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A FIELD TEST OF HABITAT EVALUATION PROCEDURES FOR CREEK CHUB (*Semotilus atromaculatus*) AND CHANNEL CATFISH (*Ictalurus punctatus*)

by

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A FIELD TEST OF HABITAT EVALUATION PROCEDURES FOR CREEK CHUB (Semotilus atromaculatus) AND CHANNEL CATFISH (Ictalurus punctatus)

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University of Nebraska-Lincoln, 1987

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The U.S. Fish and Wildlife Service habitat evaluation procedure (HEP) models for creek chub and channel catfish were tested during the mid and late summer of 1985 and spring of 1986. The objective of this study was to field test the models as published. Habitat suitability index (HSI) values were obtained and correlated with population and biomass estimates taken from the same stream study reaches. Kendall's *tau* correlation coefficients between population and biomass versus observed HSI values were .541 for creek chub and .500 for channel catfish. At sites where population, biomass, and HSI values greater than zero were obtained, Kendall's *tau* correlation coefficients ranged from .935 to1.000 for creek chub and .714 to .857 for channel catfish.

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INTRODUCTION

BACKGROUND

Habitat evaluation procedures (HEP) were developed by the U.S. Fish and Wildlife Service (USFWS). Habitat evaluation procedures were developed as "non-monetary" procedures for the evaluation and quantification of fish and wildlife resources (USFWS 1980a). These procedures were intended to aid in environmental impact assessment and resource development project planning (USFWS 1980b). Once environmental impacts have been assessed, HEP can also serve as a basis for generating environmental mitigation recommendations and proposals.

A brief description of the legal basis for the development of HEP and the HSI (habitat suitability index) models includes two major pieces of legislation. The National Environmental Policy Act of 1969 states its purpose in part to be ".....to promote efforts which will prevent or eliminate damage to the environment and biosphere.....". The Clean Water Act states, "The objective of this Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters." Initial government efforts to implement these objectives tended to address individual facets (water chemistry parameters) of natural systems. Little attention was given to the interrelationships between organisms and their environment.

In these procedures, habitat is evaluated with respect to individual species through the use of mathematical models and an HSI value is obtained. The procedures consist of species specific habitat parameter measurement and evaluation using a habitat suitability curve for each parameter (Orth, et al. 1981). The models are composed of habitat variables shown in the literature to impact the species of interest. Habitat variables are categorized into life requisite groups. In most models, requisite groups or components are food, cover, water quality, reproduction, and, in the creek chub model, a miscellaneous category termed "other". An HSI is a unitless number between 0.0 and 1.0, where 0.0 indicates unsuitable habitat for the species of concern and 1.0 is optimal habitat. The USFWS states the proper use of HSI values to be one of comparison. If two water bodies have large differences in HSI's, then the one with the higher HSI should be able to support more fish than the water body with the lower HSI, given that the model assumptions have not been violated (McMahon and Terrell 1982). However, the USFWS also states that HSI's are not statements of proven cause and effect between habitat and standing crop.

STUDY OBJECTIVES

Two HEP models were field tested in this study, those for creek chub (Semotilus atromaculatus) and channel catfish (Ictalurus punctatus). The primary study purpose was to determine how well HSI values obtained for a stream segment correlated to population and biomass estimates obtained in the same stream segment. The question asked was: "Using the models as published, do HSI values obtained vary in a mannner similar to creek chub and channel catfish population and biomass estimates?". The null hypothesis was: correlations between creek chub and channel catfish HSI values and their respective population and biomass estimates will yield correlation coefficients ≤ 0.8. The alternative hypothesis was: correlations between creek chub and channel catfish HSI values and their respective population and biomass estimates will yield correlation coefficients ≥ 0.8.

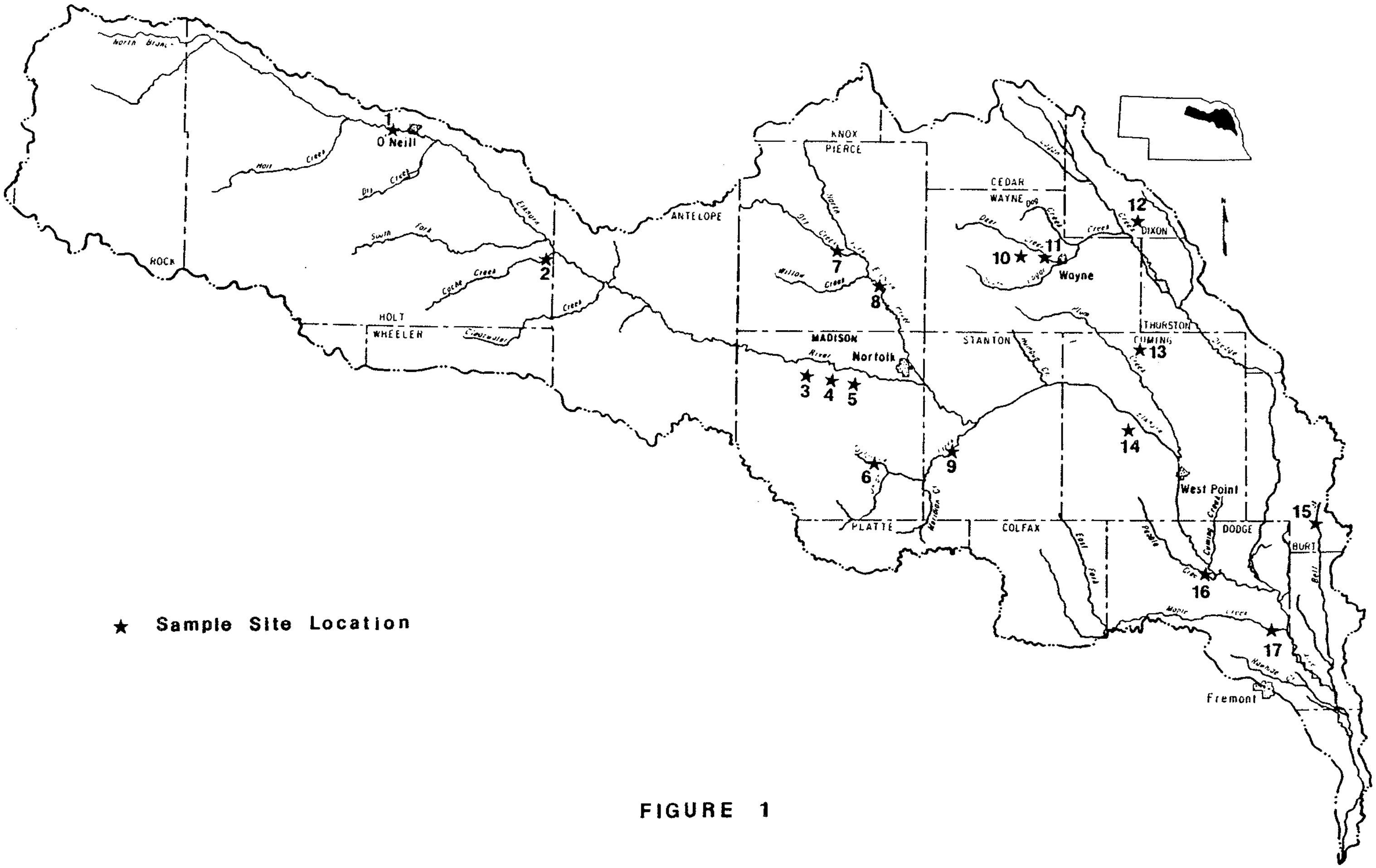
STUDY AREA DESCRIPTION

This study was conducted in the Elkhorn River basin of north central and northeast Nebraska (Figure 1). The basin has a surface area of 26,850 sq. km. (6,953 sq. mi.) (USDA 1971). Originating in the eastern Nebraska sandhills, the Elkhorn River flows east and south to its confluence with the Platte River about four miles west of Gretna, Nebraska. Total valley length of the Elkhorn River is approximately 536 km (335 mi.) (USDA 1971). The 93 streams in the basin total 2,014 km (1,259 mi.) of which 466 km or 23% have been lost to channelization (Nebraska Natural Resources Commission (NNRC) 1975).

