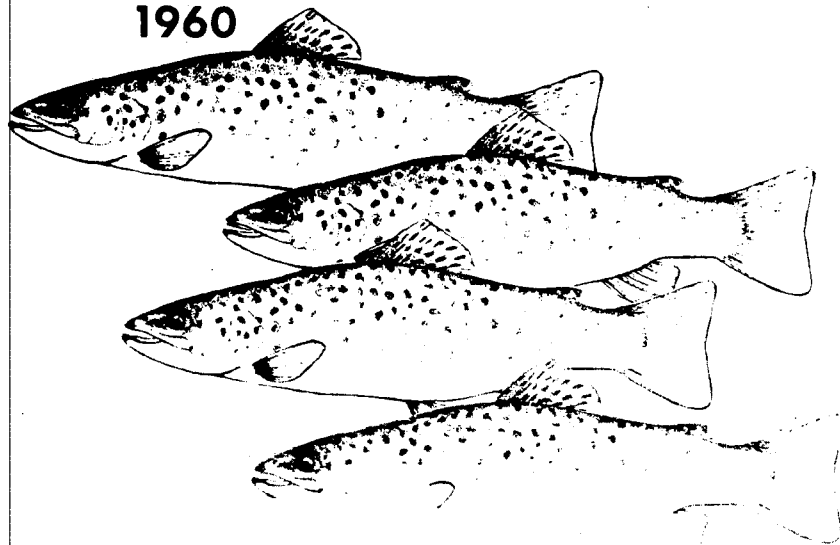


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**Evaluation of Coldwater Tributaries
for Trout Habitation
in the
Lower Niobrara River Basin**

1960



1980



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ABSTRACT

Several tributaries in the lower Niobrara River Basin in northeastern Nebraska have been managed for trout production since the turn of the century. The plateau-like area where the streams originate underwent extensive agricultural changes during the 1960's and 70's, with the principal land usage changing from grazing to row crop farming. This expanse of grassland was converted to row crop farmland with the advent of the center-pivot irrigation system.

In 1980-81 fish populations in three streams were sampled with explosives and electrofishing gear to gather information for use in evaluating the impact of land-use changes on the quality of the coldwater fish habitat. During and prior to the study, marked trout were released into the streams to determine the degree of emigration and survival and the extent of natural reproduction.

Physical and chemical parameters of the streams were determined throughout the study to calculate a Habitat Quality Index and to permit identification of the factors limiting trout survival and densities.

The land-use changes that have occurred in the stream's watersheds have decreased or eliminated the amount of coldwater habitat suitable for trout production.

INTRODUCTION

During the early 1900's several of the larger tributaries of the lower Niobrara River in northeastern Nebraska were considered coldwater habitat by Nebraska Game and Parks biologists, and trout were introduced (Jones 1963). These streams all originate in a rather flat plateau-like area south of the Niobrara River and flow north to the river. Numerous springs and seeps join the streams along their course. These base flow sources of water not only increase stream volume but also maintain cooler water temperatures.

Subsequent to the initial introduction of trout it became apparent that some of the streams could not support coldwater species and, according to Nebraska Game and Parks Commission records, stocking of trout was discontinued. During the 1960's-70's the upper reaches of the north, south, and middle branches of Verdigre Creek, Steele Creek and Louse Creek were the only streams that were periodically stocked with trout (Nebraska Game and Parks Comm. 1967).

The sport fishermen of northeastern Nebraska have limited local fishery resources available to them consisting primarily of privately owned farm ponds, warmwater rivers and streams and a few publicly owned lakes. Streams that are capable of supporting trout are considered an important potential fishery resource.

Trout streams are unique, and fishermen using them are aware that habitat changes have occurred. Fishermen complaints increased in the mid to late 1970's regarding the paucity of trout in the streams. During this time period the streams were stocked on an annual basis with brown trout (*Salmo trutta*) and some rainbow trout (*Salmo gairdneri*) (Appendix Table 1).

Since the apparent decline in the quality of trout fishing during the decade of the 1970's coincided with extensive groundwater withdrawal for center-pivot irrigation in the stream's upper watersheds, a study was implemented on three representative streams with the following objectives:

1. Identify the area from which these streams receive their base groundwater flow.
2. Identify and describe land uses associated with groundwater development for irrigation.
3. Determine present and estimate future coldwater habitat quality and describe the physicochemical properties of the streams.
4. Estimate fish populations and identify fish community structures in these streams.
5. Quantify reproduction of trout and identify contribution of stocked fish to the population.

DESCRIPTION OF STUDY STREAMS

The three study streams, the North Branch of Verdigre Creek, Steele Creek, and Louse Creek, have drainage areas that originate on the northern edge of the Holt table northeast of O'Neill in northeastern Holt County, Nebraska (Figure 1). This flat plateau-like area has undergone significant agricultural changes in the last 20 years due to deep-well center-pivot irrigation systems which made it possible to produce row crop grain on land formerly used as pasture.

The soils of the upper drainages on the Holt table are primarily sandy loams of the O'Neill and Thurman series, while those in the lower drainage areas of the study streams are primarily sands and sandy loams of the Valentine and Dickensen series. These soils were deposited during the Pleistocene epoch (Moran 1932).

Underlying the soils is a bedrock of light-colored Ogallala sandstone of Tertiary age. This bedrock is exposed at various locations along the study streams. Beneath the Ogallala layer lies dark-olive Pierre shale of Cretaceous age (Moran 1932). No exposed shale was found along the study streams. However, areas of shale exposure can be found along the Niobrara River in the general area where the study streams enter the river.

The watershed vegetative cover consists principally of grasses such as Kentucky bluegrass (*Poa pratensis*) along the stream banks, blue grama (*Bouteloua gracilis*) and sideoats grama (*B. curtipendula*) on the gravelly slopes, and on the upland soils sandlove grass (*Eragrostis trichodes*), switch grass (*Panicum virgatum*) and little bluestem (*Andropogon scoparius*). Scientific names were taken from Hitchcock (1935).

Trees and shrubs found in wooded ravines in the lower drainage area of the streams include; burr oak (*Quercus macrocarpa*), American elm (*Ulmus americana*), eastern red cedar (*Juniperus virginiana*), boxelder (*Acer negundo*), black walnut (*Juglans nigra*), cottonwood (*Populus deltoides*), smooth sumac (*Rhus glabra*), American plum (*Prunus americana*), gooseberry (*Ribes missouriense*), and buckbrush (*Symphoricarpos occidentalis*). Scientific names were taken from Grimm (1966) and Pool (1978).

The riparian land along the entire length of the three streams is privately owned. Since the streams provide abundant water for livestock, the adjacent land is used extensively for grazing. The unrestricted stream access by livestock, primarily cattle, along stream banks contributes to erosion in the sandy soils of the area.

The North Branch of Verdigre Creek begins in the SW 1/4 of Section 29, R9W, T30N, Holt County, Nebraska and flows northerly and then easterly for 39.4 km before joining Verdigre Creek 2.2 km southwest of the village of Verdigre in the NE 1/4 of Section 18, R6W, T30N, Knox County, Nebraska. The drainage area of the north branch is 37,596 hectares, which is divided between northeast Holt County and western Knox County (Figure 1).

Steele Creek originates in the SE 1/4 of Section 21, R9W, T31N, Holt County, Nebraska and flows northeasterly for 22.8 km, joining the Niobrara River in the NW 1/4 of Section 17, R8W, T32N, Knox County, Nebraska. Steele Creek drains 6,325 hectares; the upper 75% of this area is in

northeastern Holt County and the lower 25% in northwestern Knox County (Figure 1).

Louse Creek begins in the SE 1/4 of Section 14, R10W, T31N, Holt County, Nebraska and flows north for 16.2 km, joining the Niobrara River in the NW 1/4 of Section 12, R10W, T32N, Holt County, Nebraska. The Louse Creek drainage area is 6,708 hectares, which is entirely in northeastern Holt County (Figure 1).

The upper reaches of these order two streams are narrow with stream widths ranging from 2.5 m on Louse Creek to 5.0 m on the North Branch of Verdigre Creek. Pools are generally shallow with depths ranging from 0.5 m to 0.8 m.

Aquatic macrophytes common in the streams are watercress (*Nasturtium officinale*), and water buttercup (*Ranunculus subrigidus*). Scientific names were taken from Fassett (1960).

METHODS AND MATERIALS

STREAM PHYSICAL PROPERTY COLLECTION PROCEDURES

The suitability of the study streams for trout habitation was assessed by collecting data on several physical parameters throughout the open water season. The two physical parameters considered most important for trout habitation were water volume flow rates and temperatures. Several other stream parameters were also measured and used in calculating a Habitat Quality Index (H.Q.I.) for each stream. The H.Q.I. is a mathematical model that predicts trout standing crop by measuring certain physicochemical stream characteristics. The model was developed to give biologists and water resource planners a standard method to quantify trout stream habitat (Binns and Eiserman 1979).

