the three-year-old (Kurtz) and six-year-old (Oppelt) dugout ponds during 1982-83, South Dakota.

Source	d.f.	SS	MS	F
Dugout	1	125,951,327	125,951,327	28.87*
Period	21	198,546,490	945,459	2.17*
Dugout X Period	21	232,478,421	1,107,040	2.54*
Error	188	383,906,721	436,258	

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

Table 14. The analysis of variance procedure showing significant differences in macrobenthic abundance between the three-year-old (Kurtz) and six-year-old (Oppelt) dugout ponds during 1982-83, South Dakota.

Source	d.f.	SS	MS	F
Dugout	1	452,753,254	452,753,254	42.12*
Period	21	924,497,308	4,402,368	4.10*
Dugout X Period	21	179,330,604	853,955	0.79
Error	88	945,855,157	1,074,835	

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

The mean annual chironomid numerical abundance and biomass was 1,840/m^2 and 1,579 mg/m^2, respectively. *Chironomus attenuatus* and *C. plumosus* were the predominant dipterans present, comprising 83% of the dipterans by number. *Chironomus attenuatus* was the most numerically abundant dipteran species. Four other chironomid genera were rarely sampled (Table 15). *Procladius* spp. were the second most abundant dipteran genera, totaling 13%. Other dipterans infrequently sampled were *Chaoborus* spp. and *Palpomyia tibialis*.

Chironomid numbers peaked on 4 June 1982 (9,273/m^2) and biomass peaked on 4 November 1982 (2,491 mg/m^2). Numbers and biomass were lowest on 10 September 1982 at 81/m^2 and 66 mg/m^2, respectively (Table 16); this was due to the emergence of adults. Large numbers of empty pupae cases were observed during June and July.

The Kurtz dugout dipteran production was found to be significantly ($P \leq 0.05$) greater in mean biomass and mean numerical abundance than the Oppelt dugout. Biomass and number between sample dates were also significantly ($P \leq 0.05$) different.

Oligochaetes were the most numerous benthic macroinvertebrate in the Kurtz dugout with a mean annual abundance of 3,253/m^2. The mean annual biomass was 1,458 mg/m^2. Biomass and numerical abundance were variable throughout the study period (Table 17). Highest biomass and number occurred 23 April 1983 at 4,288 mg/m^2 and 6,908/m^2, respectively. Oligochaete biomass and number were lowest on 23 April 1982 at 418 mg/m^2 and 380/m^2, respectively. Kurtz dugout oligochaete production was significantly ($P \leq 0.05$) greater in mean annual biomass and number than the Oppelt dugout.

Table 15. Macroinvertebrates collected from a three-year-old (Kurtz) dugout pond during 1982-83, South Dakota.

- Phylum - Nematodea

- Phylum - Annelida
  - Class - Oligochaetae
  - Class - Hirudinea
    - *Helobdella stagnalis*
    - *Erpobdella punctata*

- Phylum - Arthropoda
  - Class - Crustacea
    - Order - Amphipoda
      - *Hyalella azteca*
    - Order - Hydracarina
      - *Limnochares* spp.*
  - Class - Insecta
    - Order - Coleoptera
      - Family - Dytiscidae
        - *Copelatus* spp.*
    - Order - Diptera
      - Family - Chironomidae
        - Tanypodinae
          - *Procladius* spp.*
        - Chironominae
          - *Chironomus* spp.
          - *Chironomus attenuatus*
          - *Chironomus plumosus*
          - *Cryptochironomus* spp.*
          - *Endochironomus* spp.*
          - *Glyptotendipes* spp.
        - Orthocladiinae
          - *Tanytarsus* spp.*
      - Family - Ceratopogonidae
        - *Palpomyia tibialis*
      - Family - Chaoboridae
        - *Chaoborus* spp.
    - Order - Hemiptera
      - Family - Corixidae
        - *Callicorixa* spp.*
      - Family - Notonectidae
        - *Notonecta* spp.*

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*Not collected in six-year-old (Oppelt) dugout.

Table 16. Mean abundance and biomass (mg) per square meter of Chironominae for a six-year-old (Oppelt) and a three-year-old (Kurtz) dugout pond during 1982-83, South Dakota.

Date	Six year (Oppelt)		Three year (Kurtz)	
	Number	Biomass	Number	Biomass
04/23/82	1,061[a]	1,162[b]	2,768	2,835
05/06/82	415	625	588	965
05/20/82	2,756	1,076	3,149	841
06/04/82	13,575	7,174	9,273	3,170
06/18/82	4,867	1,672	4,982	2,921
07/01/82	104	48	3,264	1,872
07/16/82	12	3	1,695	778
07/29/82	0	0	1,199	1,621
08/13/82	104	18	254	420
08/28/82	0	0	138	175
09/10/82	12	3	81	66
09/23/82	0	0	957	450
10/07/82	12	1	1,926	2,688
10/22/82	0	0	1,165	1,392
11/04/82	23	T[c]	1,984	3,775
11/17/82	69	41	1,557	2,958
12/13/82	300	99	1,234	1,874
01/13/83	23	8	577	727
02/10/83	12	2	911	1,354
03/15/83	12	T	1,176	1,340
04/09/83	0	T	715	1,170
04/23/83	23	13	877	1,405

[a] Number/m^2.

