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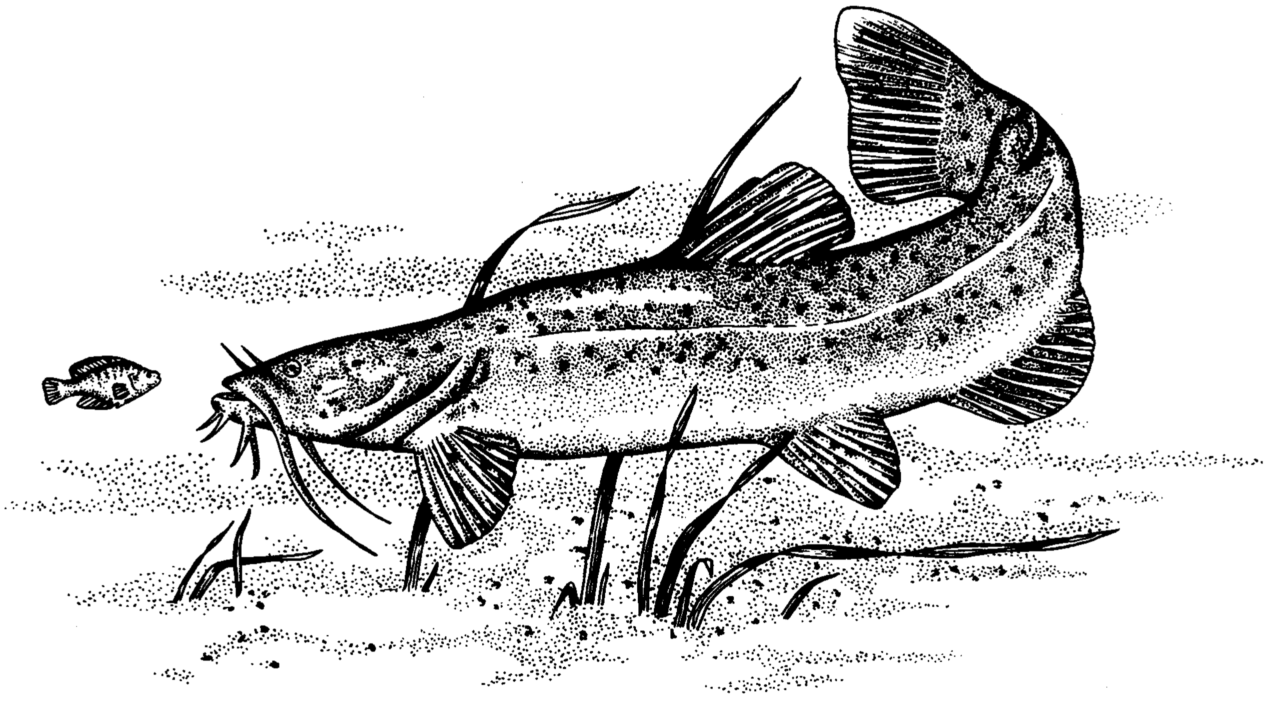
HABITAT SUITABILITY INDEX MODELS: FLATHEAD CATFISH



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Biological Report 82(10.152) ERRATA

Page 2, par. 3, line 3: change "Swiber" to "Surber"

Page 2, par, 4, line 1: change "20 to 50 cm" to "20 and 50 cm"

Page 4, par. 3, line 7: change "between 23.8" to "23.8"

Page 4, par. 4, line 1: change "20 to 25°C" to "20-25 °C"

Page 4, par. 4, line 2: change "24 to 29°C" to 24-29°C"

Page 11, par. 1, line 8: change "Table 1" to "Table 2"

Page 21, par. 1, line 2: change "Forestry Fish" to "Forestry, Fish"

Page 37, ref. 4, line 1: change "Layher, W.G., and W.D. Warde" to
"Layher, W.G., O.E. Maughan, and W.D. Warde"

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HABITAT SUITABILITY INDEX MODELS: FLATHEAD CATFISH

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PREFACE

The habitat use information and Habitat Suitability Index (HSI) models presented in this document are intended for use in impact assessment and habitat management activities. Literature concerning the habitat requirements and preferences of flathead catfish is reviewed and then synthesized into HSI models, which are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into these quantitative models are noted, and guidelines for model application are described. Other habitat models found in the literature are presented.