Stream Volume Measurements

Stream flow rates were measured monthly from June 1980 through October 1981, except during February of 1981 when ice conditions made accurate measurements impossible. An upper and a lower station were established on each stream (Figure 1). The upper station on Louse Creek was moved downstream approximately 1 km between January and March, 1981, so that a large spring which contributed considerably to the stream's volume could be included in the flow measurements. Empirically determined flow rates were converted to volume estimates by measuring the flow rates at several locations in the profile of each stream at each station.

A Pygmy No. 2 current meter attached to a calibrated standing rod was used to orient the meter properly in the water current. A battery-operated headset was worn so that a series of meter revolutions could be counted within a timed period using a stop watch. This information was then relayed to a data collector nearby. A static line was staked to span the stream as perpendicular to the current as possible. Marks on the static line 0.3 m apart enabled the investigator to determine the desired distance between each measurement of current velocity. Ten measurements were taken at different locations across the stream's cross section to get accurate mean flow rates (pers. comm. Tom Lamberson, Nebr. Dept. of Water Resources). Since the streams were narrow, current velocities and depths were measured at 15.2 cm intervals across the stream. Field data were entered on Nebraska Department of Water Resources Discharge Measurement Notes (Appendix Figure 1).

Stream Temperature Measurements

Water temperatures were monitored with Ryan J-90 continuous recording thermometers with a temperature span of 0-30 C. Steel fence posts were driven into the stream bed and the thermometers secured below the water line with noncorrosive wire. Two thermometers were placed in the North Branch of Verdigre Creek because of its greater length, while only one thermometer was placed in each of Steele and Louse Creeks (Figure 1). Stream temperatures were scheduled to be monitored from June 1, 1980 through October 31, 1981, to obtain information during two summer seasons. However, one thermometer was stolen from the lower station of the North

Branch of Verdigre Creek during June, 1980, preventing data from being collected at that station. The thermometer at the upper station of the North Branch of Verdigre Creek was separated from the anchor post during March, 1981, (presumably from spring ice thaw) and lost. Consequently, stream temperatures on the North Branch of Verdigre Creek were collected from June 1, 1980 to January 31, 1981, only at the upper station. The thermometer that was placed in Louse Creek malfunctioned during September, 1981, hence collection of stream temperatures was terminated August 31, 1981. The accuracy of the thermometers was checked with a Taylor hand held thermometer when the instruments were lifted to change recording tapes or batteries.

Physical Properties Needed to Calculate Habitat Quality Index

A model for predicting trout standing crop developed by Binns and Eiserman (1979), the Habitat Quality Index, was used to identify stream parameters which limit trout habitation and assess a stream's suitability for trout in eastern Nebraska, and to compare trout standing crop estimates using the H.Q.I. with those determined by sampling the trout population. Several habitat parameters in addition to stream temperatures and flows were needed to calculate Model II of the Habitat Quality Index (H.Q.I.). These parameters included nitrate nitrogen (mg/l), cover (%), eroding banks (%), substrate type, water velocity (m/second) and stream width (m) and were collected during September, 1981. The nitrate nitrogen samples were analyzed in Lincoln, Nebraska by personnel of the Nebraska Department of Environmental Control.

Measurements of the habitat parameters were taken on two sections randomly selected within the electrofished sampling areas of each stream. The estimates of trout standing crop from the two sections were then averaged. This value was considered the expected trout standing crop.

FISH COLLECTIONS

The stream fish communities were sampled every other month starting in June 1980 and continuing through October 1981 for a total of nine samples. Fish were sampled using an explosive (primacord) and electrofishing devices. Three or four detonations in randomly selected areas of the stream constituted a primacord sample. Each blast consisted of detonating a 20 m section of primacord containing 25 grains of PETN per 0.3 meter. The primacord was detonated with an electric blasting cap which was taped securely to the cord with black electrician's tape. Approximately 10 m of 20 gauge insulated wire connected the blasting cap to a Fidelity 10 cap detonator. Several small pieces of broken concrete were taped at various intervals along the primacord so it would sink quickly in the stream. When the section of cord was ready for detonation it was placed in the stream with a minimal amount of disturbance. A seine 15.2 m long, 1.2 m deep, with 6.3 mm mesh was positioned a safe distance downstream from the lower end of the primacord and held in place for 5 minutes after the blast. This time period allowed stunned or killed fish to drift into the net. After the required time period the seine was removed to an adjacent bank where the fish were separated from the debris and preserved in 10% formalin. Fish were identified and the data recorded in the laboratory of the Nebraska Game and Parks Commission's District III headquarters in Norfolk, Nebraska. Primacord was used for fish

samples during June, August and December, 1980, and February, June and August, 1981.

Electrofishing was used to sample fish during October 1980; and in April, and October, 1981. Three types of electrofishing equipment were used, all equally effective in sampling fish in small streams. In October 1980 a 2.4 m plastic Sport-Yak was used to transport a Coffelt VVP-10 pulsator and the 3500 watt Power-Gard generator, along with a holding tub, measuring board and data box. Fish were narcotized using interrupted DC current of 200 volts, 5 to 7 amps. Since the streams were shallow it was quite labor intensive to drag the loaded Sport-Yak upstream and a different device was used the following April.

During the April 1981 sampling trip, I used a reel manufactured by Coffelt Electronics, containing two 152 m long electrical cords to which the hand-held electrodes were attached. The same Coffelt pulsator and Power-Gard generator with approximately the same electrical settings were used. The amount of stream that could be sampled was limited with this device since access to the stream bank was required, and then only a 304 m section of stream could be sampled without moving the base unit (generator and pulsator).

In October 1981 a BP-2 Coffelt backpack electrofishing unit was obtained and used to sample large sections of the three study streams. This unit was more compatible for stream use and produced approximately 100 volts of continuous direct current at 3 amps.

Trout sampled with the electrofishing equipment were counted, weighed and measured in the field. Other fish narcotized with the shockers were not netted because adequate samples were being collected with primacord.

Brown trout stocked in the study streams in 1980 were marked by clipping one pelvic fin, while trout stocked in 1979 had the right pectoral fin removed. The three sampling periods in which electrofishing equipment was used represented one month, six months and one year after the September 1980 trout stocking. This staggered sampling together with the presence of marked fish in the population allowed me to determine the percentage of trout lost from the streams as well as the contribution stocked fish made to the population.

RESULTS AND DISCUSSION

STREAM FLOW MEASUREMENTS

Historical flow rates in the study streams prior to the onset of irrigation development were difficult to find in the records or literature. When flow rates were taken, it was done at irregular intervals. Annual flow rates were not regularly recorded until the early 1970's when irrigation development had progressed considerably.

The only flow rate estimates of Steele and Louse Creeks were taken in 1940. One measurement was taken on the lower end of each stream in June and September of that year, so comparison between flow rates in pre-and post-irrigation development periods was not possible.

Two landowners from the upstream end of Steele and Louse Creeks indicated that the most upstream point of flowing water in both creeks was farther upstream in the watershed during the 1950's and previous decades. Both landowners estimated that the initial point of flowing water was approximately 0.8 km upstream from its present location. They attributed the loss of flowing water to irrigation development in the respective watersheds of the creeks.

Table 1. Stream volumes (cubic meters/sec.) by month for Steele, Louse, and the North Branch of Verdigre Creeks, June 1980 to October 1981.

	Steele		Louse		N. Branch	
	Upper	Lower	Upper	Lower	Upper	Lower
1980						
June	0.24	0.25	0.04	0.21	0.14	0.56
July	0.19	0.12	0.05	0.10	0.12	0.32
August	0.14	0.03	0.05	0.11	0.10	0.39
September	0.16	0.25	0.06	0.18	0.13	0.48
October	0.20	0.27	0.06	0.19	0.12	0.52
November	0.21	0.30	0.05	0.24	0.14	0.56
December	0.20	0.34	0.05	0.28	0.11	0.72
1981						
January	0.20	0.27	0.06	0.32	0.11	0.52
February	*	*	*	*	*	*
March	0.23	0.36	0.18**	0.25	0.11	0.57
April	0.22	0.30	0.17	0.25	0.11	0.59
May	0.21	0.32	0.14	0.23	0.11	0.45
June	0.15	0.23	0.11	0.20	0.13	0.52
July	0.18	0.20	0.12	0.08	0.12	0.34
August	0.19	0.39	0.13	0.38	***	***
September	0.17	0.20	0.13	0.26	—	—
October	0.20	0.20	0.12	0.29	—	—

* No flows taken due to ice conditions

** Flow station moved downstream so large spring could be included.

*** Flows discontinued

The amount of irrigation development is known, but the impact of this development on the stream flow regimen is difficult to determine. From 1960 until August of 1979 at least 348 irrigation wells were drilled in the Holt table which includes the watersheds of the study streams plus a 2 km wide peripheral area extending around the watersheds (Nebr. Dept. Water Resour. 1979) The wells were counted in the peripheral area because groundwater in this flat area could contribute to the flow of the study streams.