The Elkhorn River basin is covered by Pleistocene deposits ranging from sand, sandy silt, and clay in the western portion to Peorian loess and glacial till (Kansan, Nebraskan) in the eastern portion (USDA 1971). Major soil associations found in the basin include Moody-Crofton, Thurman-Valentine, Thurman-Jansen, Valentine-Dunday, Loup-Valentine, Leshara-Platte, and Luton-Haynie (NNRC 1975).

Topography of the basin varies from rolling sand dunes and associated meadows in the west to dissected loess plains and rolling hills in the east (NNRC 1975). Topographic relief is approximately 497 m (1,630 ft.), ranging in altitude from 823 m (2,700 ft.) in western Rock County to 327 m (1,074 ft.) in western Sarpy County (Bentall, et al. 1971).

Elkhorn River basin land use is 97% agricultural with 58% as cropland, 36% as range, pasture, or native hay, and 3% as woodlands. The remaining 3% is comprised of urban areas, farmsteads, wildlife areas, and water (USDA 1971).



★ Sample Site Location
KNOX
PIERCE
CEDAR
WAYNE
DIXON
THURSTON
CUMING
MADISON
STANTON
ANTELOPE
HOLT
WHEELER
ROCK
PLATTE
COLFAX
DODGE
BURT
O'Neill
Norfolk
Wayne
West Point
Fremont
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Elkhorn
North Branch
Holt Creek
Dry Creek
South Fork
Cache Creek
Clearwater
Willow Creek
North Fork
River
Deer Creek
Dog Creek
Logan
Plum
Humbug Cr.
East Fork
Pebble
Cuming Creek
Maple Creek
Bell

FIGURE 1

Annual precipitation in the basin averages 53 cm (21 in.) in the west to 74 cm (29 in.) in the east. Mean annual temperature is approximately 10° C. Frost free days average 165 in the southeast portion of the basin to 155 days in the northwest (NNRC 1975).

The Elkhorn River basin is situated in the Humid Temperate domain, Praire division, and Tall-grass Praire province (Bailey 1976). The western basin is classified as the Wheatgrass-Bluestem-Needlegrass section and the eastern portion as the Bluestem Praire section. The western half of the basin is classified in the Western Great Plains Range and Irrigated region and Nebraska Sandhills area. The eastern half of the basin is classified as the Central Feed Grains and Livestock region and the Loess Uplands and Till Plains area (USDA, SCS 1981).

SAMPLE SITE DESCRIPTION

Seventeen sample sites were selected to test the HSI models. Legal descriptions (Township, Range, Section, 1/4, 1/4, County) for the sample sites are:

Site 1: Elkhorn River near Emmet, Nebraska. T. 29 N, R. 13 W, S. 22, SE, SE, Holt County. One half mile west and 0.5 miles south of Emmet and upstream of the county road bridge.

Site 2: Cache Creek near Ewing, Nebraska. T. 26 N, R. 9 W, S. 22, SE, NE, Holt County. Approximately 3 miles south of the U. S. Highway 275 and State spur L45B junction and upstream of the county road bridge.

Site 3: Buffalo Creek near Meadow Grove, Nebraska. T. 24 N, R. 4 W, S. 26, SW, SE, Madison County. One half mile south and 0.75 miles west of Meadow Grove and upstream of the county road bridge.

Site 4: Deer Creek near Meadow Grove, Nebraska. T.24 N, R. 3 W, S. 30, SE, SW, Madison County. One half mile south and 1.7 miles east of Meadow Grove and downstream of the county road bridge.

Site 5: Battle Creek near Battle Creek, Nebraska. T. 24 N, R. 3 W, S. 36, NE, NE, Madison County. Eight tenths of a mile north of Battle Creek on State Highway 121 and upstream of the bridge.

Site 6: Taylor Creek near Madison, Nebraska. T. 22 N, R. 1 W, S. 30, NW, SW, Madison County. 2.2 miles west of U.S. Highway 81 and State Highway 32 junction on Highway 32, 1.6 miles north of Highway 32 on the county road, and downstream of the bridge.

Site 7: Dry Creek near Foster, Nebraska. T. 27 N, R. 3 W, S. 28, SE, SW, Pierce County. North edge of Foster and upstream of the county road bridge.

Site 8: North Fork Elkhorn River near Pierce, Nebraska. T. 26 N, R. 1 W, S. 31, SW, SE, Pierce County. 1.2 miles southeast of Pierce on State Highway 13, 1.4 miles east on the county road, and upstream of the bridge.

Site 9: Union Creek near Stanton, Nebraska. T. 22 N, R. 1 E, S. 13, SE, SE, Stanton County. 2.0 miles south of Stanton on State Highway 57, approximately 6.0 miles southwest on the county road, and upstream of the bridge.

Site 10: Unnamed tributary to Deer Creek near Wayne, Nebraska. T. 26 N, R. 3 E, S. 18, NE, NE, Wayne County. 5.0 miles west of the State Highways 15 and 35 junction on Highway 35 and upstream of the bridge.

Site 11: Deer Creek near Wayne, Nebraska. T. 26 N, R. 3 E, S. 10, SW, SE, Wayne County. 2.7 miles west of the State Highways 15 and 35 junction on Highway 35 and upstream of the bridge.

Site 12: Middle Creek near Emerson, Nebraska. T. 27 N, R. 6 E, S. 20, SE, SW, Dixon County. 1.3 miles west of the State Highways 35 and 9 junction on Highway 35 and upstream of the bridge.

Site 13: Dry Creek near Wisner, Nebraska. T. 24 N, R. 5 E, S. 15, SW, SE, Cuming County. 2.8 miles east of the junction of U.S. Highway 275 and State Highway 51, 3.0 miles north and 2.3 miles east on the county road, and upstream of the bridge.

Site 14: Rock Creek near Beemer, Nebraska. T. 22 N, R. 4 E, S. 12, NE, NE, Cuming County. 5.0 miles south of Beemer, 1.0 mile east, 1.0 mile south on the county road, and upstream of the bridge.

Site 15: Bell Creek near Craig, Nebraska. T. 21 N, R. 9 E, S. 26, SW, SW, Burt County. 2.0 miles south of Craig, 0.9 mile west on the county road, and upstream of the bridge.

Site 16: Pebble Creek near Scribner, Nebraska. T. 20 N, R. 6 E, S. 34, NE, SE, Dodge County. 2.0 miles west of Scribner, 0.4 mile south on the county road, and upstream of the bridge.

Site 17: Maple Creek near Hooper, Nebraska. T. 18 N, R. 8 E, S. 5, NE, SE, Dodge County. 3.4 miles south of Hooper on the county road and upstream of the bridge.

CREEK CHUB MODEL SUMMARY

The Creek Chub Habitat Suitability Index Model (McMahon 1982) is comprised of 20 variables. These variables represent factors indicated by the literature as contributors to creek chub habitat quality and are listed below:

Variable 1 (CB1): Stream pool percentage during average summer flow.