Use of habitat models for impact assessment requires the setting of clear objectives and may require modifications of the models to meet those objectives. Methods for modifying HSI models and recommended measurement techniques for model variables are presented in Terrell et al. (1982)[1] and Hamilton and Bergersen (1984).[1] A discussion of HSI model-building techniques is presented in U.S. Fish and Wildlife Service (1981).[1]

The HSI models presented here are hypotheses of species-habitat relationships, not statements of proven cause and effect relationships. The HSI models have not been tested against field population data. The U.S. Fish and Wildlife Service encourages model users to send comments and suggestions that may help increase the utility and effectiveness of habitat models in fish and wildlife planning. Please send comments to:

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[1]Citations listed in References.

CONTENTS

TABLES

ACKNOWLEDGMENTS

We would like to thank W.G. Layher, W.A. Hubert, O.E. Maughan, and R.J. Muncy for their many helpful comments in reviewing this document. However, the reviewers do not necessarily endorse the models presented. Word processing was provided by D. Ibarra and P. Gillis. We would also like to recognize K. Lindgren for obtaining many of the manuscripts used to develop this document, S. Strawn for Figure 1, and J. Shoemaker for the cover illustration.

FLATHEAD CATFISH (Pylodictis olivaris)

HABITAT USE INFORMATION

General

The flathead catfish, Pylodictis olivaris (Rafinesque), is native to the Mississippi River and Rio Grande drainages (Moore 1957; Pflieger 1971; Moyle 1976). It originally inhabited large rivers in these drainage basins, including northeastern portions of Mexico (Lee et al. 1980). The flathead catfish has been introduced into Florida, South Carolina, Idaho, Oregon, Washington, Arizona, and California (Gholson 1970) (Figure 1).