The results of stream flow measurements on the upper and lower area of each stream (Table 1) provide some insight into the impact of irrigation and the relationship between precipitation and stream flows. Precipitation amounts at O'Neill, Nebraska, which is located 35 km southwest of the study area, were obtained from the University of Nebraska-Lincoln Agricultural Engineering Department (Table 2). This department records Nebraska climatological data for the National Oceanic and Atmospheric Administration.

Comparisons between stream volumes and precipitation revealed that precipitation influences the flow volume on the lower area of the streams more than the upper area. This should be expected due to the greater amount of water from the watershed which would be drained into the stream upstream from the lower flow measurement station.

Generally, during the summer months when groundwater for irrigation was being removed at a high rate, flows decreased in the upper reaches of the streams. The upper portions of the streams are more sensitive to groundwater withdrawal because the water supply is hydrologically interconnected.

Table 2. Precipitation (cm) recorded at O'Neill, Holt Co. Nebraska from June 1980 to October 1981.

	<i>Actual Recorded</i>	<i>Normal</i>	<i>Departure</i>
1980			
June	3.6	9.6	-6.0
July	4.0	7.2	-3.2
August	10.8	7.2	+3.6
September	1.5	6.1	-4.6
October	4.0	3.6	+0.4
November	0.6	1.6	-1.0
December	0.7	1.6	-0.9
1981			
January	0.2	1.2	-1.0
February	0.9	1.6	-0.7
March	2.9	3.3	-0.4
April	1.6	5.8	-4.2
May	7.6	8.1	-0.5
June	6.5	9.6	-3.1
July	11.2	7.2	+4.0
August	10.9	7.2	+3.7
September	3.0	6.1	-3.1
October	2.8	3.6	-0.8

The lower portion of the streams were more sensitive to direct water withdrawal from the stream by irrigators. All three streams had irrigation pumps that removed water from the streams between the upper and lower flow-measurement stations. This explains the difference in water volumes between the flow stations on Steele Creek during July and August, 1980 when flows on the lower reach of stream were less than those on the upper portion. This same event happened during July, 1981 on Louse Creek (Table 1). The North Branch of Verdigre Creek also exhibited the phenomena of decreasing flows with downstream movement. On July 11, 1980 the flows increased from the upper station to the lower station (Table 1), but from that point flows decreased with downstream movement until the stream ceased to flow at the point where it joins Verdigre Creek.

It appears that deep-well irrigation development reduces the stream volume during the peak irrigation season. This reduction in base volume flow occurs during the time of year when air temperatures are maximum. This situation allows the remaining water in the stream to warm more rapidly, resulting in loss of coldwater habitat. The direct withdrawal of water from the streams by irrigation appropriation can instantaneously reduce flows, thereby impacting the integrity of the stream ecosystem. Increased future direct withdrawal for irrigation development on the study streams has the potential to eliminate the existing fish populations, or at the very least, alter the structure of the fish community.

STREAM TEMPERATURE MEASUREMENTS

Water temperatures in the three study streams was a critical factor influencing trout survival. The Critical Thermal Maxima (CTM) and lethal temperatures of both brown and rainbow trout are well known, as extensive research has been done on this subject. CTM is defined as that temperature at which a fish loses its ability to escape lethal conditions (Lee and Rinne 1980). Brown trout have a CTM of 28.96 C when acclimated at 10 C and a CTM of 29.85 C when acclimated at 20 C (Lee and Rinne 1980). Brynildson et al. (1967) stated that brown trout can survive temperatures of 27.2 C for short periods of time. The McConaughy strain of rainbow trout, which appear to be genetically adapted to higher water temperatures, has a CTM of 32.7 C (Vancil et al. 1979). Lee and Rinne (1980) reported a CTM of 28.45 C for a domestic strain of rainbow trout when acclimated to 10 C and a CTM of 29.35 C when acclimated to 20 C.

The CTMs of brown and rainbow trout are less important than maximum lethal temperatures in a stream environment because fish usually cannot immediately return to a cooler ambient temperature. Trout may be exposed to a warmer stream temperature for several hours on a hot summer afternoon, therefore the maximum upper lethal temperature of the species becomes the critical temperature parameter in a natural stream environment. Vancil et al. (1979) found the upper lethal temperature (ULT) of a domestic strain of rainbow trout was approximately 26 C (> 24 C but < 26 C). Kaya (1978) found the ULT of two hatchery strains and the geothermally heated Firehole River strain of rainbow trout to be 26.2 C.

Binns and Eisermen (1979) considered 26.3 C as the maximum summer water temperature which trout could tolerate when calculating trout standing crop using the Habitat Quality Index. In this study 26.3 C was used as the

upper lethal temperature in all study streams since it was similar to the ULT values used by other investigators. Moreover, by using a standard ULT when computing separate Habitat Quality Indices for each study stream, it was not necessary to alter temperature in the predictive model. Van Velson (1977) stated that in many instances neither brown trout or rainbow trout are superior to the other as far as tolerance to high water temperature is concerned.

Thermographs produced by the Ryan J-90 recording thermometers agreed closely to temperatures taken with hand thermometers. I routinely measured temperatures with a hand thermometer when the thermograph instrument was removed for maintenance. The temperatures observed by both methods never differed more than 1 C.

The data obtained from the thermographs indicated water temperatures in all three study streams reached or exceeded the upper lethal temperature for trout on several hot afternoons in the summers of 1980 and 1981.

The waters of Steele Creek reached or exceeded 26.4 C on three occasions, all in July 1981. The maximum water temperature recorded on Steele Creek was 27 C on July 13, 1981. The air temperature recorded in O'Neill, Nebraska on that day was 38.8 C (NOAA 1981).

Louse Creek reached or exceeded 26.4 C on 9 occasions, once in 1980 and eight times in 1981. The maximum water temperature attained was 27.4 C on June 27, 1981 when the air temperature was 37.2 at O'Neill, Nebraska.

The North Branch of Verdigre Creek reached or exceeded 26.4 C on 29 occasions during 1980. No data were available in 1981 because the recording thermometers on the North Branch were lost or stolen. The maximum water temperature reached in the North Branch was 30.0 C on June 26, 1980 when air temperature reached 37.8 C at O'Neill, Nebraska.

The length of time that the water temperature was 26.4 C or above varied with each stream. For comparison purposes, the length of time water temperatures reached or exceeded 26.4 C was calculated from thermograph charts on the day the maximum water temperatures were recorded in each stream. Steele and Louse Creeks reached or exceeded 26.4 C for an average of 4 hours and the North Branch reached or exceeded 26.4 C for an average of 7 hours for each occurrence.

The June 1980 maximum daily air and water temperatures from the three study sites were correlated but the resulting correlation coefficients were not exceptionally high (Table 3).

In view of the modest positive correlations between maximum air and water temperatures it becomes apparent another parameter also contributed to the variation in maximum daily water temperatures. This parameter apparently is the minimum air temperature during the previous night. A low air

Table 3. Correlation of daily maximum air temperatures and daily maximum water temperatures during June, 1980 for Steele, Louse and the North Branch of Verdigre Creeks.

<i>Stream</i>	<i>Number Observations</i>	<i>Correlation Coefficient</i>
North Branch Verdigre Creek	30	+ 0.55
Steele Creek	30	+ 0.36
Louse Creek	30	+ 0.30

temperature (15.6-18.3 C) during the night allowed the streams to cool, thus air temperatures the following afternoon of > 35.0 C did not always result in stream temperatures that exceed the ULT for trout.

However, there are numerous occasions during Nebraska summers when minimum night air temperature remain above 21.1 C. It is during these periods of warm nights and high afternoon air temperature which exceed 35.0 C that trout ULT's can be reached in the streams.

The streams obviously undergo periods when water temperatures become unsuitable for trout. This is particularly true of the North Branch of Verdigre Creek and Louse Creek, and to a lesser extent Steele Creek. The data derived from fish sampling conducted during the study concurred with the temperature data, i.e. all of the study streams had periods when their water temperatures were unsuitable for trout. Exceeding the ULT's in the streams reduced or eliminated trout populations.

FISH COLLECTIONS

After the initial field investigation in June 1980, when samples of the fish community were obtained from the entire length of the three streams, it became apparent that the lower reaches of the streams were unsuitable for trout. This was confirmed by previous data on the streams which indicated that only the upper reaches were capable of maintaining coldwater species (Nebr. Game and Parks Comm. 1967). Since the primary objective of the study was to determine the trout population structure in each stream, sampling was then restricted to the upper 6.7 km, 6.4 km and 21.7 km of Steele, Louse, and the North Branch of Verdigre Creeks, respectively. Seventeen species of fish were sampled during the course of the study using two collection methods (Table 4).