Variable 2 (CB2): Dominant (>50%) pool class rating during average summer flow.

Variable 3 (CB3): Cover percentage during summer in pools and runs.

Variable 4 (CB4): Proximity to suitable winter instream cover.

Variable 5 (CB5): Stream gradient within the sampling reach.

Variable 6 (CB6): Average stream width during average summer flow.

Variable 7 (CB7): Maximum monthly average turbidity during summer.

Variable 8 (CB8): Annual pH range.

Variable 9 (CB9): Streambank vegetation index.

Variable 10 (CB10): Food production potential within the stream by substrate type present during average summer flow.

Variable 11 (CB11): Average water temperatures during the summer (adult, juvenile, and fry life stages).

Variable 12 (CB12): Minimum dissolved oxygen level during summer (adult, juvenile, and fry life stages).

Variable 13 (CB13): Average current velocity (at 0.6 depth) during average summer flow (adult and juvenile life stages).

Variable 14 (CB14): Average water temperature during spring (embryo life stage).

Variable 15 (CB15): Minimum dissolved oxygen level during spring (embryo life stage).

Variable 16 (CB16): Average current velocity (0.6 depth) in riffle/run areas during April -June (embryo life stage).

Variable 17 (CB17): Percent substrate type in riffle and run areas during spawning (embryo life stage).

Variable 18 (CB18): Stream edge velocity during average summer flow (fry life stage).

Variable 19 (CB19): Average percent of stream shaded between 1000 and 1500 hours during midsummer.

Variable 20 (CB20): Average of maximum stream depths during average summer flow.

Suitability graphs presented and assumptions used in constructing the model are based on previously published literature and the author's professional judgement. The assumptions used may be summarized as:

1. Conditions associated with high creek chub abundance are optimum (CB3, CB5, CB6, CB7, CB8, CB13, CB18, CB20).
2. Environmental conditions under which the highest growth, production, and survival rates are achieved and maintained are optimum (CB11, CB12, CB14, CB15, CB16, CB17).
3. Streambank vegetation, aquatic vegetation, and substrates which provide for maximum insect input is optimum (CB9, CB10).
4. Nearly equal pool and riffle percentages within a stream will provide optimum cover, spawning habitat, and forage for creek chubs (CB1).

5. Large, deep pools provide optimum creek chub cover while small, shallow pools do not (CB2).
6. If suitable winter cover is within 5 km and is freely accessible, conditions are optimum (CB4).
7. High summer water temperatures and or widely fluctuating temperatures are suboptimum. A high stream shading percentage is desirable in small streams (CB19).

The creek chub model combines habitat variables into five life requisite components: food (C_f), cover (C_c), water quality (C_{wq}), reproduction (C_r), and a component labelled in the model as "other" but described here as stream morphometry (C_{sm}). After suitability values for each habitat variable were obtained from the suitability graphs, model components and HSI were calculated as follows:

$C_f = (CB9+CB10) \div 2$

$C_c = (CB1 \times CB2 \times CB3 \times CB4 \times CB13 \times CB18)^{.1667}$

$C_{wq} = (CB7 \times CB8 \times CB11 \times CB12 \times CB19)^{.2}$

If CB8, CB11, or CB12 is ≤ 0.4, then C_{wq} equals the lowest of CB8, CB11, CB12, or the above equation.

$C_r = [CB14 \times CB15 \times CB16 \times (CB17)^2]^{.2}$

If CB14 or CB15 is ≤ 0.4, then C_r equals the lowest of CB14, CB15, or the above equation.

$C_{sm} = (CB5+CB6+CB20) \div 3$

$HSI = (C_f \times C_c \times C_{wq} \times C_r \times C_{sm})^{.2}$

If C_c, C_{wq}, or C_r is ≤ 0.4, then the HSI equals the lowest of C_c, C_{wq}, C_r, or the above equation.

CATFISH MODEL SUMMARY

The riverine channel catfish Habitat suitability index model (McMahon and Terrell 1982) contains 14 variables. Variables 1, 4, and 18 apply only to riverine environments. Variables 2 and 5-14 are applicable to riverine and lacustrine environments. Variables 3, 15, 16, and 17 apply to lacustrine habitat attributes only. The riverine model variables are:

Variable 1 (CF1): Percent pools during average summer flow.

Variable 2 (CF2): Percent cover in pools, backwaters, and littoral areas during summer.

Variable 4 (CF4): River food production potential categorized by substrate type present during average summer flow.

Variable 5 (CF5): Average midsummer water temperature within pools, backwaters, or littoral areas (adult life stage).

Variable 6 (CF6): Length of agricultural growing season (optional variable).

Variable 7 (CF7): Maximum monthly average turbidity during summer.

Variable 8 (CF8): Average minimum dissolved oxygen levels within pools, backwaters, or littoral areas during midsummer.

Variable 9 (CF9): Maximum summer salinity (adult life stage).

Variable 10 (CF10): Average water temperatures in pools, backwaters, and littoral areas during spawning and embryo development (embryo life stage).

Variable 11 (CF11): Maximum salinity during spawning and embryo development (embryo life stage).

Variable 12 (CF12): Average midsummer water temperature in pools, backwaters, or littoral areas (fry life stage).

Variable 13 (CF13): Maximum summer salinity (fry and juvenile life stages).

Variable 14 (CF14): Average midsummer water temperature in pools, backwaters, and littoral areas (juvenile life stage).

Variable 18 (CF18): Average cover area current velocity in during average summer flow.

Suitability graphs presented and assumptions used in constructing the model are based on previously published literature and the authors' professional judgement. The assumptions used may be summarized as:

1. Temperature and salinity levels at which spawning and highest growth rates occur are optimum (CF5, CF10, CF11, CF12, CF13, CF14).
2. Environmental conditions which allow the highest channel catfish abundance and or standing crops are optimum (CF6, CF7, CF9).
3. Nearly equal pool and riffle percentages within the stream are optimum (CF1).
4. At least some instream cover must be present for optimum channel catfish conditions to occur (CF2).
5. Aquatic vegetation and substrate conditions which allow for maximum aquatic insect production are optimum (CF4).
6. Dissolved oxygen levels which reduce feeding are suboptimum (CF8).
7. High cover area velocities are suboptimum (CF18).

The channel catfish riverine model combines habitat variables into four life requisite components: food (C_f), cover (C_c), water quality (C_{wq}), and reproduction (C_r). Suitability values for each habitat variable were obtained from the published model index graphs. Model components and stream habitat suitability indexes (HSI) were calculated as follows:

$C_f = (CF2+CF4) \div 2$

$C_c = (CF1 \times CF2 \times CF18)^{.333}$

$C_{wq} = [2(CF5+CF12+CF14)/3+CF7+2(CF8)+CF9+CF13] \div 7$

If CF5, CF12, CF14, CF8, CF9, or CF13 is ≤ 0.4, then C_{wq} equals the lowest of CF5, CF12, CF14, CF8, CF9, CF13, or the above equation.

$C_r = [CF1 \times (CF2)^2 \times (CF8)^2 \times (CF10)^2 \times CF11]^{.125}$

If CF8, CF10, or CF11 is ≤ 0.4, then C_r equals the lowest of CF8, CF10, CF11, or the above equation.

$HSI = [C_f \times C_c \times (C_{wq})^2 \times (Cr)^2]^{.167}$

If C_{wq} or C_r is ≤ 0.4, then the HSI equals the lowest of C_{wq}, C_r, or the above equation.