[b] mg/m^2.

[c] Less than 1.0.

Table 17. Mean abundance and biomass (mg) per square meter of Oligochaetae for a six-year-old (Oppelt) and a three-year-old (Kurtz) dugout pond during 1982-83, South Dakota.

Date	Six year (Oppelt)		Three year (Kurtz)	
	Number	Biomass	Number	Biomass
04/23/82	58[a]	27[b]	381	419
05/06/82	208	106	980	438
05/20/82	1,476	155	3,287	1,171
06/04/82	173	99	3,379	1,143
06/18/82	830	91	1,845	204
07/01/82	1,753	91	4,037	374
07/16/82	0	0	669	163
07/29/82	81	T[c]	3,956	1,009
08/13/82	23	14	2,410	215
08/28/82	150	T	2,053	600
09/10/82	81	65	3,287	2,397
09/23/82	81	10	7,116	420
10/07/82	12	T	2,941	1,404
10/22/82	12	6	5,213	2,805
11/04/82	323	4	5,190	4,558
11/17/82	208	T	1,684	1,164
12/13/82	231	1	6,078	2,527
01/13/83	0	0	657	479
02/10/83	334	10	2,526	2,062
03/15/83	58	T	3,264	1,908
04/09/83	12	1	3,702	2,334
04/23/83	334	40	6,908	4,288

[a] Number/m^2.

[b] mg/m^2.

[c] Less than 1.0.

Other macroinvertebrates infrequently sampled in the Kurtz dugout were: Amphipoda, Hydracarina, Nematoda, three Insecta genera, and two Hirudinea species (Table 15). Hydracarina and Nematoda were not collected in the Oppelt dugout.

Oppelt Dugout Benthic Community

The Oppelt dugout was dominated by chironomids, oligochaetes, and hirudineans. These taxa averaged 41, 2, and 51%, respectively, of the total biomass. Chironomids, oligochaetes, and hirudineans comprised 68, 19, and 10%, respectively, of the total benthic organisms by number.

The mean annual chironomid numerical abundance and biomass was 1,063/m^2 and 543 mg/m^2, respectively. *Chironomus attenuatus* and *C. plumosus* were the predominant dipterans present, accounting for 97% of the dipterans by number; *C. attenuatus* was the most numerically abundant species. Four other chironomid genera were infrequently collected (Table 18). Other dipterans present were *Chaoborus* spp. and *Palpomyia tibialis.*

Chironomid biomass and number peaked on 4 June 1982 at 7,174 mg/m^2 and 13,575/m^2, respectively. Biomass and number rapidly decreased through 29 July 1982 when no chironomids were collected (Table 16). Densities remained low for the remainder of the study period, never exceeding 300/m^2.

Oligochaetes were the second most common taxon collected. Mean annual numerical abundance and biomass were 293/m^2 and 33 mg/m^2, respectively. Highest biomass occurred on 20 May 1982 (155 mg/m^2), while greatest number was on 16 July 1982 (1,753/m^2). Lowest number

Table 18. Macroinvertebrates collected from a six-year-old (Oppelt) dugout pond during 1982-83, South Dakota.

- Phylum - Annelida
  - Class - Oligochaetae
  - Class - Hirudinea
    - *Helobdella stagnalis*
    - *Helobdella nepheloidea**
    - *Erpobdella punctata*
- Phylum - Arthopoda
  - Class - Crustacea
    - Order - Amphipoda
      - *Hyalella azteca*
  - Class - Insecta
    - Order - Coleoptera
      - Family - Dytiscidae
        - *Coptotomus* spp.*
        - *Agabus* spp.*
    - Order - Diptera
      - Family - Chironomidae
        - Chironominae
          - *Chironomus* spp.
          - *Chironomus attenuatus*
          - *Chironomus plumosus*
          - *Glyptotendipes* spp.
          - *Paralauterborniella* spp.*
        - Orthocladiinae
          - *Trissocladius* spp.*
      - Family - Ceratopogonidae
        - *Palpomyia tibialis*
      - Family - Chaoboridae
        - *Chaoborus* spp.
- Phylum - Mollusca
  - Class - Pelecypoda
    - Family - Sphaeriidae
      - *Pisidium**

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*Not collected in three-year-old dugout (Kurtz).

and biomass occurred on 29 July 1982 and 13 January 1982, respectively, when oligochaetes were not collected (Table 17).