Fish Species Excluding Trout

Six fish species: red shiners (*Notropis lutrensis*), flathead chubs (*Hybopsis gracilis*), northern pike (*Esox lucius*), black bullhead (*Ictalurus melas*), stonecat (*Noturus flavus*), and northern plains minnow (*Hybognathus placitus*) were only collected during June 1980 when the lower reaches of the streams were sampled. Two additional species, bigmouth shiners (*Notropis dorsalis*) and sand shiners (*Notropis stramineus*), were sampled in the lower reaches of all three streams during June 1980, but were found only in the North Branch of Verdigre Creek when sampling was restricted to the upper reaches of the streams.

Green sunfish (*Lepomis cyanellus*) and fathead minnows (*Pimephales promelas*) were sampled in each stream on one occasion, but they were not abundant with a total of nine and seven, respectively. One bluegill (*Lepomis macrochirus*) was sampled during the study in August 1980 in Steele Creek. Red shiners (*Notropis lutrensis*) were sampled in the North Branch of Verdigre Creek on two occasions, August and December 1980.

The remaining three species of fish, longnose dace (*Rhinichthys cataractae*), creek chub (*Semotilus atromaculatus*), and white sucker (*Catostomus commersoni*) were the most abundant species sampled with primacord in all three streams. These three species collectively comprised > 90% of the total number of fish sampled (Table 4).

Population estimates were calculated for longnose dace, creek chub and white sucker in the upper reaches of each study stream using the partial

Table 4. Species composition and numbers of fish collected with primacord (PC) and electrofishing gear (EG) from Steele, Louse, and the North Branch of Verdigre Creeks, 1980-1981. Scientific names were taken from Am. Fish. Soc. (1980).

	Steele		Louse		N. Branch		% of Total No.
	PC	EG	PC	EG	PC	EG	
Brown trout <i>Salmo trutta</i> Linnaeus	6	120	1	10	-	10	2.0
Rainbow trout <i>Salmo gairdneri</i> Richardson	-	2	-	-	-	-	T
Longnose dace <i>Rhinichthys cataractae</i> (Valenciennes)	638	-	1,198	-	1,054	-	39.8
Creek club <i>Semotilus atromaculatus</i>	638	-	1,672	-	963	-	49.1
White sucker <i>Catostomus commersoni</i> (Lacepeide)	62	-	9	-	98	-	2.3
River shiner <i>Notropis blennioides</i> (Girard)	-	-	-	-	72	-	1.0
Red shiner <i>Notropis lutrensis</i> Baird and Girard	16	-	11	-	-	-	0.4
Flathead chub <i>Hybopsis gracilis</i> Richardson	11	-	4	-	8	-	0.3
Bigmouth shiner <i>Notropis dorsalis</i> (Agassiz)	1	-	3	-	34	-	0.5
Northern pike <i>Esox lucius</i> Linnaeus	-	-	1	-	-	-	T
Green sunfish <i>Lepomis cyanellus</i> Rafinesque	3	-	4	-	2	-	0.1
Black bullhead <i>Ictalurus melas</i> (Rafinesque)	6	-	-	-	6	-	0.2
Stoneroller <i>Noturus flavus</i> Rafinesque	3	-	-	-	-	-	0.1
Northern plains minnow <i>Hybognathus placitus</i> Girard	3	-	-	-	-	-	T
Fathead minnow <i>Pimephales promelas</i> Rafinesque	2	-	3	-	2	-	0.1
Bluegill <i>Lepomis macrochirus</i> Rafinesque	1	-	-	-	-	-	T
Sand shiner <i>Notropis stramineus</i> (Cope)	36	-	54	-	206	-	4.1

counts method. Separate point estimates were obtained by using the number of each fish species collected in each primacord sample (Hansen and Muncy 1971; Hesse et al. 1979). The mean number of fish and their standard deviation was then calculated for all primacord samples on each stream. The student's t test was used to obtain confidence limits. Hansen and Muncy (1971) reported 50 grain PETN/0.3 m primacord would kill or stun fish 1.5 m on either side of the cord when detonated. In this study 25 grain PETN/0.3 m primacord was used and was equally effective in the shallow waters sampled. Louse Creek is less than 3 m wide throughout the 6.4 km section in which population estimates were derived. Therefore, when the cord was detonated it was assumed that all fish in the 20 m section of stream were killed or stunned and retrieved in the net. Steele Creek and the North Branch of Verdigre Creek have mean widths that exceed 3 m in the sections from which population estimates were calculated. The estimates of fish abundance were obtained on Steele Creek and the North Branch of Verdigre Creek by calculating the total area in the sampled section on each stream, and then multiplying the mean number of fish per blast area by the number of 60 m² areas in the sampled sections. (20 m length of cord $\times$ 3 m effective width = 60 m² area sampled.) These population estimates with their 95% confidence intervals are listed in Table 5. The confidence intervals were large for most of the estimates. This was caused by the large sampling variation (see Table 2, Appendix) Statistical texts by Christensen (1977) and Haber and Runyun (1977) were used for reference.

Trout

During the course of this study only seven brown trout were collected with primacord (Table 4); four in Steele Creek in August 1980, one in Louse Creek in December 1980, and two juveniles in Steele Creek in August 1981. Since only four trout were collected during the first two sampling periods (June and August 1980), I decided that the primacord method was sampling too small an area to effectively determine the survival, density and distribution of trout in the study streams. A second sampling technique, electrofishing, was used to evaluate trout populations in areas of each stream that appeared to have the highest quality trout habitat. The areas electrofished (Table 6) were the release sites for trout in 1979 (12, 18 and 24 months prior to sampling) and in 1980 (1, 6 and 12 months prior to sampling). From these samples, trout survival and the contributions trout made to the ichthyofauna of the streams were determined (Table 7).

Trout Density

An estimate of trout density (fish/100 m) was calculated by dividing the number of trout sampled during the sampling period in each stream by the length of area electrofished (Table 8). It was assumed that the number of trout sampled in one pass through a section of each study stream closely approximated the true trout abundance in that section. The streams are narrow and shallow which made the efficiency of the electrofishing equipment very high because its electrical field spanned the entire stream width.

The density of trout found in the three project streams was low when compared to the density of trout found in other Nebraska streams and streams in other states. Schleuter (pers. comm. Nebr. Game and Parks Comm.) while working on Long Pine Creek in north central Nebraska

Table 5. Population estimates for longnose dace, creek chub, and white sucker in Steele, Louse and the North Branch of Verdigre Creek. Estimates are for the upper reach of each stream with 95% confidence intervals in parenthesis.

	Steele Creek 6.7 km	Louse Creek 6.4 km	N. Branch Verdigre Creek 21.7 km
Longnose dace	10,735 (4,028-17,442)	21,424 (10,608-32,240)	105,408 (40,971-169,846)
Creek chub	13,639 (5,950-21,328)	11,117 (5,174-17,059)	93,850 (49,298-138,402)
White sucker	2,410 (1,315-3,509)	134 (13-256)	9,493 (1,199-17,987)

Table 6. Areas and length of stream sampled with electrofishing equipment in Steele, Louse and the North Branch of Verdigre creek, 1980-81. All sites are located in Holt County, Nebraska.

	Steele	Louse	N. Branch
October 1980	SW1/4, 11, NW1/4, 14, NE1/4, 15 R 9W, T 31N 1.7 km in	S1/2, 36, R 10W, T 32N and W1/2, 1, R 10W, T 31N 2.4 km in	S1/2, 1, R 9W, T 30N 2.6 km in
April 1981	NW1/4, 14, SW1/4, 11 R 9W, T 31N 0.7 km in	W1/2, 1, R 10W, T 31N .3 km in	SE1/4, 15, R 9W, T 30N .3 km in
October 1981	W1/2, 11, NW1/4, 14, NE1/4, 15 R 9W, T 31N 3.7 km in	W1/2, 1, R 10W, T 32N 2.0 km in	S1/2, 1, R 9W, T 30N 2.6 km in

Table 7. Total number of brown trout (*Salmo trutta*) and rainbow trout (*Salmo gairdneri*) sampled by electrofishing in Steele, Louse, and the North Branch of Verdigre Creeks, 1980-1981.

	Steele		Louse		N. Branch	
	Brown Trout	Rainbow Trout	Brown Trout	Rainbow Trout	Brown Trout	Rainbow Trout
October 1980	49	2	3	-	8	-
April 1981	22	-	7	-	2	-
October 1981	49	-	-	-	-	-
Totals	120	2	10	0	10	0

Table 8. Mean number of trout sampled per 100 meters during each sampling period in Steele, Louse and the North Branch of Verdigre Creeks, 1980-1981.

	Steele	Louse	N. Branch
October 1980	3.0	0.125	0.308
April 1981	3.143	2.333	0.667
October 1981	1.324	*	*

* No trout sampled in these streams during this period.

Table 9. Trout standing crop estimates (kg/ha) for Steele, Louse and the North Branch of Verdigre Creeks during October 1980.