METHODS

Sample sites were selected from 245 sites evaluated in the Nebraska Department of Environmental Control (NDEC) stream classification survey of the Elkhorn River basin. Flow and substrate were used as stratification criteria. Flow categories were; < 5 cubic feet per second (cfs), 5-25 cfs, 25-100 cfs, and 100- 250 cfs. Substrate categories were silt/clay and sand. It was estimated 17 sites were required to obtain significant results at the .95 level (Cochran and Cox 1957). Sites were randomized in each category and a total of 17 were drawn. An initial fish collection attempt indicated only 5 sites would permit effective sampling. Additional sites were selected by randomizing NDEC fish collection sites where a minimum of 5 fish species were collected. Twelve additional sites were selected.

Habitat was assessed at each site 3 times. To determine study reach length, average stream width was multiplied by 10. Values were rounded up to allow for convenient transect placement. Total reach length was divided by 4 to ascertain habitat transect locations. Each study reach was characterized by habitat measurements on each of 5 equally spaced transects.

Transect measurements included instream cover, substrate, percent stream shading, streambank vegetation index, steam width, stream depth, stream discharge, cover area velocity, stream edge velocity, and riffle/run velocity. These parameters were measured from or along a tape measure stretched across the stream at each transect location.

Cover items transected by the tape were measured and counted as instream cover for creek chubs and channel catfish. Cover types for all life stages were considered and included anything which provided shelter from current or direct observation. Undercut banks, overhanging vegetation, large objects, and inundated vegetation were included. Large object cover types were natural and manmade debris comprised of log jams, beaver dams, trees, car bodies, concrete riprap, current diversion pilings, tires, and other items large enough to provide cover. Inundated vegetative cover included filamentous algae, submerged and emergent aquatic macrophytes, and submerged or emergent terrestrial vegetation.

Substrate texture composition estimates were made from visual observation of the streambed directly beneath the tape (Platts, et al. 1983). Categories noted were rubble, gravel, sand, clay/silt, organic debris, consolidated clay, and dry soil. If a portion of the transect was a combination of substrate types (i.e. sand and gravel mix), the relative proportion of each component was estimated and marked for that transect segment.

Percent stream shading was estimated by visual observation of the canopy cover directly above the transect and streambank tree cover immediately of each end of the transect. The streambank vegetation index was determined by estimating the percent coverage directly off each transect end.

Stream width was measured at each transect within the study reach. Stream depth was measured on at least one study reach transect. Except in very narrow streams, velocities were obtained from 10 equally spaced verticals on the transect from which the depths were taken (U.S. Bureau of Reclamation, 1974). Stream discharge was calculated from this data. Cover and riffle/run velocities were measured where these habitat types occurred within the study reach. Stream edge velocities were measured at the ends of each transect. Velocity measurements were made using a pygmy meter modified for use with a Swoffer model 2200 open stream current meter. Calibration of the Swoffer meter and free spinning time (at least one minute) of the pygmy were checked each day prior to use.

Pool parameters were measured from all pools encountered within the study reach (Hamilton and Bergersen 1984). Stream pool percentage was determined by dividing the pool surface area sum by the study reach surface area. All pool areas in the study reach were measured. Percent cover within pools was determined by establishing a transect across the widest point of the pool and assessing the amount of cover directly beneath the transect. A pool rating was obtained for each pool within the study reach by visual observation of the pool as a whole. Measured percent cover was used to substantiate the initial pool rating.

Proximity to suitable instream winter cover was determined using Nebraska Department of Roads county road maps and 7.5 minute U.S. Geological Survey (USGS) topographic maps where needed. Stream gradient was obtained from 7.5 minute USGS topographic maps.

Water quality measurements included water temperature, turbidity, dissolved oxygen, pH, and total filterable residue (total suspended solids). Salinity was measured only during the initial stages of this study and confirmed the NDEC fingings that at the sites assessed, salinity concentrations were very low.

Instantaneous water temperature data were collected at all study sites. Maximum/ minimum thermometers were set at sample sites 1, 3, 5, 8, 10, 11, and 15. During each site visit, the maximum/minimum thermometers were checked against the hand held thermometers. Once set, no further calibration was required by any of the maximum/minimum thermometers.

Turbidity samples were collected from all study sites at 0.6 of the depth in the main channel. Replicate analyses of one site per sample batch was done to provide a precision assessment of the methodology, instrumentation, and analyst. High and low turbidity samples were replicated. The turbidity suitability graph in the creek chub model is scaled for turbidity measured in Jackson Turbidity Units (JTU). The turbidity suitability graph in the channel catfish model is scaled for turbidity measured in parts per million (ppm) or milligrams per liter (mg/L). Apparatus available for turbidity measurements in this study measured turbidity in nephelometric turbidity units (NTU). Standard Methods (APHA, et al. 1975 and 1985) states no direct relationship exists between Jackson candle turbidity and the intensity of light scattered at a 90 degree angle (nephelometric method) and advises reporting the two methods separately. Conversely, the U.S. Environmental Protection Agency (USEPA 1979) states turbidity values measured in NTU are "considered comparable" to turbidity values measured in JTU. In this study, turbidity was measured using the NTU scale and the values obtained were compared to the published suitability graphs.

Dissolved oxygen was measured at all study sites using the azide modification of the Winkler method (APHA, et al. 1985). Replicate samples were collected to verify results. Minimum dissolved oxygen estimates were collected during predawn hours (0230-0530 hours) using a dissolved oxygen meter which was calibrated each morning.

A portable meter, calibrated daily, was used to measure pH at all study sites. All pH measurements were taken in the field.

Habitat data and fish population data were collected during separate trips. Electrofishing (AC and DC) was used to collect fish at all of the study sites except for site 2 (Cache Creek near Ewing). During the first collection effort at site 2, seining was used due to low flow and low conductivity. Fish were collected from the same stream segment as the habitat data. Study reach length and average stream width were measured during each fish collection effort.

The removal method (Armour, et al. 1983 and Platts, et al. 1983) was used to estimate fish populations. Study reaches were isolated with 6.35 mm (1/4 in.) mesh block nets. In most instances, two sampling runs provided sufficient creek chub or channel catfish catch declines (at least 50%) to calculate a meaningful population estimate. If after assessing the first two runs a 50% reduction had not been obtained, a third sampling run was conducted. A fourth sampling pass was never required. A sampling run was defined as a continuous upstream and downstream pass through the study reach. The downstream block net was cleaned of fish at the end of each run. Upon completion of the sampling effort, fish in the removed downstream block net were counted separately. Fish large enough to conveniently handle were weighed and measured (total length) in the field and released at the site. All other specimens were field preserved in 10% Formalin and transported to the laboratory for analysis. Taxonomic keys employed in identification included those published by Becker (1983), Cross (1967), Pflieger (1975), Scott and Crossman (1979), Smith (1985), and Trautman (1981). Species names were verified using <u>Common and Scientific Names of Fishes</u> (Robins, et al. 1980).

Population estimates, biomass estimates, capture probabilities, and 95% confidence intervals were calculated using the formulas presented by Armour, et al. (1983) for two and three sampling runs.

Population estimates derived from two sampling passes were calculated as $N = U_1 \div (1 - U_2/U_1)$, where N = the population estimate, U_1 = the number of fish removed on the first pass, and U_2 = the number of fish removed on the second pass. Estimated capture probability for two removal passes was calculated as $p = 1 - (U_2/U_1)$, where p = the capture probability estimate. An approximate 95% confidence interval was calculated as 95% C.I. = $N \pm 2[se(N)]$, where se = the standard error of N. Equations used in the estimation of population, capture probability, and 95% C.I. for more than two removal passes were originally developed by Zippin (1958).