Hirudinae was the third most numerically abundant organism collected. Mean annual abundance and biomass were $161/m^2$ and $674\ mg/m^2$. Erobdella punctata and Helobdella stagnalis were the predominant leeches present, comprising 65 and 34%, respectively, of the leeches by number. Helobdella nepheloidea was infrequently collected and constituted 1% of the sample. Highest biomass occurred on 23 September 1982 ($2{,}773\ mg/m^2$) and greatest numbers on 1 July 1982 ($427/m^2$). The density low occurred 4 June 1982 ($12/m^2$), while the biomass low as on 13 January 1982 ($13\ mg/m^2$) (Table 19). The Oppelt dugout hirudinea mean annual biomass and abundance were significantly ($P \leq 0.05$) greater than the Kurtz pond.

Other benthic taxa infrequently collected were: Amphipoda, Pelecypoda, and three Insecta genera (Table 18). Pelsecypods were not found in the Kurtz dugout.

Benthic Production Summary

The newer (Kurtz) dugout was determined to have a significantly ($P \leq 0.05$) greater production than the older (Oppelt) dugout. This production evaluation is contrary to a recent study finding zooplankton production to be signficantly ($P \leq 0.01$) greater in the Oppelt dugout (DiLauro 1982). DiLauro reported the greater production in the Oppelt dugout was due to longer cattle exposure, resulting in more organically rich waters.

An explanation of the lower benthic production in the Oppelt dugout appears to be at least partially due to the differential cattle exposure between ponds. The Kurtz dugout cattle exposure never exceeded 15

Table 19 . Mean abundance and biomass (mg) per square meter of Hirudinea for a six-year-old (Oppelt) and a three-year-old (Kurtz) dugout pond during 1982-83, South Dakota.

Date	Six-year (Oppelt)		Three-year (Kurtz)	
	Numbers[1]	Biomass[2]	Numbers	Biomass
04/23/82	81	717	0	0
05/06/82	46	74	0	0
05/20/82	104	236	0	0
06/04/82	12	27	0	0
06/18/82	58	533	0	0
07/01/82	423	1,315	12	6
07/16/82	23	220	23	17
07/29/82	35	316	12	13
08/13/82	381	1,375	0	0
08/28/82	242	337	0	0
09/10/82	231	1,372	0	0
09/23/82	381	2,773	0	0
10/07/82	127	617	0	0
10/22/82	254	853	0	0
11/04/82	150	115	0	0
11/27/82	254	1,292	0	0
12/13/82	231	674	35	635
01/13/83	23	13	12	7
02/10/83	231	292	0	0
03/15/83	35	39	0	0
04/09/83	92	939	0	0
04/23/83	138	699	0	0

[1] number/m^2

[2] mg/m^2

cattle, while in the Oppelt pasture the herd numbered 64 animals. Both dugouts were exposed to pasturing cattle from mid-June to November. Intensive cattle watering and wallowing in the Oppelt dugout resulting in a decrease in water clarity from a Secchi disc reading of 2.2 m on 4 June 1982 to 0.3 m on 18 June 1982. This introduction of cattle corresponds with the decline of dipteran larvae (Figure 7); Hilsenhoff and Narf (1968) found Chironomus attenuatus larvae to be negatively correlated with high turbidity. The dipteran larvae decline did not appear to result from pupation since few pupae were collected (Appendix Table 4) and empty floating pupae cases were never observed. Oppelt Secchi disc readings remained low (0.3 - 0.4 m) from 28 June 1982 to ice-up, resulting in continued low dipteran densities. Kurtz dugout Secchi disc readings were never below 1.0 m.

An explanation of the higher Hirudinea population in the Oppelt dugout appeared to be due to differential substrate composition between dugouts. The Oppelt dugout has an area of approximately 70 m^2 containing rocks ranging in size from 10 - 50 cm. The Kurtz dugout substrate contains few rocks. Solid substrate is necessary for proper functioning of the leech sucker. The suckers are used for locomotion, feeding, and reproduction and cannot function well in mud or sand. In addition, a solid substrate is required by most leeches for cacoon deposition (Sawyer 1981).

The lower oligochaete population in the Oppelt dugout may be due to a predator-prey relationship between oligochaetes and leeches. *Helobdella stagnalis* and *Erobdella punctata* feed predominately on oligochaetes (Moore 1912; Sapkarev 1963, 1968; Sawyer 1970).

Using benthic communities as an indicator of aquatic system productivity, the Kurtz and Oppelt dugouts can be considered highly productive for this region. The Kurtz and Oppelt dugouts were more productive in terms of mean annual benthic biomass and number than several eastern South Dakota lakes (Schmulbach and Sandholm 1962; Hartung 1968; Smith 1971; Sloane 1980).

The Kurtz dugout may be considered organically polluted. High chironomid and oligochaete densities are associated with organic pollution. Brinkhurst (1969) found that numbers of oligochaetes relative to chironomids increased in lakes as organic enrichment increased. In the Kurtz dugout, chironomids comprised 35% and oligochaetes 62% of the total number of organisms found. These values approximate the chironomid - oligochaetae composition of 35 and 60% in Lake Erie during 1958.