Stream	Estimated Standing Crop
Steele Creek	7.125 kg/ha
Louse Creek	0.50 kg/ha
N. Branch Verdigre Creek	0.57 kg/ha

found trout (brown and/or rainbow) densities of 13.8 fish/100 m, 224.7 fish/100 m, and 62.4 fish/100 m for the upper, middle and lower sections, respectively. Avery and Hunt (1981) found that brown trout mean densities in four Wisconsin streams were 155.4 fish/100 m, 144.2 fish/100 m, 123.7 fish/100 m and 78.9 fish/100 m for Emmons, Radley, South Branch of Wedde Creeks, and the Mecon River, respectively. Yundt (1980) listed the density of brown trout in the Little Laramie River, Wyoming, as 135.8 fish/100 m in 1979 and 251.1 fish/100 m in 1980.

Trout standing crop estimates were calculated for each of the intensively sampled areas of the study streams where trout habitat appeared to be the best (Table 9). These estimates were derived by first determining the mean trout weight during October 1981 in Steele Creek and then multiplying the mean weight by the number of trout sampled in each of the three streams during October 1980. Only trout from Steele Creek were used in computing mean weights in October, 1981 since no trout were collected in Louse or the North Branch of Verdigre Creek during that time period.

Trout standing crops of the three study streams were extremely low compared to other streams. Schleuter (pers. comm. Nebr. Game and Parks

Comm.) found trout standing crop estimates on Long Pine Creek of 19.8 kg/ha, 257.70 kg/ha, and 45.45 kg/ha for the upper, middle and lower sections respectively. Ellis and Gowing (1957) reported standing crops of 134.4 kg/ha and 142.3 kg/ha for two sections of Houghton Creek, Michigan. Avery and Hunt (1981) reported standing crops of 112.0 kg/ha, 127.7 kg/ha, 125.4 kg/ha and 66.1 kg/ha for Emmons, Radley, South Branch Wedde Creeks and The Mecon River, respectively in Wisconsin. Yundt (1980) found standing crops of 120 kg/ha in 1979 and 812 kg/ha in 1980 in the Little Laramie River, Wyoming.

Trout Movements and/or Mortality

The degree of movement and/or mortality of trout from the sampled sections in the streams was high in Louse Creek and the North Branch, and moderate in Steele Creek. When the number of brown trout fingerlings stocked (Appendix, Table 1) is compared to the number remaining after one month (Table 7) only a small percentage remains at the release point. Graphic representation of the degree of movement and or mortality is found in Figures 2, 3, and 4. Length-frequency histograms of the trout sampled in each stream for three electrofishing samples show the reduction in numbers over time. The histograms also reveal the length of trout sampled and growth of the major cohort of trout over time.

The probable reasons for trout emigration and mortality from the study streams can be attributed to a paucity of cover and high water temperatures during summer months.

The percentage of cover, as described by Binns and Eisermen (1979), in the study streams was generally less than 25%, with only one area on Steele Creek having 32% cover. Hunt (1977) reported that it is common for brook trout to migrate downstream to larger water during their second and third years of life in an attempt to find more desirable habitat in relation to their size. Binns and Eisermen (1979) in developing a standing crop prediction model found trout streams with greater than 55% cover were optimum when considering the cover parameter.

High water temperatures probably contributed to the loss of trout from the streams although trout were initially released into the streams in the fall when stream temperatures were suitable for trout. Nevertheless in both Louse Creek and the North Branch a high percentage of the trout were gone after one month (Figures 3 and 4). Even fewer trout were found in the North Branch six months after stocking and, after being subjected to high water temperatures in the summer months, trout were absent 12 months after stocking (Figure 4). This was not the case in Louse Creek, as more trout were sampled six months after stocking than after one month. However, trout were absent from the stream 12 months after stocking just as they were in the North Branch of Verdigre Creek (Figure 3).

Steele Creek has the ability to sustain trout throughout the year as evidenced by the number of trout sampled that were stocked in previous years (Table 10, Figure 2). High water temperatures apparently don't negatively impact the trout as greatly in Steele Creek as in the other two streams.

Trout Natural Reproduction

No evidence of trout spawning or reproduction success was observed in Louse Creek or the North Branch of Verdigre Creek. However, age 0 brown

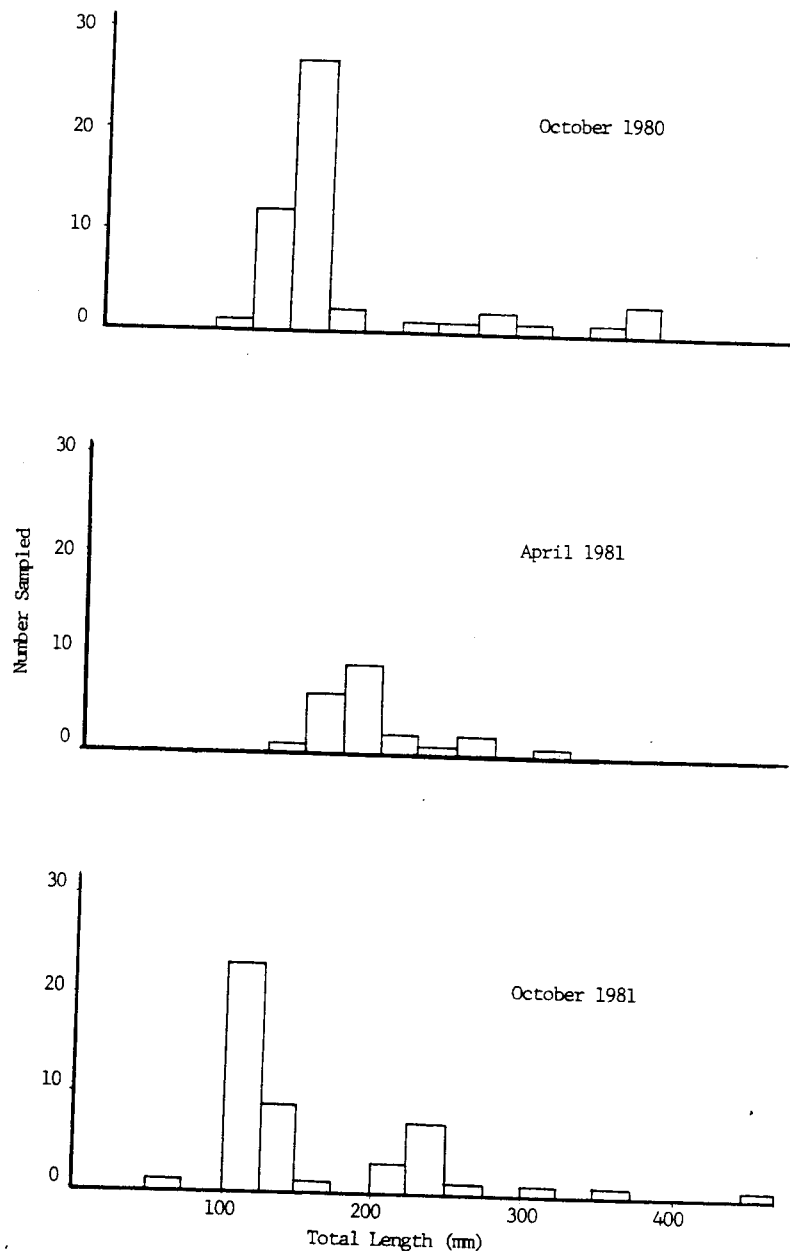


Figure 2. Length frequency of trout sampled in Steele Creek, one, six and twelve months after the October 1980 stocking.