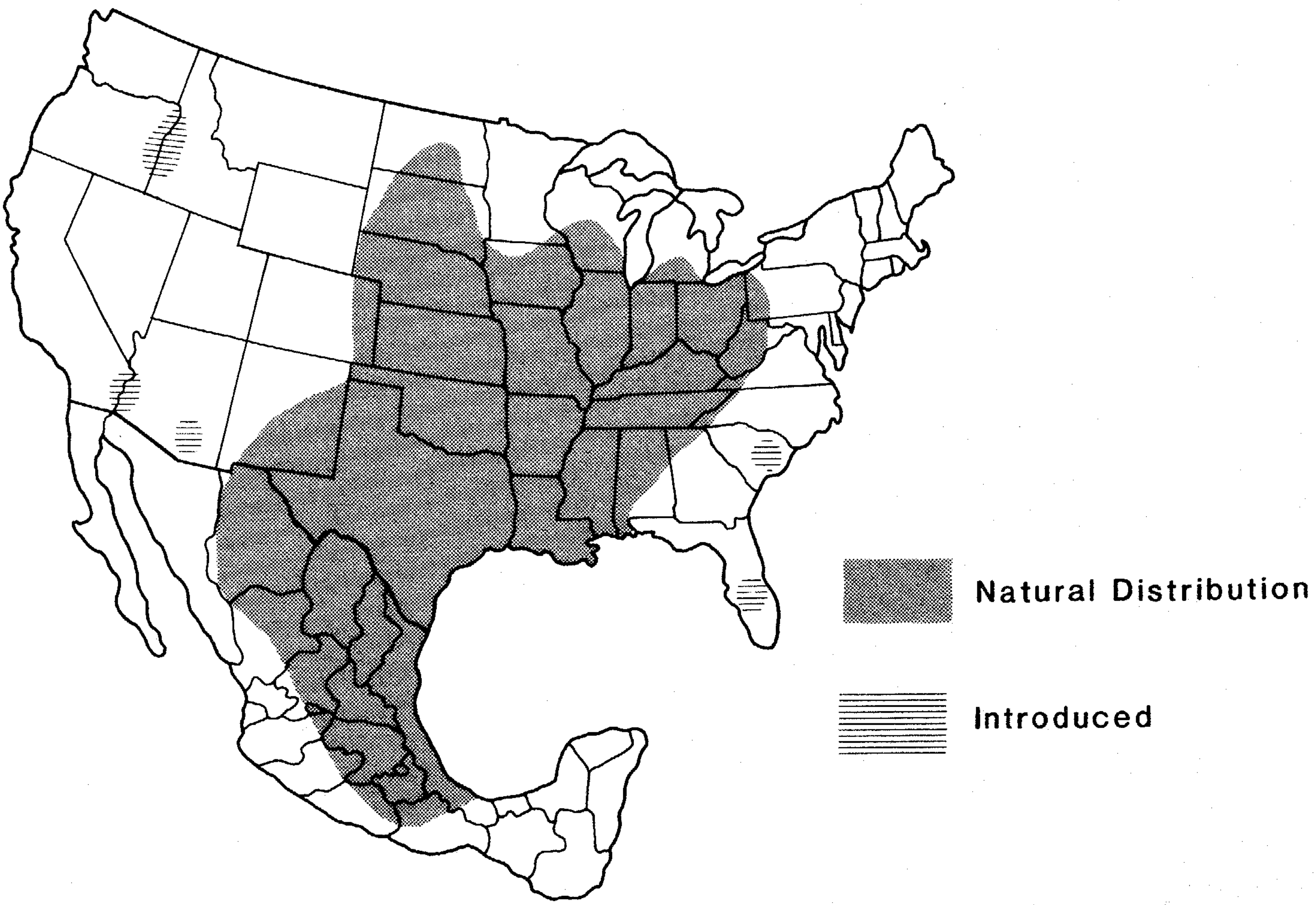


Figure 1. Distribution of flathead catfish (Pylodictis olivaris) in North America as adapted from Gholson (1970).

Age, Growth, and Food

Age of flathead catfish is determined in most studies by analyzing the annuli on sections of pectoral or dorsal spines; the latter are considered to provide more accurate readings (Jenkins 1952; Muncy 1957; Layher 1981). Maximum ages of XIV to XVI and maximum lengths of 98 to 150 cm have been reported (Barnickol and Starrett 1951; Brown 1960) (symbols for age follow convention of Carlander, 1969). In Ohio, adults are commonly 38.1 to 114.3 cm and 0.5 to 20.4 kg. The largest Ohio specimen reported was about 135 cm and weighed 37.2 kg (Trautman 1981). Other maximum weights reported include 56.7 kg from the Mississippi River (Bachay 1944) and 42.6 kg from the St. Francis River, Missouri (Trautman 1981). McCoy (1953) reported a 15-year-old flathead catfish that weighed 43 kg and was 140.9 cm. The oldest specimen from Milford Reservoir, Kansas, was 16 years old (Layher and Boles 1979).

Flathead catfish growth is highest in turbid, relatively shallow areas and in the lower portions of streams (Forbes and Richardson 1920; Minckley and Deacon 1959). Jenkins (1952) reported that the growth of flathead catfish was faster in the upper reaches of Grand Lake, Oklahoma (typified by shallow mudflats and relatively turbid water) than in the clear, rocky lower portions of the lake. Minckley and Deacon (1959) suggested that flathead catfish grew faster in the Big Blue River, Kansas, than in the Neosho River because they began feeding on fish at a smaller size. Purkett (1957) indicated that, in Missouri, stream fishes in general tend to grow more rapidly in downstream habitats than in upstream habitats.