The Oppelt dugout also appeared to be organically rich. Sawyer (1981) found Helobdella stagnalis and Erobdella punctata to be consistently associated with organically polluted waters and may be considered "indicator species" of disturbed waters if numbers become unusually high ($500/m^2$). While these two species were present in both dugouts, numbers were high only in the Oppelt dugout, exceeding $500/m^2$ on three sample periods (Table 19).

BENTHOS CONCLUSION

Benthic fauna, biomass, and abundance were dominated by chironomids, oligochaetes, and hirudineans. These respective taxa, when found in large numbers, indicate eutrophic conditions. Production in terms of mean annual benthic macroinvertebrate biomass and numbers exceed several eastern South Dakota lakes. Benthic macroinvertebrate composition and production may be highly variable between dugout ponds due to dugout age, nutrient load, cattle usage, substrate type, and other possible factors.

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APPENDIX

Appendix Table 1. Physical description of cage and benthic production dugout ponds used to study the culture of rainbow trout (*Salmo gairdneri*) during 1982-83 in Brookings County, South Dakota.

Name	Legal Description Section/Township/Range			Hectares	Stocking Rate
Trout dugouts					
Schwartz	SW 1/4	27	111-49	0.056	35 fish/cage
Starkenburg South	NE 1/4	33	111-51	0.064	52 fish/cage
Starkenburg North	NE 1/4	33	111-51	0.062	70 fish/cage
Benthos production dugouts					
Kurtz	NW 1/4	6	110-47	0.048	--
Oppelt	NW 1/4	1	110-48	0.054	--

Appendix Table 2. Rainbow trout (Salmo gairdneri) capture data during sampling dates of cage culture, 1983.

Date	Dugout	Feeding rate	$\bar{x}$ weight (grams)	Weight range (grams)
05-05	Schwartz	0[a]	30.5	24 - 39
		3	33.3	26 - 42
		5	32.9	25 - 46
	Starkenburg South	0	35.0	28 - 51
		3	38.2	27 - 51
		5	42.0	30 - 62
	Starkenburg North	0	26.4	22 - 34
		3	35.8	25 - 45
		5	44.9	32 - 70
05-14	Schwartz	0	28.8	26 - 40
		3	48.0	36 - 65
		5	53.7	41 - 73
	Starkenburg South	0	32.9	27 - 40
		3	44.0	33 - 52
		5	45.8	25 - 66
	Starkenburg North	0	29.5	22 - 39
		3	49.7	32 - 62
		5	50.0	31 - 84
05-24	Schwartz	0	31.6	26 - 38
		3	59.6	24 - 92
		5	52.7	41 - 66
	Starkenburg South	0	36.8	30 - 54
		3	55.9	36 - 71
		5	51.6	39 - 71
	Starkenburg North	0	28.4	22 - 44
		3	48.4	28 - 65
		5	54.5	36 - 77
06-03	Schwartz	0	27.1	24 - 31
		3	60.4	40 - 81
		5	68.3	53 - 98
	Starkenburg South	0	34.9	27 - 60
		3	67.1	45 - 94
		5	73.1	54 -114
	Starkenburg North	0	30.8	25 - 50
		3	57.1	37 - 76
		5	57.5	38 - 90

Appendix Table 2. (Continued)

Date	Dugout	Feeding rate	$\bar{x}$ weight (grams)	Weight range (grams)
06-15	Schwartz	0	30.0	25 - 48
		3	90.1	75 -104
		5	80.4	61 -155
	Starkenburg South	0	31.9	27 - 39
		3	83.0	52 -111
		5	80.1	57 -122
	Starkenburg North	0	27.3	23 - 43
		3	66.0	43 -110
		5	57.4	34 - 89

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[a] Expressed as percent body weight/day.

Appendix Table 3. Chemical-physical properties of rainbow trout (*Salmo gairdneri*) cage culture dugouts, during 1983.

Date			Schwartz	Starkenburg South	Starkenburg North
04-18	Oxygen (mg/l)	0.0 m	9.4	10.6	8.2
		1.0 m	9.2	10.2	7.6
		2.0 m	8.6	8.8	7.0
	Temperature (C)	0.0 m	3.2	3.8	3.8
		1.0 m	3.2	3.8	3.8
		2.0 m	3.2	3.8	3.8
	Alkalinity (mg/l $CaCO_3$)	CO_3	0	0	0
		HCO_3	258	148	205
	Hardness (mg/l $CaCO_3$)		440	184	253
	Salinity (parts/thousand)		0.2	0.1	0.2
	Specific conductivity (µmhos/cm)		440	240	310
	Maximum depth (m)		3.2	3.0	4.0
	Secchi disc (m)		2.0	0.6	0.7
	pH		8.3	8.3	8.2
05-04	Oxygen (mg/l)	0.0 m	9.4	9.4	10.0
		1.0 m	9.0	8.6	9.4
		2.0 m	7.6	8.2	8.4
	Temperature (C)	0.0 m	10.5	11.6	13.1
		1.0 m	10.2	11.0	11.5
		2.0 m	9.9	9.7	10.2
	Alkalinity (mg/l $CaCO_3$)	CO_3	0	0	0
		HCO_3	209	192	261
	Hardness (mg/l $CaCO_3$)		329	258	344
	Salinity (parts/thousand)		0.3	0.3	0.3
	Specific conductivity (µmhos)		470	350	490
	Maximum depth (m)		3.1	3.0	3.9
	Secchi disc (m)		1.7	1.0	0.9
	pH		8.3	8.2	8.2