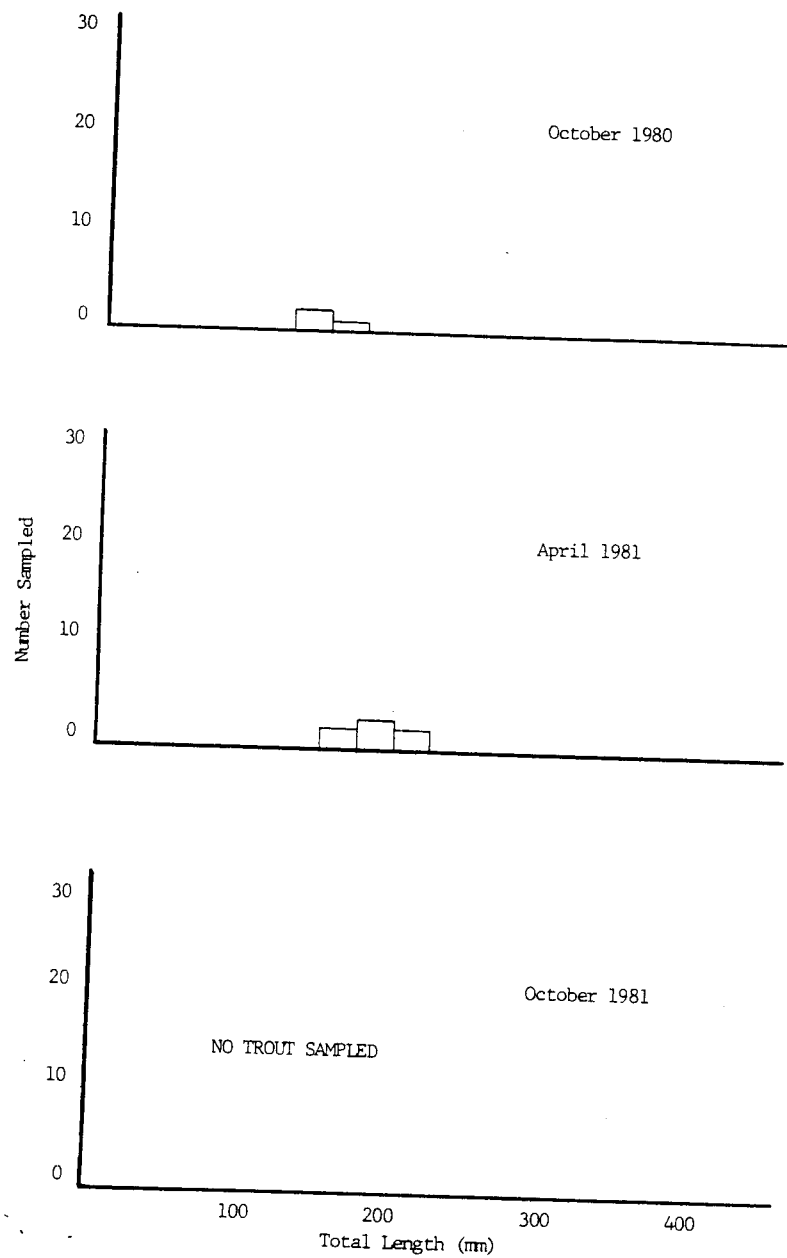


Figure 3. Length frequency of trout sampled in Louse Creek, one, six and twelve months after the October 1980 stocking.

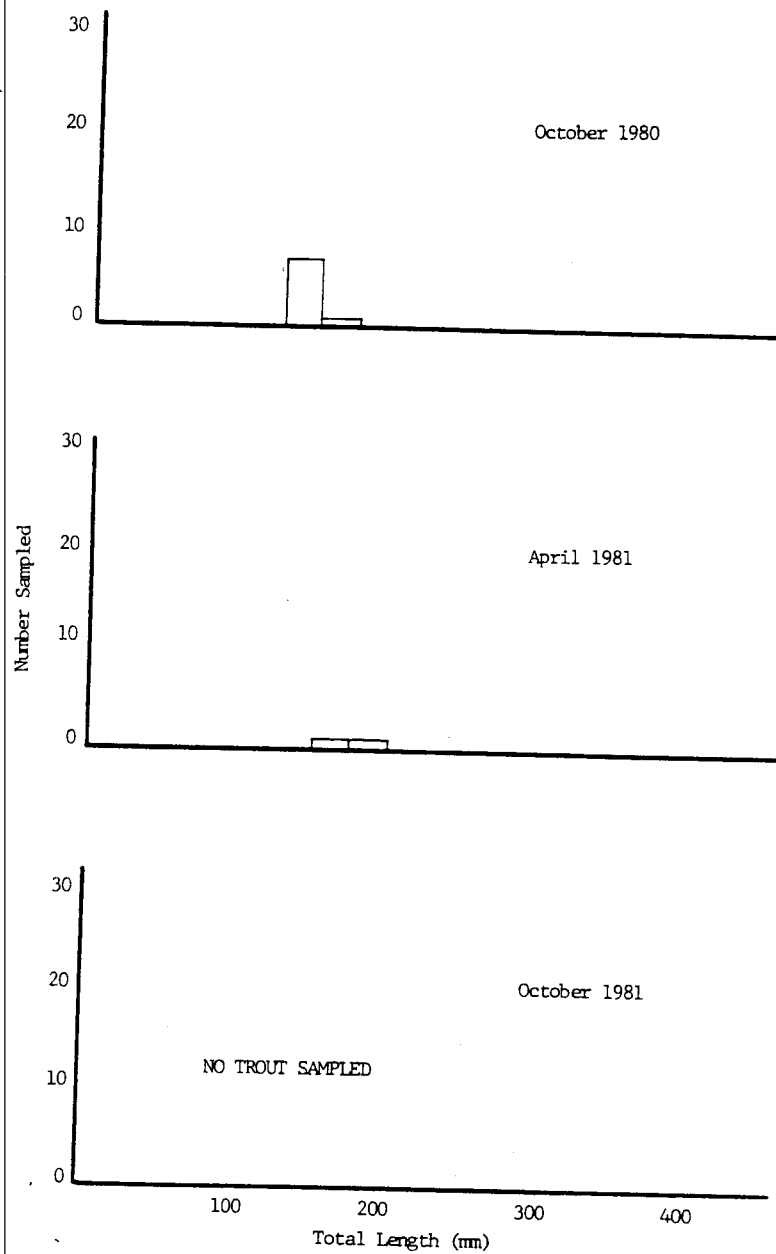


Figure 4. Length frequency of trout sampled in North Branch of Verdigre Creek, one, six and twelve months after the October 1980 stocking.

Table 10. Trout recaptured in Steele Creek samples.

Recovery Period	Date Stocked			
	Total Sample	September 1980	October 1979	Prior to 1979
	No. Trout	No. Trout	No. Trout	No. Trout
October 1980	51	42	4	5
April 1981	22	17	2	3
October 1981	49*	5**	***	***

* 34 fish were age 0

** 6 additional trout were sampled in the size range of those stocked in 1980, but had no detectable fin clip.

*** 4 additional trout were sampled that were large enough to have been stocked in 1979 or previous years. However, no fin clip could be found.

trout were sampled in Steele Creek, initially with primacord during the August 1981 sample when two were collected, and also in the October 1981 electrofishing sample when 34 were taken (Table 10). Successful trout natural reproduction apparently occurs sporadically in Steele Creek as no unmarked age 0 fish were found in the October 1980 sample. All age 0 trout taken during that sample had a pelvic fin removed, indicating they were stocked during September 1980 (Table 10). Therefore, if a trout population is to be maintained in Steele Creek, it will be dependent upon stocked fish.

HABITAT QUALITY INDEX (H.Q.I.) CALCULATIONS

A Habitat Quality Index (Binns and Eiserman 1979) was calculated for each study stream to test the validity of the index in predicting habitat suitability and standing crop estimates in eastern Nebraska streams. The nine attributes (listed in Table 11) needed to compute the Model II prediction were measured during September 1981. With these data the corresponding values for each attribute were rated from 0 (worst) to 4 (best) and these values were used to calculate the Model II H.Q.I. The attribute values for two sections of each of the three streams, with the Model II standing crop prediction are listed in Table 11.

The predicted and empirically determined trout standing crops agree quite well. The empirical standing crop estimates and the predicted standing crop estimates were 7.125 kg/ha (2.0 kg/ha), 0.50 kg/ha (1.45 kg/ha) and 0.57 kg/ha (1.45 kg/ha) for Steele Creek, Louse Creek and the North Branch, respectively.

Using Steele Creek Section No. 1 as the model for H.Q.I. standing crop estimates I substituted higher ratings for some attributes in an attempt to determine what factor(s) were primarily responsible for limiting trout standing crops. When the maximum summer water temperature rating was increased to '1' the standing crop prediction was increased to 6.1 kg/ha. This prediction was similar to the empirically determined standing crop of 7.125 kg/ha. The maximum summer water temperature measured on Steele Creek was borderline, missing a rating of '1' by only 0.7 C. Since trout do survive the water temperatures attained, a rating of '1' was probably more accurate.

Table 11. Habitat quality index attributes and ratings from two sections of Steele, Louse, and the North Branch of Verdigre Creek, September 1981. No. 1 = upper station, No. 2 = lower station.

Attribute	Steele		Rating Louse		N. Branch	
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
Late summer stream flow	4	4	4	4	4	4
Annual stream flow variation	4	4	3	3	4	3
Max. summer stream temperature	0	0	0	0	0	0
Nitrate nitrogen	0	0	0	0	0	0
Cover	2	1	1	1	1	0
Eroding stream banks	1	3	4	2	3	2
Substrate	3	3	1	2	1	1
Water velocity	3	3	3	3	2	2
Stream width	3	2	2	2	3	3
Model II standing crop prediction (kg/ha)	2.0	2.0	1.6	1.3	2.2	0.7
Average	2.0		1.45		1.45	

When the maximum summer water temperature rating was considered as '1' and the nitrate nitrogen ($\text{NO}_3\text{-N}$) rating was increased to a '2', the H.Q.I. predicted a standing crop of 44.2 kg/ha. From this prediction, it appeared that the amount of nitrate nitrogen present in the stream could have a negative impact on the trout standing crop in Steele Creek. The H.Q.I. guidelines rate nitrate-nitrogen a '0' when its concentration is <0.01 mg/l or >2.0 mg/l. The nitrate-nitrogen measurement on Steele Creek was 3.1 mg/l.