Biomass estimates were calculated by multiplying the population estimate by the average weight of all individuals captured from that species.

Determination of habitat suitability index (HSI) values was accomplished by compiling raw data into individual variables, combining variables into habitat components and then calculating the index value.

The non-parametric Kolmogorov-Smirnov goodness of fit test (Sokal and Rohlf 1969) was applied to the population, biomass, and HSI estimate values to assess the normality of their distributions. Correlations between non-normal data sets were obtained using the Spearman and Kendall non-parametric tests. Correlations between normal data sets were obtained using a traditional parametric test (Steele and Torrie 1980).

SUITABILITY INDEX COMPILATION

Habitat suitability index (HSI) variables common to both the channel catfish and creek chub models are CB1 & CF1, CB3 & CF2, CB10 & CF4, and CB7 & CF7. Riverine HSI variables unique to the channel catfish model are CF5, CF8, CF9, CF10, CF11, CF12, CF13, CF14, and CF18. (CF6 was not used.) HSI variables unique to the creek chub model are CB2, CB4, CB5, CB6, CB8, CB9, CB11, CB12, CB13, CB14, CB15, CB16, CB17, CB18,CB19, and CB20.

Variables CF1 and CB1 were compiled by calculating pool percentage for each trip individually and then the overall mean. Variables CF2 and CB3 were compiled by calculating the mean cover percentage for the entire study reach separately for each trip and then obtaining the overall mean. CF4 and CB10 were compiled by using pool vegetation only, not taking substrate into account. Accounting for substrate would have placed all streams into the lowest food production rating or class D because all substrate materials would be classified as "fines" (Platts, et al. 1983). Stream segment ratings from individual trips were reduced to a single average and then the mean of all trips was obtained. CF7 and CB7 were compiled by taking the highest summer monthly average turbidity from all observations.

Variables CF5, CF12, and CF14 were obtained by averaging water temperature observations from June, July, and August. Variable CF8 was obtained by averaging the early morning and lowest June, July, or August dissolved oxygen observations. Variables CF9, CF11, and CF13 were all given a suitability value of 1.0 because no salinity value above 0.5 ppt was ever observed during this study or reported in any of the NDEC assessments. CF10 was compiled by averaging May and early June water temperatures. Variable CF18 was obtained by averaging all cover velocity observations in feet/second units and converting into centimeter/second units. Variable CB2 was compiled by taking the surface area of each pool type present and comparing it to the total pool surface area present. Suitability index values from individual trips were then averaged into a single value. CB4 was compiled using the equations provided in the model. CB5 in feet/mile stream gradient estimates was converted into meters/kilometer estimates. Estimates obtained in feet/mile units were converted to meters/kilometer units. CB6 was compiled by averaging all stream width measurements and converting the mean to meters. Variable CB8 was given a suitability index value of 1.0 at all stations because no pH observations outside the 6.0 to 9.0 range were collected. CB9 was compiled by averaging all vegetative cover observations from all trips and performing the calculations provided in the model. CB11 was obtained by averaging all June through August water temperature readings. CB12 was compiled by averaging the early morning and lowest daytime dissolved oxygen observations. CB13 was derived by averaging all transect velocity measurements. CB14 was obtained by averaging all May and early June water temperatures. CB15 was the lowest May or early June dissolved oxygen measurement taken. CB16 was the average of all riffle/run velocity measurements collected during May and June. CB17 was compiled from transects where gravel was noted and an overall mean was obtained. CB18 was derived from velocity measurements taken at both ends of each transect and averaged. CB19 was obtained from visual estimates of the shading directly above each transect. CB20 was derived by averaging all maximum depth measurements at each site.

RESULTS

STUDY WIDE RESULTS

Thirtythree species of fish were collected from the 17 sites sampled in this study. Species numbers per site ranged from 23 at site 5 (Battle Creek near Battle Creek) to 5 at site 13 (Dry Creek near Wisner). Species collected and mean population estimates obtained at each sampling station are presented in Appendix A.

No population, biomass, or HSI estimates were obtained at site 8 (North Fork Elkhorn River near Pierce). Excessive depth prohibited closing a study reach for quantitative population estimates and measuring habitat parameters along transects.

Virtually all of the temperature measurements from pools and backwaters were identical to those in the main channel. Factors having the greatest influence on this were channelization, stream shallowness, and rolling sand substrates. The maximum salinity measured in this study and in the NDEC stream classification survey was 0.5 parts per thousand (ppt).

CREEK CHUB

Creek chubs were collected at 10 sites (3, 4, 5, 6, 10, 11, 12, 13, 14, 15). Creek chub suitability index values for each variable at each site are presented in Table 1 (2 pages). Suitability values of 1.0 were obtained at all sites for variables 8, 12, and 13. These variables are omitted from Table 1. Creek chub population, biomass, and HSI estimates are listed in Table 2.

TABLE 1. Creek chub variable (excluding 8, 12, & 13) suitability values.

	CB1	CB2	CB3	CB4	CB5	CB6	CB7	CB9	CB10	CB11
Site 1	0.2	0.6	0.3	0.13	0.15	0.35	1.0	1.0	0.5	1.0
Site 2	0.2	0.6	0.5	0.6	0.2	0.65	1.0	1.0	0.7	1.0
Site 3	0.6	0.3	0.7	0.7	0.55	1.0	0.0	1.0	0.7	1.0
Site 4	0.7	1.0	0.95	1.0	0.25	1.0	0.0	1.0	0.7	1.0
Site 5	0.2	0.6	0.55	0.6	0.15	0.8	0.0	1.0	0.7	0.0
Site 6	1.0	1.0	1.0	1.0	0.2	1.0	0.0	1.0	1.0	0.8
Site 7	0.45	0.6	0.6	0.35	0.15	1.0	0.9	0.8	0.7	1.0
Site 9	0.25	0.3	0.25	0.07	0.15	0.3	0.0	1.0	0.5	1.0
Site 10	0.35	0.6	0.4	0.64	0.3	1.0	0.0	0.45	0.5	0.0
Site 11	1.0	0.3	0.2	0.19	0.2	1.0	0.0	1.0	0.2	1.0
Site 12	0.2	0.3	0.2	0.03	0.15	1.0	0.0	1.0	0.2	1.0
Site 13	0.2	0.3	1.0	0.14	0.35	0.9	0.55	1.0	1.0	1.0
Site 14	1.0	1.0	0.85	0.75	0.25	1.0	0.4	1.0	1.0	0.95
Site 15	0.2	0.3	0.2	0.03	0.15	1.0	0.8	0.95	0.2	1.0
Site 16	0.25	0.6	0.65	0.26	0.25	0.9	0.8	1.0	0.7	1.0
Site 17	0.2	0.3	0.3	0.06	0.2	0.2	0.0	0.2	0.2	1.0

TABLE 1. (continued). Creek chub variable (excluding 8, 12, & 13) suitability values.