Appendix Table 3. (Continued)

Date			Schwartz	Starkenburg South	Starkenburg North
05-17	Oxygen (mg/l)	0.0 m	9.0	8.2	10.0
		1.0 m	8.8	7.0	9.2
		2.0 m	8.2	7.0	7.8
	Temperature (C)	0.0 m	14.1	14.2	14.5
		1.0 m	14.1	14.2	13.9
		2.0 m	12.1	12.1	11.9
	Alkalinity (mg/l $CaCO_3$)		0	0	0
			240	185	235
	Hardness (mg/l $CaCO_3$)		402	245	345
	Salinity (parts/thousand)		0.5	0.4	0.3
	Specific conductivity (μmhos/cm)		680	400	520
	Maximum depth (m)		2.9	2.9	3.9
	Secchi disc (m)		1.4	1.6	0.3
	pH		8.2	8.2	8.1
06-03	Oxygen (mg/l)	0.0 m	11.2	9.2	9.6
		1.0 m	10.4	9.2	8.6
		2.0 m	10.2	6.8	5.8
	Temperature (C)	0.0 m	18.3	20.0	19.0
		1.0 m	17.9	18.0	18.3
		2.0 m	10.2	6.8	5.8
	Alkalinity (mg/l $CaCO_3$)	CO_3	0	0	0
		HCO_3	198	240	251
	Hardness (mg/l $CaCO_3$)		444	290	360
	Salinity (parts/thousand)		0.4	0.3	0.3
	Specific conductivity (μmhos/cm)		500	360	440
	Maximum depth (m)		2.8	2.9	3.6
	Secchi disc (m)		1.1	1.4	0.3
	pH		8.2	8.3	8.2

Appendix Table 3. (Continued)

Date			Schwartz	Starkenburg South	Starkenburg North
06-18	Oxygen (mg/l)	0.0 m	9.0	8.6	7.8
		1.0 m	5.4	8.0	7.0
		2.0 m	5.0	7.0	6.6
	Temperature (C)	0.0 m	20.5	19.8	18.1
		1.0 m	19.0	18.9	17.9
		2.0 m	18.3	18.0	17.1
	Alkalinity (mg/l $CaCO_3$)	CO_3	0	0	0
		HCO_3	146	240	264
	Hardness ($CaCO_3$)		379	296	353
	Salinity (parts/thousand)		0.4	0.3	0.4
	Specific conductivity (μmhos/cm)		480	380	480
	Maximum depth (m)		2.7	2.9	3.6
	Secchi disc (m)		1.3	1.7	0.3
	pH		8.3	8.2	8.2
06-27	Oxygen (mg/l)	0.0 m	9.2	8.0	8.2
		1.0 m	7.2	6.6	5.4
		2.0 m	5.0	1.2	0.6
	Temperature (C)	0.0 m	29.0	29.0	29.1
		1.0 m	25.1	26.5	26.5
		2.0 m	21.9	23.1	21.2
	Alkalinity (mg/l $CaCO_3$)	CO_3	-	-	-
		HCO_3	-	-	-
	Hardness (mg/l $CaCO_3$)		-	-	-
	Salinity (parts/thousand)		-	-	-
	Specific conductivity (μmhos/cm)		-	-	-
	Maximum depth (m)		-	-	-
	Secchi disc (m)		-	-	-
	pH		-	-	-

Appendix Table 4. Abundance and biomass (mg) determinations of the macrobenthic organisms collected in a six-year-old (Oppelt) dugout pond during 1982-83. T = less than 1.0 mg.