The amount of cover present in the stream was also thought to be a limiting factor. Leaving the maximum summer water temperature rating at '1' and increasing the cover index to '4', the optimum condition, the Model II standing crop prediction was 6.9 kg/ha. This value was only a slight increase from the 6.1 kg/ha predicted when the cover rating was a '2' (the original rating value).

The rating substitutions suggest that the principal factors that limit trout standing crops in the study area streams are nitrate-nitrogen and maximum summer water temperatures. Angling apparently has no effect on the standing crop of trout in the streams as landowners questioned about the amount of fishing pressure, indicated they had not observed fishermen using the streams. The Habitat Quality Index Model II seems to be well suited for use in eastern Nebraska streams.

SUMMARY AND CONCLUSIONS

For several decades tributaries to the lower Niobrara River were managed for coldwater fisheries. During the 1960's and 70's, changes in agricultural practices in the watersheds of the streams decreased or eliminated the amount of coldwater habitat needed by trout to survive.

The paucity of reliable stream flow data (volume/unit time) prior to extensive irrigation development in the watersheds of the streams precluded direct comparisons of flow rates before and after irrigation development. However, during the study, direct removal of water from the streams by surface irrigation pumps did result in flow rates which were lower below than above the points of water removal. As stream volume decreases, less solar energy is needed to increase water temperatures. These streams, prior to irrigation development, had summer water temperatures that approached the maximum tolerated by coldwater species, so even small increases in water temperature reduces or eliminates the habitat suitable for trout.

Stream temperatures were continuously recorded for 17, 15 and 8 months on Steele, Louse and the North Branch, respectively, which included two summer seasons for Steele and Louse Creeks, but only one summer season for the North Branch of Verdigre Creek.

Water temperatures were too high in summer to support or maintain trout in Louse and the North Branch of Verdigre Creeks. Steele Creek had water temperatures that were marginal, but trout did survive summer water temperatures, probably seeking undercut banks or other cover to avoid maximum water temperatures. These high water temperatures generally occur during the midafternoon on days when air temperatures reach 35 C and the previous night's low air temperature was > 21 C.

Although 17 species of fish were sampled with explosives and electrofishing gear during the study, only three species other than trout were sampled frequently enough to obtain population estimates. These three species were the longnose dace, creek chub and white sucker.

Trout were collected in the study streams primarily with electrofishing gear. Seven brown trout were collected with explosives compared to 140 with electrofishing gear. Only two rainbow trout were collected, both in Steele Creek using electrofishing gear.

Trout sampled in the streams during three time periods allowed the author to estimate trout densities in the most suitable trout habitat in the stream. Most trout either emigrate or die shortly after being released, as one month post-release densities were very low. Twelve months after being released, which includes a summer season when maximum water temperatures are experienced, trout were absent in Louse and the North Branch of Verdigre Creeks. The absence of trout in Louse and the North Branch of Verdigre Creeks cannot be attributed to fishing mortality as landowners observed no fishermen on these streams. Some trout survive in Steele Creek throughout the year, but densities and standing crop estimates were extremely low when compared to other coldwater streams in Nebraska and other states. Fishing pressure on Steele Creek was similar to that on the other two streams, thus, low trout densities were not the result of fishing mortality.

Successful natural reproduction was documented only in Steele Creek

during 1981. Two young-of-the-year (age 0) brown trout were collected with primacord during August 1981 and 34 of the 49 (69.4%) trout collected during October 1981 were age 0. No evidence of natural reproduction was found in Steele Creek during 1980, as all age 0 fish collected during October 1980 had a pelvic fin clipped indicating they were stocked one month prior to sampling. If a limited trout fishery is to exist in Steele Creek at least an annual stocking of fish will be necessary.

The Habitat Quality Index analysis provided insight into factors which are probably responsible for the extremely low trout populations in the study streams. Predicted trout standing crop estimates derived from the H.Q.I. Model II agreed favorably with the empirically determined standing crop estimates, proving the reliability of the index on these streams. When substitute ratings were used in computing standing crop estimates nitrate nitrogen appeared to be the most important limiting factor. The maximum summer water temperatures are less important in limiting trout standing crops in Steele Creek. However, maximum summer water temperatures were probably the most important limiting factor in Louse and North Branch of Verdigre Creeks since no trout survived for 12 months.

Some of the attributes used to calculate the Habitat Quality Index such as cover, eroding stream banks, substrate, water velocity, stream width and to a lesser extent, maximum summer water temperatures, can be improved for trout by constructing and maintaining instream structures and planting or removing certain types of vegetation (White and Brynildson 1967). The nitrate-nitrogen levels would be difficult to alter, since the probable source of this nutrient is groundwater contamination by center-pivot irrigators who apply large amounts of fertilizer on sandy soils subject to leaching.

The practicality and economic feasibility of attempting to restore the study streams to a point where they could be considered good coldwater habitat should be addressed in planning future management. If restoration to coldwater habitat is impractical and not economically feasible on these streams, then alternative management plans should be pursued. The introduction of a coolwater predator, such as smallmouth bass (*Micropterus dolomieu* Lacepede) should be considered.

Under present Nebraska statutes there are no provisions to regulate the nutritive quality and quantity of groundwater and surface water which enter streams. Had there been adequate protection, three unique coldwater ecosystems capable of supporting trout in the lower Niobrara River Basin would be available for future generations of anglers.

LITERATURE CITED

- American Fisheries Society, 1980. A list of Common and Scientific Names of Fishes from the United States and Canada, Fourth edition. Special Publ. No. 12. 174 p.
- Avery, E.L., and R.L. Hunt, 1981. Population Dynamics of Wild Brown Trout and Associated Sport Fisheries in Four Central Wisconsin Streams. Wis. Dep. of Nat. Resour., Tech. Bull. No. 121. 26 p.
- Binns, N.A. and F.M. Eiserman. 1979. Quantification of Fluvial Trout Habitat in Wyoming., Trans. Am. Fish. Soc. 108:215-228.
- Brynildson, O.M., V.A. Hacker, and T.A. Klick. 1967. Brown Trout, Life History, Ecology and Management. Wisconsin Conservation Dept. Pub. 234-67. 14 p.
- Christensen, H.B. 1977. Statistics Step by Step, Houghton Mifflin Co. Boston, Mass. USA. 643 p.
- Ellis, R.J. and H. Gowing, 1957. Relationship Between Food Supply and Condition of Wild Brown Trout, *Salmo trutta* Linnaeus, in a Michigan Stream., Limnol. and Oceanog. 2(4):299-308.
- Fassett, N.C. 1960. A Manual of Aquatic Plants. U. of Wisconsin Press. Madison. 405 p.
- Grimm, W.C. 1966. Recognizing Native Shrubs, The Stackpole Co. Harrisburg, Penn. USA. 319 p.
- Haber, A. and R.P. Runyon. 1977. General Statistics. Addison-Wesley Publishing Co. Reading Mass. USA. 343 p.
- Hansen, D. and R. Muncy. 1971. Effects of Stream Channelization on Fishes and Bottom Fauna in the Little Sioux River, Iowa. Iowa St. Water Resour. Res. Inst. Completion Report No. A-035-IA. 119 p.
- Hesse, L., G. Zuerlein, R. Vancil, L. Koziol, B. Newcomb and L. Retelsdorf. 1979. Niobrara - Missouri River Fishery Investigations. Nebr. Game and Parks Comm. Tech. Series No. 5, 39 p.
- Hitchcock, A.S. 1935. Manual of the Grasses of the United States. 2nd Edition revised by Agnes Chase. Dover Publ., Inc. N.Y. 1051 p.
- Hunt, R.L. 1977. Instream Enhancement of Trout Habitat. Pages 19-27. In K. Hashagen, (ed.) Proceeding of a National Symposium of Wild Trout Management. California Trout, Inc. San Francisco.
- Jones, D.J. 1963. A history of Nebraska's Fisheries Resources. D-J Fed. Aid in Sport Fish. Restoration Proj. F-4-R. Nebr. Game, Forest. and Parks Comm., Lincoln, Nebr. 76 p.
- Kaya, C.M. 1978. Thermal Resistance of Rainbow Trout from a Permanently Heated Stream, and of Two Hatchery Strains. The Prog. Fish-Cult. 40(4):138-142.