Adult flatheads move from deep water or cover at night to feed in riffles and the shallows of pools (Koster 1957; Pflieger 1975; Trautman 1981). Various food habit studies (Forbes and Richardson 1920; Eddy and Swiber 1947; Beckman 1953; Koster 1957; Kansas Forestry, Fish and Game Commission 1962; Turner and Summerfelt 1970; Minckley 1973) indicate that adult flathead catfish are piscivorous throughout their range.

Layher and Boles (1980) found that flathead catfish between 20 to 50 cm ate benthic macroinvertebrates and fish; flatheads >50 cm were entirely piscivorous. Most of the insects eaten were in the orders Ephemeroptera, Trichoptera, and Diptera. Adult flathead catfish (≥20 to 40.6 cm, depending on the study) feed mainly on fish and crustaceans (Brener 1947; Swingle 1954; Minckley and Deacon 1959; Brown and Dendy 1961; Langemeier 1965; Morris et al. 1968; Holz 1969; Singleton 1970; Edmundson 1974). Gizzard shad (Dorosoma cepedianum), freshwater drum (Aplodinotus grunniens), and common carp (Cyprinus carpio) were the fish species most commonly eaten by flathead catfish in studies reported by Minckley and Deacon (1959), Jester (1971), Summerfelt (1971), Turner and Summerfelt (1970, 1971), and Turner (1977); however, many other species are consumed (Table 1). Preference for larger fish increases as flatheads increase in size (Hackney 1966; Swingle 1967; Turner and Summerfelt 1970).

Table 1. Species of fish taken as food by flathead catfish (Morris et al. 1968; Boaze and Lackey 1974; Layher and Boles 1980; Pisano et al. 1983).

Family	Scientific name	Common name
Catostomidae[a]		suckers
Centrarchidae	*Lepomis cyanellus*	green sunfish
	Lepomis macrochirus	bluegill
	Micropterus salmoides	largemouth bass
Clupeidae	*Dorosoma cepedianum*	gizzard shad
	Dorosoma pentenense	threadfin shad
	Alosa pseudoharengus	alewife
Cyprinidae	*Hybognathus nuchalis*	Mississippi silvery minnow
	Hybopsis storeriana	silver chub
	Notropis lutrensis	red shiner
	Cyprinus carpio	common carp
Ictaluridae	*Pylodictis olivaris*	flathead catfish
	Ictalurus punctatus	channel catfish
Percidae[a]		perches
Sciaenidae	*Aplodinotus grunniens*	freshwater drum

[a]Only family name is listed in original paper, no species given.

Reproduction

Male flathead catfish in rivers mature somewhere between 33 and 46 cm total length (TL) or between 3 to 5 years of age (Barnickol and Starrett 1951; Minckley and Deacon 1959; Langemeier 1965; Morris et al. 1968; Holz 1969). In reservoirs, males mature between 4 to 5 years of age (40.6 to 42.5 cm TL) (Turner and Summerfelt 1970, 1971; Turner 1977). Female flathead catfish in rivers mature in 3 to 6 years (35 to 51 cm TL) (Barnickol and Starrett 1951; Minckley and Deacon 1959; Langemeier 1965; Morris et al. 1968; Holz 1969). In reservoirs, females mature in 5 to 7 years (45.8 to 58 cm TL) (Turner and Summerfelt 1970, 1971; Turner 1977). Layher (1976) found that female flathead catfish in Kansas reservoirs mature as early as age IV. Flathead catfish are assumed to mature at larger sizes in reservoirs than in rivers because of faster growth in reservoirs (Sneed et al. 1961). Minckley and Deacon (1959) suggested that the loss of the light patch at the tip of the upper lobe of the caudal fin may indicate sexual maturity in flathead catfish.