	CB14	CB15	CB16	CB17	CB18	CB19	CB20
Site 1	1.0	0.6	1.0	0.01	1.0	0.3	1.0
Site 2	1.0	1.0	1.0	0.0	1.0	0.2	0.7
Site 3	1.0	0.95	1.0	0.0	1.0	0.45	0.7
Site 4	1.0	0.95	1.0	0.1	1.0	0.3	0.85
Site 5	1.0	0.65	1.0	0.0	0.95	0.2	0.85
Site 6	1.0	0.8	1.0	0.15	1.0	0.25	1.0
Site 7	1.0	0.9	1.0	0.05	1.0	0.95	0.85
Site 9	1.0	0.9	1.0	0.05	0.9	0.2	1.0
Site 10	1.0	0.9	1.0	0.6	0.7	0.2	0.95
Site 11	1.0	1.0	1.0	0.9	1.0	0.2	1.0
Site 12	1.0	1.0	0.9	0.25	1.0	0.2	0.85
Site 13	1.0	1.0	0.9	0.85	1.0	0.4	0.7
Site 14	1.0	1.0	1.0	0.25	1.0	0.5	1.0
Site 15	1.0	1.0	1.0	0.01	1.0	0.2	0.9
Site 16	0.8	1.0	1.0	0.05	0.8	0.2	0.9
Site 17	0.95	0.7	1.0	0.25	0.9	0.2	0.9

TABLE 2. Creek chub population, biomass, and HSI estimates.

	Estimate (N/ha)	Estimate (kg/ha)	HSI
Site 1	0.0	0.0	0.143
Site 2	0.0	0.0	0.0
Site 3	47.0	2.2	0.0
Site 4	2131.1	163.2	0.0
Site 5	68.3	1.0	0.0
Site 6	705.2	36.8	0.0
Site 7	0.0	0.0	0.295
Site 9	0.0	0.0	0.0
Site 10	1858.9	40.5	0.0
Site 11	692.1	20.9	0.0
Site 12	671.5	18.4	0.0
Site 13	30870.4	70.8	0.724
Site 14	3868.5	223.4	0.779
Site 15	279.2	2.7	0.158
Site 16	0.0	0.0	0.289
Site 17	0.0	0.0	0.0

Sites 3, 4, 5, 6, 10, 11, and 12 yielded population and biomass estimates greater than 0.0 and HSI estimates of 0.0. Population and biomass estimates at sites 1, 7, and 16 were 0.0 while HSI estimates were greater than 0.0. Population, biomass, and HSI estimates greater than 0.0 were obtained at sites 13, 14, and 15. Population, biomass, and HSI estimates of 0.0 were obtained at sites 2, 9, 17.

The non-parametric Kolmogorov-Smirnov goodness of fit test (Sokal and Rohlf 1969) was applied to the population, biomass, and HSI estimate values to assess the normality of their distributions. In this comparison, the null hypothesis is the observed distributions are normal. The alternate hypothesis is the distributions are not normal. The observed sample statistics for the population, biomass, and HSI distributions are 0.398, 0.290, and 0.344 respectively. The Kolmogorov-Smirnov function critical value for 16 observations at the .05 level is 0.32733 (Rohlf and Sokal 1969). Based on these figures, the null hypothesis is rejected for the population and HSI distributions and is not rejected on the biomass distribution. Variance for each set of values was also determined. Variances of creek chub population, biomass, and HSI were 58,100,000; 4,290; and .066 respectively. Data transformations to achieve distribution normality are ineffective due to the frequency of zeros in the population, biomass, and HSI data sets.

Since two of three data distributions were not normal and variances of the three data sets were not equal, non-parametric correlation tests based on the ranks of the data were employed. Spearman's *rho* and significance level (in parentheses) for the creek chub population versus HSI comparison are .122 (.652) and for the creek chub biomass versus HSI comparison are .093 (.732). Kendall's *tau* and significance level (in parentheses) for the population versus HSI comparison are .541 (.005) and for the biomass versus HSI comparison are .541 (.005). The significance level indicates the probability of observing the degree of correlation measured if the two variables are independent.

CHANNEL CATFISH

Channel catfish were collected at sites 1, 5, 9, 15, 16, and 17. Channel catfish suitability index values for each riverine variable at each site are presented in Table 3. Variable CF6, length of agricultural growing season, is an optional variable and was not used. Suitability values of 1.0 were obtained at all sites for variables CF9, CF11, and CF13. These variables are omitted from Table 3. Channel catfish population estimates, biomass estimates, and observed HSI values for each site are listed in Table 4.

Sites 2, 3, 4, 7, 10, 11, 12, and 13 yielded population and biomass estimates of 0.0 and HSI values greater than 0.0. Sites 1, 5, 9, 15, 16, and 17 yielded population, biomass, and HSI values greater than 0.0. Sites 6 and 14 yielded population, biomass, and HSI values of 0.0. The non-parametric Kolmogorov-Smirnov goodness of fit test was applied to the population, biomass, and HSI estimate values to assess the normality of their distributions. Observed sample statistics for the population, biomass, and HSI distributions were .391, .346, and .157 respectively. The Kolmogorov-Smirnov function critical value for 16 observations at the .05 level was 0.32733 (Rohlf and Sokal 1969). Based on this test, the HSI values appear to be normally distributed and the population and biomass values appear to have a distribution other than normal. Variances of the channel catfish population, biomass, and HSI data sets are 2108.0, 36.0, and .034

TABLE 3. Channel catfish riverine variable (excluding 6, 9, 11, & 13) suitability values.

	CF1	CF2	CF4	CF5	CF7	CF8	CF10	CF12	CF14	CF18
Site 1	0.25	1.0	0.2	0.45	1.0	1.0	0.2	0.35	0.35	1.0
Site 2	0.25	0.8	0.2	0.6	1.0	1.0	.05	0.5	0.5	1.0
Site 3	0.6	0.85	0.5	0.1	0.2	0.9	.05	0.2	0.2	1.0
Site 4	0.75	1.0	0.7	0.3	0.2	1.0	0.1	0.3	0.3	1.0
Site 5	0.4	1.0	0.5	0.3	0.2	1.0	0.4	0.3	0.3	1.0
Site 6	1.0	1.0	0.7	0.0	0.2	0.85	0.2	.05	.05	1.0
Site 7	0.5	1.0	0.5	0.35	1.0	0.85	0.35	0.35	0.35	1.0
Site 9	0.35	0.85	0.2	0.55	0.2	0.9	0.25	0.45	0.45	1.0
Site 10	0.45	1.0	0.5	0.35	0.2	1.0	0.35	0.35	0.35	0.75
Site 11	0.9	0.15	0.5	0.6	0.2	1.0	0.35	0.45	0.5	1.0
Site 12	0.2	0.2	0.2	0.45	0.7	1.0	0.3	0.4	0.4	1.0
Site 13	0.2	1.0	0.7	0.4	1.0	1.0	0.3	0.35	0.35	1.0
Site 14	0.75	0.7	0.7	0.01	1.0	1.0	0.1	0.1	0.1	1.0
Site 15	0.2	0.1	0.2	1.0	1.0	1.0	0.15	0.9	0.9	1.0
Site 16	0.35	0.75	0.5	0.6	1.0	1.0	0.5	0.5	0.5	1.0
Site 17	0.25	1.0	0.2	0.65	0.2	0.9	0.4	0.5	0.55	1.0

TABLE 4. Channel catfish population, biomass, and HSI estimates.

	Estimate (N/ha)	Estimate (kg/ha)	HSI
Site 1	3.4	2.2	0.2
Site 2	0.0	0.0	0.05
Site 3	0.0	0.0	0.05
Site 4	0.0	0.0	0.1
Site 5	25.5	2.5	0.3
Site 6	0.0	0.0	0.0
Site 7	0.0	0.0	0.35
Site 9	129.6	19.2	0.25
Site 10	0.0	0.0	0.35
Site 11	0.0	0.0	0.35
Site 12	0.0	0.0	0.3
Site 13	0.0	0.0	0.3
Site 14	0.0	0.0	0.01
Site 15	6.4	0.5	0.15
Site 16	133.6	15.8	0.722
Site 17	68.4	6.9	0.4

respectively. Data transformations to approximate normality are ineffective due to the frequency of zeros in the population and biomass data sets.