Sample		Chaoborus	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
01A	Number	3	46	-	-	1	2	-	52
	Dry weight	T	57	-	-	T	5	-	62
01B	Number	1	13	-	-	2	4	-	20
	Dry weight	1	13	-	-	T	56	-	70
01C	Number	4	33	-	-	2	1	2	40
	Dry weight	T	31	-	-	2	1	4	38
02A	Number	8	15	-	-	-	-	-	23
	Dry weight	2	25	-	-	-	-	-	27
02B	Number	2	11	1	-	8	-	-	22
	Dry weight	T	21	1	-	8	-	-	30
02C	Number	-	10	-	-	10	4	-	24
	Dry weight	-	9	-	-	1	6	-	16
03A	Number	-	22	-	-	31	2	-	55
	Dry weight	-	19	-	-	1	14	-	34
03B	Number	-	27	-	-	86	6	-	119
	Dry weight	-	8	-	-	7	3	-	18
03C	Number	-	190	10	-	11	1	1	213
	Dry weight	-	66	14	-	5	4	T	89
04A	Number	-	392	7	-	2	1	1	403
	Dry weight	-	219	6	1	T	2	T	227
04B	Number	-	386	3	-	11	-	-	399
	Dry weight	-	166	1	-	1	-	-	168
04C	Number	1	399	6	-	5	-	1	412
	Dry weight	T	208	4	-	1	-	1	214

Appendix Table 4. (Continued)

Sample		<u>Chaoborus</u>	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
05A	Number	-	91	1	-	18	2	3	115
	Dry weight	-	38	T	-	5	1	1	45
05B	Number	3	101	-	-	36	1	-	141
	Dry weight	2	32	-	-	2	19	-	55
05C	Number	6	230	2	-	18	2	1	259
	Dry weight	3	83	T	-	T	26	T	112
06A	Number	3	3	-	-	89	27	-	122
	Dry weight	T	T	-	-	5	79	-	84
06B	Number	-	1	-	-	59	10	-	70
	Dry weight	-	2	-	-	3	35	-	40
06C	Number	4	5	-	-	4	-	-	13
	Dry weight	2	2	-	-	T	-	-	4
07A	Number	-	-	-	-	-	2	-	2
	Dry weight	-	-	-	-	-	19	-	19
07B	Number	1	1	-	-	-	-	-	2
	Dry weight	2	T	-	-	-	-	-	2
07C	Number	2	-	-	-	-	-	-	2
	Dry weight	1	-	-	-	-	-	-	1
08A	Number	-	-	-	-	2	-	-	2
	Dry weight	-	-	-	-	T	-	-	T
08B	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
08C	Number	-	-	-	-	5	3	-	8
	Dry weight	-	-	-	-	T	27	-	27

Appendix Table 4. (Continued)

Sample		Chaoborus	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
09A	Number	-	-	-	-	2	28	-	30
	Dry weight	-	-	-	-	1	97	-	98
09B	Number	-	3	-	-	-	3	-	6
	Dry weight	-	1	-	-	-	19	-	20
09C	Number	-	6	-	-	-	2	-	8
	Dry weight	-	1	-	-	-	3	-	4
10A	Number	-	-	-	-	1	7	1	9
	Dry weight	-	-	-	-	T	4	15	19
10B	Number	-	-	-	-	12	14	-	26
	Dry weight	-	-	-	-	T	26	-	26
10C	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
11A	Number	-	1	-	-	3	2	-	6
	Dry weight	-	T	-	-	4	8	-	12
11B	Number	-	-	-	-	2	9	-	11
	Dry weight	-	-	-	-	1	67	-	68
11C	Number	-	-	-	-	2	9	-	11
	Dry weight	-	-	-	-	T	44	-	44
12A	Number	-	-	-	-	-	7	-	7
	Dry weight	-	-	-	-	-	41	-	41
12B	Number	-	-	-	-	2	22	-	24
	Dry weight	-	-	-	-	T	147	-	147
12C	Number	-	-	-	-	5	4	-	9
	Dry weight	-	-	-	-	1	53	-	54

Appendix Table 4. (Continued)

Sample	*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
13A Number	-	-	-	-	-	4	-	4
Dry weight	-	-	-	-	-	29	-	29
13B Number	-	-	-	-	-	3	-	3
Dry weight	-	-	-	-	-	8	-	8
13C Number	-	1	-	-	1	4	-	6
Dry weight	-	T	-	-	T	16	-	16
14A Number	-	-	-	-	1	12	-	13
Dry weight	-	-	-	-	1	24	-	25
14B Number	-	-	-	-	-	8	-	8
Dry weight	-	-	-	-	-	28	-	28
14C Number	-	-	-	-	4	2	-	8
Dry weight	-	-	-	-	T	22	-	22
15A Number	-	1	-	-	6	2	-	9
Dry weight	-	T	-	-	T	3	-	3
15B Number	-	-	-	-	2	-	-	2
Dry weight	-	-	-	-	T	-	-	T
15C Number	-	1	-	-	20	11	1	33
Dry weight	-	T	-	-	T	8	T	8
16A Number	-	3	-	-	3	9	1	16
Dry weight	-	T	-	-	T	91	27	118
16B Number	-	2	-	-	2	-	-	4
Dry weight	-	3	-	-	T	-	-	3
16C Number	-	-	-	-	13	13	1	27
Dry weight	-	-	-	-	T	21	T	21