- Lee, R.M. and J.N. Rinne. 1980. Critical Thermal Maxima of Five Trout Species in the Southwestern United States. *Trans. Am. Fish. Soc.* 109:632-635.
- Moran, W.J. 1932. Soil Survey of Holt County, Nebraska U.S. Dept. of Agriculture. Series 1932. No. 27, 38 p.
- National Oceanic and Atmospheric Administration. 1980. Environmental Data and Information Service, Climatological Data. Vol. 85:6-12.
- National Oceanic and Atmospheric Administration. 1981. Environmental Data and Information Service, Climatological Data. Vol. 86:1-10
- Nebraska Department of Water Resources. 1979. List of Registered Irrigation Wells in Holt and Knox Counties. (unpublished) Lincoln, NE. 84 p.
- Nebraska Game and Parks Commission. 1967. Unpublished data on file at the Dist. III Headquarters, Norfolk, Nebr. 10 p.
- Pool, R.J., 1978. Handbook of Nebraska Trees. Cons. and Survey Div. U. of Nebr.-Lincoln., Nebr. Cons. Bull. No. 32, 179 p.
- Vancil, R., G. Zuerlein and L. Hesse. 1979. Nebraska Rainbow Trout. Nebr. Technical Series No. 7. Chapter 1. 16 p.
- VanVelson, R. 1977. Unpublished report. Nebraska Game and Parks Commission. Lincoln, NE. 3 p.
- White, R.J. and D.M. Brynildson. 1967. Guidelines for Management of Trout Stream Habitat in Wisconsin. Wisc. Dept. of Nat. Res. Tech. Bull. No. 39. 65 p.
- Yundt, S. 1980. Comparison of Population Age Structure and Mortality of Brown Trout Under Different Fishing Regulations on Two Wyoming Streams. pp. 49-55 in Proceedings of 16th Annual Colorado-Wyoming Amer. Fish Soc. Chapter Meeting. Feb. 25-26, 1980. 67 p.

APPENDIX 1

Table 1. Trout stocking history of Steele, Louse and North Branch Verdigre Creeks, 1928-1983. Fng = fingerling; Adt = adult > 200 mm TL.

Steele Creek			
Date	Species	Size	Number
1928	Rainbow	Fng	800
1930	Rainbow	Fng	7500
1930	Rainbow	Fng	2000
1931	Brown	Fng	9000
6/15/36	Rainbow	Fng	2000
10/12/36	Rainbow	Adt	600
6/25/37	Rainbow	Fng	2000
6/25/37	Rainbow	Adt	500
3/31/38	Rainbow	Adt	500
1939	Rainbow	Adt	1000
1939	Rainbow	Adt	1000
3/21/40	Rainbow	Adt	1200
5/19/41	Rainbow	Adt	250
4/2/42	Rainbow	Adt	600
3/30/43	Rainbow	Adt	400
5/10/43	Rainbow	Fng	2000
4/24/45	Rainbow	Fng	2250
4/24/45	Brown	Fry	4000
3/23/46	Rainbow	Adt	300
3/23/46	Brown	Fry	11648
3/29/48	Brown	Adt	300
4/24/48	Brown	Adt	300
4/24/48	Brown	Fng	2000
4/24/48	Brook	Fng	1000
4/24/48	Rainbow	Fng	2000
5/9/49	Rainbow	Adt	800
5/9/49	Rainbow	Fng	2000
5/9/49	Brook	Fng	1000
4/8/50	Rainbow	Adt	1000
4/8/50	Brown	Adt	200
2/16/51	Rainbow	Adt	1000
5/24/51	Rainbow	Fng	2000
5/24/51	Brown	Fng	2000
10/8/51	Brown	Fng	1000
3/10/52	Rainbow	Adt	800
4/9/52	Brown	Adt	200
4/9/52	Brown	Fry	25000
2/17/53	Brown	Fry	19920
6/22/53	Brown	Fng	1000
6/22/53	Brown	Fng	400
6/22/53	Rainbow	Fng	500
6/11/53	Rainbow	Fng	2000
6/11/53	Brown	Fng	1000
3/30/53	Brown	Adt	600

<i>Steele Creek</i>			
<i>Date</i>	<i>Species</i>	<i>Size</i>	<i>Number</i>
3/30/53	Rainbow	Adt	300
3/27/53	Rainbow	Fng	1000
3/23/53	Brown	Fng	200
4/12/54	Rainbow	Adt	1000
4/12/54	Brown	Adt	200
6/4/54	Rainbow	Fng	1000
6/4/54	Brown	Fng	1000
4/14/54	Rainbow	Fng	1500
3/15/54	Brown	Fng	200
4/26/55	Brown	Adt	904
4/26/55	Rainbow	Adt	1034
4/12/55	Rainbow	Adt	600
4/12/55	Brown	Adt	200
9/16/55	Brook	Fng	500
1/13/56	Brown	Fry	2128
3/14/56	Rainbow	Adt	700
3/27/56	Brown	Adt	500
6/2/60	Rainbow	Fng	4000
9/15/64	Rainbow	Adt	400
10/19/66	Rainbow	Adt	1000
8/14/67	Brown	Fng	2000
9/11/68	Rainbow	Fng	1500
9/11/68	Brown	Fng	3500
5/26/69	Brown	Fng	3500
6/11/70	Brown	Fng	3000
5/19/72	Brown	Adt	1900
4/10/74	Brown	Adt	3448
5/8/75	Rainbow	Adt	1200
9/17/76	Rainbow	Fng	375
9/17/76	Brown	Fng	500
10/20/77	Brown	Fng	512
10/26/78	Brown	Fng	500
10/4/78	Rainbow	Fng	2500
10/18/79	Brown	Fng	500
9/20/80	Brown	Fng	550
10/15/81	Brown	Fng	800
9/23/82	Brown	Fng	500
9/28/83	Brown	Fng	500

<i>Louse Creek</i>			
<i>Date</i>	<i>Species</i>	<i>Size</i>	<i>Number</i>
5/18/54	Brown	Fng	500
7/26/74	Rainbow	Adt	50
5/28/75	Rainbow	Fng	500
10/20/77	Brown	Fng	202
10/26/78	Brown	Fng	200
10/18/79	Brown	Fng	200
9/20/80	Brown	Fng	275

<i>North Branch Verdigre Creek</i>			
<i>Date</i>	<i>Species</i>	<i>Size</i>	<i>Number</i>
4/19/56	Rainbow	Fng	7560
10/19/66	Rainbow	Adt	1000
8/14/67	Brown	Fng	1000
5/26/69	Brown	Fng	450
5/18/72	Brown	Adt	600
6/4/73	Brown	Adt	1000
4/15/74	Brown	Adt	2000
5/28/75	Rainbow	Adt	900
9/17/76	Rainbow	Fng	375
9/17/76	Brown	Fng	500
10/20/77	Brown	Fng	297
10/4/78	Rainbow	Fng	1000
10/26/78	Brook	Fng	300
6/7/79	Rainbow	Fng	1000
10/18/79	Brown	Fng	300
9/20/80	Brown	Fng	200

APPENDIX 2

Table 2. Number of longnose dace (LND), creek chub (CC), and white sucker (WS) sampled per primacord blast on Steele, Louse and the North Branch of Verdigre creeks, 1980-81, with data used in calculating population estimates.

	<i>Steele</i>			<i>Louse</i>			<i>North Branch of Verdigre</i>		
	<i>LND</i>	<i>CC</i>	<i>WS</i>	<i>LND</i>	<i>CC</i>	<i>WS</i>	<i>LND</i>	<i>CC</i>	<i>WS</i>
June	75	51	1	10	2	1	307	151	2
1980	43	21	4	14	4	0	93	70	0
Aug.	129	85	2	146	45	1	95	112	7
1980	84	81	4	256	383	3	90	146	24
	60	27	0	141	136	0	43	56	2
	57	50	0	79	76	0	26	147	31
Dec.	42	34	3	21	33	1	5	17	0
1980	9	4	0	8	7	1	8	10	2
	6	5	0	23	13	0	12	6	0
Feb.	2	3	1	35	42	0	104	39	0
1981	4	22	1	1	5	0	143	58	0
	0	11	1	30	3	0	19	10	2
	2	4	0	27	7	0	19	2	0
June	2	23	0	32	8	0	35	56	22
1981	20	23	0	31	4	0	45	40	0
	17	39	0	52	8	0	14	23	5
	7	35	0	-	-	-	18	15	1
Aug.	6	22	2	187	97	1	Not Sampled In August 1981		
1981	40	129	6	68	43	0			
	17	176	5	-	-	-			
TOTALS	631	902	34	1272	960	8	1076	958	98
$\bar{X}$	24.8	31.5	5.6	67.0	34.7	0.4	63.3	56.4	5.8
SD	34.0	39.0	5.1	70.2	38.6	0.8	75.2	52.0	9.8

.0 .10 .20 .30 .40 .50 .60 .70 .75

Meas. No. _____
Comp. by _____ 80
Chk. by _____

CAGE READINGS

Angle coef.	Dist. from initial point	Width	Depth	Observ- ation depth	Revol- utions	Time in seconds	VELOCITY		Adjusted for angle or	Area	Discharge
							At point	Mean in vertical			
											.99
											.98
											.97
											.96
											.94
											.92
											.90
											.85
											.80
0	.10	.20	.30	.40	.50	.60	.70	.75			

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