Since two of three data distributions are not normal and variances of the three data sets are not equal, nonparametric correlation tests based on the ranks of the data were employed. Spearman's *rho* and significance level (in parentheses) for the channel catfish population versus HSI comparison are .395 (.130) and for the channel catfish biomass versus HSI comparison are .371 (.157). Kendall's *tau* and significance level (in parentheses) for both the population versus HSI and biomass versus HSI comparisons are .500 (.008). The significance level indicates the probability of observing the degree of correlation measured if the two variables are independent.

DISCUSSION

CREEK CHUB

Population, biomass, and HSI estimates obtained at sites 2, 9, 13, 14, 15, and 18 fit the model. At sites where population and biomass estimates either equalled or were greater than 0.0, HSI estimates equalled or were greater than 0.0. Normality tests on these three data subsets indicated they were all normally distributed. Simple parametric correlation of the population and biomass data sets with the HSI data set yields coefficients of .682 and .858 respectively. Spearman's non-parametric correlation test yields coefficients of .935 and 1.000 respectively. In both tests, the biomass estimates correlated more closely to the HSI values than did population estimates.

Observations which did not fit the model were obtained at the remaining ten sites. At sites 3, 4, 5, 6, 10, 11, and 12, creek chubs were sampled and HSI values were 0.0. Variable CB7 (maximum monthly average turbidity during summer) contributed a zero to the water quality component of each of these sites. Variable CB11 (average water temperatures during the summer, adult, juvenile, and fry life stages) contributed a zero to the water quality component of sites 5 and 10. Variable CB17 (percent substrate type in riffle/run areas during spawning, embryo life stage) contributed a zero to the reproductive component of sites 3 and 5. Three sites (1, 7, 16) yielded HSI values greater than zero and no chubs were collected. Variable CB17 controlled the HSI of these sites.

Variable CB7, as published, yields a suitability index value of 0.0 if the turbidity value is 150 NTU or greater. The assumption given with this variable is that optimum turbidity levels are those associated with high creek chub abundance. No assumption concerning unsuitable turbidity levels was given, however the author states creek chubs can tolerate higher turbidities if clean spawning gravel is present. The turbidity suitability graph does not reflect this tolerance. Four of the 5 references on which the suitability graph is based, poorly represent turbidity conditions found in the Elkhorn River basin. Two references report Kentucky studies, one from the karst topography region in north central Kentucky (Minckley 1963) and the other from the strip mining area of east central Kentucky (Branson and Batch 1972). A third reference reports a study conducted in the Mississippi River headwaters region of north central Minnesota (Barber and Minckley 1971). The other 2 references are Scott and Crossman (1973) and Pflieger (1975).

Based on results from this study, it appears the published upper limit is low. Maximum turbidity values at sites where creek chubs were collected ranged from 100 NTU to 7600 NTU. Mean turbidity values from these sites ranged from 27.2 NTU to 740 NTU. Upper turbidity limits of 1500, 1200, and 750 NTU were set and HSI values were calculated for each scale. Each of these suitability scales was applied to turbidity values generated using the maximum monthly turbidity (original calculation) and overall mean turbidity values at all sites. No normal distributions were indicated in any of the six resulting HSI data sets. The 750 NTU scale modification and overall mean calculation produced the best non-parametric HSI correlation with the biomass data set. Spearman and Kendall correlations achieved using these data sets were .536 (.032) and .540 (.003) respectively. Little statistical improvement was noted between the 1200 NTU and 750 NTU comparisons. Statistical benefits from further turbidity limit reductions were negated by model limits placed on other model variables and components.

Variable CB11 suitability is 0.0 if water temperature reaches or exceeds 32° C. Only sites 5 and 10 were affected by this criterion. Creek chubs were collected at sites 5 and 10. No evidence of creek chub presence or absence at the time the temperature extremes were recorded is available. Maximum temperatures recorded at sites 5 and 10 were 35° C and 32.2° C. The assumption given concerning elevated summer temperatures was that reduced survival and growth are indicated in the literature. Becker (1983) also reports an upper lethal temperature of 32.5° C for creek chubs. This absolute maximum, though documented in the literature, makes no provision for avoidance of short term lethal or detrimental water quality conditions. Both sites at which high temperatures were recorded, were monitored with maximum/minimum thermometers as well as instantaneous measurements. In both instances, the extremes were measured on the maximum/minimum thermometers. Sites monitored by instantaneous grabs only may well have reached the 32° C limit and simply were not documented. Further study involving continuous temperature monitoring is required to address this situation.

Assuming creek chubs do avoid excessive water temperature conditions if refugia exist, an arbitrary suitability value of 0.01 was assigned to sites 5 and 10 for variable CB11. This model modification was applied in conjunction with the 750 NTU and overall mean turbidity modifications. Spearman and Kendall correlation coefficients with the population estimate data set are .584 (.018) and .567 (.002) and with the biomass data set are .578 (.019) and .585 (.001).

Variable CB17 contributed a zero to the reproductive component of sites 3 and 5. No gravel was noted at either site during any of the habitat measurements. These sites also yielded the lowest population and biomass estimates obtained and no young of the year were collected. Since the reproductive component is comprised of habitat variables scaled to the embryo life stage, collection of older fish will produce a negative model result even if the reproductive habitat is accurately assessed. The model needs to allow for loafing and foraging activities of juvenile and adult creek chubs. Variable CB17 also controlled the HSI values obtained at the 3 sites with 0.0 population estimates and HSI values greater than 0.0. Substrate texture may have been inadequately assessed. This situation suggests substrate assessment should be conducted throughout the entire study reach and not restricted to transect measurements.

In this study, the null hypothesis was not rejected. The model's potential, however, was demonstrated by the correlation coefficients obtained at the sites where population, biomass, and HSI estimates either equalled or exceeded 0.0. Overall the model appears to be too restrictive. Creek chubs tolerate turbidities in excess of 150 NTU in Nebraska and will avoid lethal or detrimental conditions where refugia exist. With changes to the turbidity, maximum summer temperature, and spawning substrate variables, the model should prove useful and defendable in habitat assessments and provide reliable data from which to make sound management decisions.

CHANNEL CATFISH

Observations obtained at sites 1, 5, 6, 9, 15, 16, and 17 fit the model. Normality tests on these three data sets indicated they were all normally distributed. Simple parametric correlation of the population and biomass data sets with the HSI data set yields coefficients of .739 and .625 respectively. Spearman's non-parametric correlation test yields coefficients of .857 and .786 respectively. Kendall's non-parametric correlation test yields coefficients of .714 for both comparisons. In these three comparisons, population estimates correlated as well or more closely to the HSI values than did biomass estimates.

Observations which did not fit the model were obtained at the other nine sites. HSI values were greater than zero but no channel catfish were collected. Variable CF10 (average water temperatures within pools, backwaters, and littoral areas during spawning and embryo development, embryo life stage) was the controlling variable at sites 2, 3, 4, 11, 12, and 13. HSI values at sites 7 and 10 were determined by CF10, CF12 (average midsummer water temperature within pools, backwaters, or littoral areas, fry life stage), and CF14 (average midsummer water temperature within pools, backwaters, or littoral areas, juvenile life stage). The HSI of site 14 was controlled by variable CF5 (average midsummer water temperature within pools, backwaters, or littoral areas, adult life stage).