Appendix Table 4. (Continued)

Sample		*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
17A	Number	2	25	-	-	14	11	-	52
	Dry weight	2	6	-	-	T	28	-	36
17B	Number	-	1	-	-	3	4	-	8
	Dry weight	-	3	-	-	T	12	-	15
17C	Number	-	-	-	-	3	5	-	8
	Dry weight	-	-	-	-	T	18	-	18
18A	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
18B	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
18C	Number	-	2	-	-	-	2	-	4
	Dry weight	-	1	-	-	-	1	-	2
19A	Number	-	1	-	-	21	3	-	25
	Dry weight	-	T	-	-	1	2	-	3
19B	Number	-	-	-	-	5	7	-	13
	Dry weight	-	-	-	-	T	18	-	18
19C	Number	1	-	-	-	3	10	-	14
	Dry weight	T	-	-	-	T	6	-	6
20A	Number	-	-	-	-	-	-	-	-
	Dry weight	-	-	-	-	-	-	-	-
20B	Number	-	1	-	-	2	-	-	3
	Dry weight	-	T	-	-	T	-	-	T
20C	Number	-	-	-	-	3	3	-	6
	Dry weight	-	-	-	-	T	3	-	3

Appendix Table 4. (Continued)

Sample	Chaoborus	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
21A Number	-	-	-	-	-	2	-	2
Dry weight	-	-	-	-	-	17	-	17
21B Number	-	-	-	-	1	2	-	2
Dry weight	-	-	-	-	T	49	-	49
21C Number	-	-	-	-	-	4	-	4
Dry weight	-	-	-	-	-	16	-	16
22A Number	-	1	-	-	10	4	-	15
Dry weight	-	1	-	-	T	23	-	24
22B Number	-	-	-	-	8	2	-	10
Dry weight	-	-	-	-	3	20	-	23
22C Number	-	1	-	-	11	6	-	18
Dry weight	-	T	-	-	T	18	-	18

Appendix Table 5. Abundance and biomass (mg) determinations of the macrobenthic organisms collected in a three-year-old (Kurtz) dugout pond during 1982-83. T = less than 1.0 mg.

Sample	*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
01A Number	-	163	-	-	6	-	-	169
Dry weight	-	193	-	-	6	-	-	199
01B Number	-	29	-	-	27	-	-	56
Dry weight	-	24	-	-	30	-	-	54
01C Number	-	-	-	48	-	-	-	48
Dry weight	-	-	-	29	-	-	-	29
02A Number	2	5	1	-	6	-	-	14
Dry weight	1	7	T	-	5	-	-	13
02B Number	1	35	1	7	76	-	1	121
Dry weight	T	65	1	4	31	-	3	104
02C Number	1	4	2	-	3	-	1	11
Dry weight	T	8	2	-	2	-	1	13
03A Number	-	35	6	14	225	-	2	282
Dry weight	-	12	4	9	79	-	1	105
03B Number	-	115	8	-	26	-	-	149
Dry weight	-	21	33	-	17	-	-	71
03C Number	-	109	3	-	34	-	-	146
Dry weight	-	31	T	-	5	-	-	36
04A Number	7	337	-	29	87	-	-	460
Dry weight	1	108	-	20	16	-	-	145
04B Number	-	154	-	34	103	-	1	292
Dry weight	-	49	-	23	77	-	1	150
04C Number	2	226	-	24	103	-	-	355
Dry weight	1	59	-	16	6	-	-	82

Appendix Table 5. (Continued)

Sample	*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
05A Number	12	243	4	-	106	-	7	355
Dry weight	4	164	3	-	14	-	1	186
05B Number	8	2	-	-	-	-	-	10
Dry weight	1	3	-	-	-	-	-	4
05C Number	7	187	1	-	54	-	17	266
Dry weight	6	87	2	-	4	-	2	101
06A Number	-	67	3	67	250	1	3	391
Dry weight	-	76	6	8	24	1	2	117
06B Number	-	83	-	-	71	-	1	156
Dry weight	-	58	-	-	7	-	1	66
06C Number	12	24	-	42	29	-	9	116
Dry weight	3	6	-	14	1	-	T	24
07A Number	34	1	-	2	1	-	6	44
Dry weight	17	T	-	2	T	-	T	19
07B Number	4	10	-	-	13	-	-	27
Dry weight	1	7	-	-	3	-	-	11
07C Number	1	46	-	88	44	2	-	181
Dry weight	T	43	-	16	12	2	-	73
08A Number	5	67	-	5	180	-	1	258
Dry weight	1	92	-	3	26	-	T	122
08B Number	6	1	-	6	28	1	-	42
Dry weight	T	2	-	T	2	1	-	5
08C Number	4	25	-	-	135	-	-	164
Dry weight	1	43	-	-	59	-	-	103

Appendix Table 5. (Continued)