The lower limit of CF10 allowed in the model is 15° C. Setting an arbitrary lower limit of 17° C improves the correlation of these data sets. Spearman's *rho* and Kendall's *tau* for the population to HSI correlation increased to .509 (.044) and .854 (.500) respectively. Spearman's *rho* and Kendall's *tau* for the biomass to HSI correlation increased to .484 (.057) and .854 (.500) respectively. Comparison of CF10 temperature means obtained from sites yielding affirmative observations to sites yielding negative observations using Student's t-Test, indicated no significant difference between means (.05, 14, with unpaired data and unequal sample size), however. Additional testing is required to determine if this model change is a bona fide improvement or an artifact of this particular data set. No other variable consistently produced a population parameter to HSI mismatch.

In this study, the null hypothesis was not rejected. Channel catfish were collected at an insufficient number of sites to provide an adequate model test. The controlling or limiting variables were all temperature variables indicating a need for more comprehensive temperature monitoring (continuous) and development of appropriate temperature suitability curves for Nebraska.

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APPENDIX A

APPENDIX A.1 Mean population estimates (N/ha) of species obtained at sites 1-4. (No Estimate means the species was collected but not quantified.)

SPECIES	SITE 1	SITE 2	SITE 3	SITE 4
Carpiodes carpio	No Estimate			
Carpiodes cyprinus	No Estimate			
Catostomus commersoni				928.5
Cyprinus carpio	57.2	4.8		62.9
Dorosoma cepedianum				
Esox americanus	31.5	9.6		62.9
Esox lucius				
Etheostoma exile			93.9	51.3
Etheostoma nigrum	6.8		2136.9	616.9
Fundulus sciadicus				
Hybognathus argyritis				
Hybognathus hankinsoni		339.6	2979.5	12262.7
Hybognathus placitus				
Hybopsis aestivalis				
Hybopsis gracilis				
Ictalurus melas	10.4	8.7		3947.9
Ictalurus natalis	113.3	No Estimate		354.1
Ictalurus punctatus	3.4			
Lepomis cyanellus	240.8	No Estimate	47.0	6196.5
Lepomis gibbosus	198.6			
Lepomis macrochirus	3.5			
Micropterus salmoides				
Moxostoma macrolepidotum	13.8			
Notropis blennius				
Notropis dorsalis	7.1	2835.2		101.0
Notropis lutrensis	118.0	738.6	80.6	12427.7
Notropis stramineus	42.1	779.5	1135.5	9849.5
Noturus flavus	10.4	No Estimate		
Noturus gyrinus	14.2	9.1		
Phenacobius mirabilis		4.8		
Pimephales notatus	3.5	13.9	93.9	330.1
Pimephales promelas		72.0	6430.0	10370.3
Pylodictis olivaris				
Semotilus atromaculatus		No Estimate	47.0	2131.1

APPENDIX A.2 Mean population estimates (N/ha) of species obtained at sites 5-8. (No Estimate means the species was collected but not quantified.)

SPECIES	SITE 5	SITE 6	SITE 7	SITE 8
Carpiodes carpio	7.6			No Estimate
Carpiodes cyprinus	31.4		9.9	
Catostomus commersoni	23.0	253.4		
Cyprinus carpio	25.2	165.3	15.9	No Estimate
Dorosoma cepedianum				
Esox americanus				
Esox lucius	2.4		7.9	
Etheostoma exile	5.4		344.2	
Etheostoma nigrum	27.3		54.4	
Fundulus sciadicus			314.6	
Hybognathus argyritis	2.5			
Hybognathus hankinsoni	1404.2	27.5	228.3	No Estimate
Hybognathus placitus				
Hybopsis aestivalis				
Hybopsis gracilis	9.1			
Ictalurus melas	116.1	220.4	47.5	No Estimate
Ictalurus natalis		82.6		
Ictalurus punctatus	25.5			
Lepomis cyanellus	192.4	82.6	853.3	
Lepomis gibbosus				
Lepomis macrochirus				No Estimate
Micropterus salmoides				
Moxostoma macrolepidotum	28.9			
Notropis blennius				
Notropis dorsalis	5.0		997.1	No Estimate
Notropis lutrensis	6826.7	110.2	1359.8	No Estimate
Notropis stramineus	1643.8	484.0	3657.1	No Estimate
Noturus flavus	14.4		279.0	No Estimate
Noturus gyrinus	3.2			
Phenacobius mirabilis	70.2			
Pimephales notatus	61.5			
Pimephales promelas	1762.0	1186.8	1919.0	No Estimate
Pylodictis olivaris				
Semotilus atromaculatus	68.3	705.2		

APPENDIX A.3 Mean population estimates (N/ha) of species obtained at sites 9-12. (No Estimate means the species was collected but not quantified.)

SPECIES	SITE 9	SITE 10	SITE 11	SITE 12
Carpiodes carpio	448.9		11.6	
Carpiodes cyprinus	64.5		55.4	
Catostomus commersoni			8.6	
Cyprinus carpio	16.8		11.6	
Dorosoma cepedianum				
Esox americanus				
Esox lucius				
Etheostoma exile				
Etheostoma nigrum				
Fundulus sciadicus				
Hybognathus argyritis	8.7			
Hybognathus hankinsoni	57.7	36.4		135.6
Hybognathus placitus				
Hybopsis aestivalis	17.5			
Hybopsis gracilis	171.4	116.8	65.1	
Ictalurus melas			65.1	110.4
Ictalurus natalis				
Ictalurus punctatus	129.6			
Lepomis cyanellus	5.7			
Lepomis gibbosus				
Lepomis macrochirus				
Micropterus salmoides	1.9			
Moxostoma macrolepidotum	8.6			
Notropis blennius				
Notropis dorsalis	3.4	7334.2	283.5	706.0
Notropis lutrensis	3517.3			21.9
Notropis stramineus	3710.0	5707.8	233.6	12616.9
Noturus flavus	22.8			
Noturus gyrinus				
Phenacobius mirabilis				
Pimephales notatus	6.9			
Pimephales promelas	322.5	195.8	983.6	5002.6
Pylodictis olivaris	1.9			
Semotilus atromaculatus		1858.9	692.1	671.5

APPENDIX A.4 Mean population estimates (N/ha) of species obtained at sites 13-17. (No estimate means the species was collected but not quantified.)

SPECIES	SITE 13	SITE 14	SITE 15	SITE 16	SITE 17
Carpiodes carpio				186.1	32.4
Carpiodes cyprinus			73.8	28.6	4.1
Catostomus commersoni					
Cyprinus carpio				12.2	
Dorosoma cepedianum			44.9		
Esox americanus					
Esox lucius					
Etheostoma exile					
Etheostoma nigrum					
Fundulus sciadicus					
Hybognathus argyritis					6.1
Hybognathus hankinsoni		2858.0		43.2	2.0
Hybognathus placitus					40.5
Hybopsis aestivalis					2.0
Hybopsis gracilis				3.4	71.1
Ictalurus melas		195.3		8.9	1.1
Ictalurus natalis					
Ictalurus punctatus			6.4	133.6	68.4
Lepomis cyanellus		237.2		4.4	2.0
Lepomis gibbosus					
Lepomis macrochirus					
Micropterus salmoides					
Moxostoma macrolepidotum					
Notropis blennius					4.1
Notropis dorsalis	7957.2		1934.1		10.4
Notropis lutrensis	74.1		342.1	2855.5	271.1
Notropis stramineus	14719.3	6073.2	8866.9	5177.0	226.7
Noturus flavus					
Noturus gyrinus					
Phenacobius mirabilis			22.4		
Pimephales notatus		120.5			
Pimephales promelas	5280.6	4662.7	177.1	2304.8	85.1
Pylodictis olivaris					
Semotilus atromaculatus	30870.4	3868.5	279.2	66.9	