Sample		Chaoborus	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
09A	Number	5	-	-	1	5	-	1	12
	Dry weight	1	-	-	T	T	-	9	10
09B	Number	-	9	1	3	20	-	-	33
	Dry weight	-	18	1	T	13	-	-	32
09C	Number	-	8	-	1	184	-	1	194
	Dry weight	-	18	-	T	5	-	T	23
10A	Number	-	3	-	4	123	-	-	130
	Dry weight	-	7	-	T	40	-	-	47
10B	Number	-	4	-	-	43	-	1	48
	Dry weight	-	8	-	-	11	-	T	19
10C	Number	-	1	-	-	12	-	-	13
	Dry weight	-	1	-	-	1	-	-	2
11A	Number	-	1	-	-	81	-	1	83
	Dry weight	-	2	-	-	23	-	T	25
11B	Number	-	1	-	-	22	-	1	24
	Dry weight	-	1	-	-	3	-	T	4
11C	Number	-	5	-	-	182	-	-	187
	Dry weight	-	3	-	-	182	-	-	185
12A	Number	-	2	-	-	68	-	-	70
	Dry weight	-	T	-	-	6	-	-	6
12B	Number	-	73	-	6	524	-	1	604
	Dry weight	-	38	-	T	23	-	T	61
12C	Number	1	2	1	-	25	-	1	30
	Dry weight	T	T	5	-	7	-	T	12

Appendix Table 5. (Continued)

Sample	Chaoborus	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
13A Number	1	38	-	-	118	-	2	159
Dry weight	T	48	-	-	51	-	T	99
13B Number	-	126	-	1	136	-	1	264
Dry weight	-	185	-	T	71	-	2	258
13C Number	16	2	-	-	1	-	1	20
Dry weight	4	T	-	-	T	-	24	28
14A Number	2	19	-	-	92	-	1	114
Dry weight	1	19	-	-	66	-	T	86
14B Number	1	48	-	-	125	-	2	176
Dry weight	1	56	-	-	57	-	1	115
14C Number	3	34	-	-	235	-	1	273
Dry weight	2	46	-	-	120	-	T	168
15A Number	-	39	-	4	346	-	-	379
Dry weight	-	85	-	1	247	-	-	333
15B Number	-	128	-	1	102	-	2	233
Dry weight	-	242	-	T	146	-	13	401
15C Number	-	-	-	-	2	-	1	3
Dry weight	-	-	-	-	T	-	39	39
16A Number	-	74	-	1	47	-	1	123
Dry weight	-	169	-	T	17	-	1	187
16B Number	1	17	-	1	75	-	1	95
Dry weight	T	27	-	T	62	-	T	89
16C Number	11	39	-	1	24	-	-	75
Dry weight	3	61	-	T	22	-	-	86

Appendix Table 5. (Continued)

Sample	*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
17A Number	12	8	-	-	4	-	-	24
Dry weight	8	18	-	-	T	-	-	26
17B Number	-	62	-	-	180	1	-	243
Dry weight	-	114	-	-	93	11	-	218
17C Number	-	35	-	2	343	2	-	382
Dry weight	-	30	-	1	126	45	-	202
18A Number	-	26	-	-	52	-	-	78
Dry weight	-	31	-	-	42	-	-	73
18B Number	10	19	-	-	4	-	-	33
Dry weight	7	28	-	-	T	-	-	35
18C Number	2	5	-	-	1	1	-	9
Dry weight	3	4	-	-	T	1	-	8
19A Number	4	9	-	5	96	-	-	114
Dry weight	2	15	-	T	70	-	-	87
19B Number	-	44	-	2	117	-	-	163
Dry weight	-	61	-	T	109	-	-	170
19C Number	6	17	-	2	6	-	-	31
Dry weight	2	40	-	1	T	-	-	43
20A Number	-	27	-	-	225	-	1	253
Dry weight	-	22	-	-	146	-	45	213
20B Number	12	14	-	-	6	-	-	32
Dry weight	9	25	-	-	2	-	-	36
20C Number	3	58	-	3	52	-	-	116
Dry weight	4	68	-	1	17	-	-	90

Appendix Table 5. (Continued)

Sample	*Chaoborus*	Chironominae	Chironominae pupae	Tanypodinae	Oligochaetae	Hirudinidae	Other	Total
21A Number	18	1	-	-	5	-	-	24
Dry weight	10	3	-	-	4	-	-	17
21B Number	2	41	1	-	236	-	-	280
Dry weight	2	70	2	-	122	-	-	196
21C Number	1	16	-	4	80	-	-	101
Dry weight	2	22	-	1	76	-	-	101
22A Number	3	36	1	-	273	-	4	318
Dry weight	3	57	1	-	205	-	T	266
22B Number	1	36	6	4	300	1	1	348
Dry weight	1	62	18	3	158	-	T	242
22C Number	4	-	1	-	26	-	2	33
Dry weight	1	-	1	-	9	-	1	12