Males establish territories for spawning, whereas females appear to move at random (Gholson 1975). Usually, flathead catfish move to the spawning sites and spawn during June and July (Johnson 1950; Beckman 1953; Minckley and Deacon 1959; Langemeier 1965; Holz 1969; Turner and Summerfelt 1970, 1971; Gholson 1972; Moyle 1976; Turner 1977), but sometimes they spawn as early as May (Forbes and Richardson 1920; Snow 1959; Henderson 1965) or as late as August (Turner and Summerfelt 1970, 1971; Turner 1977).

Nests are usually located in holes in the stream bank (Fontaine 1944; Cleary 1956; Deacon 1961; Kansas Forestry, Fish and Game Commission 1962; Moyle 1976), natural cavities or areas near large submerged objects (Pflieger 1975), crevices in natural rock outcroppings, or areas with dense submerged tree stands (Turner and Summerfelt 1971). Cross (1967) noted that a saucer-shaped depression is excavated in a natural cavity or near a large, submerged object by one or both sexes. He found that flatheads entered and enlarged holes he had dug into a steep clay bank. The holes were about 35.5 cm in diameter and widened to about 81 cm inside the nest chamber. Turner and Summerfelt (1971) reported that flathead catfish in reservoirs prefer to spawn at depths of 2 to 5 m.

The eggs are laid in a compact, golden-yellow mass that may contain 100,000 eggs or more (Trautman 1981). The eggs cling together in an adhesive, gelatinous mass on the substrate (Minckley 1973; Pflieger 1975). The male guards the nest and agitates the eggs with his fins (Breder and Rosen 1966; Minckley 1973). About 6 to 8 days are required for incubation (Fontaine 1944; Snow 1959; Guidice 1965; Henderson 1965; Breder and Rosen 1966; Minckley 1973) at a temperature of between 23.8 to 27.7 °C (Snow 1959; Guidice 1965). The fry are approximately 4 to 11 mm at hatching (Fontaine 1944; Snow 1959) and are guarded by the male for several days (Breder 1935; Fontaine 1943, 1944; Breder and Rosen 1966).

Water temperatures during spawning range between 20 to 25 °C (Henderson 1965; Turner and Summerfelt 1970) and 24 to 29 °C (Snow 1959; Turner and Summerfelt 1971). At the San Marcos Hatchery in Texas, fry failed to absorb their yolk sacs and died when incubated in water at 28.3 °C (Gholson 1971).

Relatively stable water levels, with some spring flooding, evidently improve flathead catfish reproduction and survival in hydropower storage reservoirs (reservoirs where the ratio of water volume at listed surface area to annual discharge volume is >0.165) (Ploskey et al. 1984). Years of successful reproduction were characterized by below-average annual changes in surface area, with above-average increases in surface area in spring (Ploskey et al. 1984). In five flood control reservoirs, Ploskey et al. (1984) reported that flathead catfish reproduction was enhanced by higher than normal rates of water release the previous fall, but low rates in spring (low inflow). Recruitment of intermediate size flathead catfish (those fish >11.4 cm but

≤31.8 cm and at least age I+) to adults apparently is increased in years when spring flooding and surface area of a flood control reservoir is higher than average, but when summer drawdown is more extensive than usual.

Specific Habitat Requirements

Flathead catfish habitat requirements vary with age and habitat. Young flathead catfish are often found in riffles (Hubbs and Lagler 1947; Koster 1957; Minckley and Deacon 1959; Pflieger 1971, 1975; Gholson 1975; Smith 1979). Minckley and Deacon (1959) reported that young-of-the-year flathead catfish remain in swift, rubble-bottomed riffles until they are 5.1 to 10.2 cm TL. In streams, Minckley and Deacon (1959) found that catfish 10.2 to 30.4 cm were generally dispersed; catfish 30.4 to 40.6 cm were associated with intermediate depths and cover (logs, brush piles, and downed trees), and catfish >40.6 cm were solitary and associated with cover in deep pools. Young catfish are active only at night (Pflieger 1975). The literature did not address the distribution of young-of-the-year flathead catfish in streams lacking riffles or in reservoirs.

Flathead catfish are most abundant in large rivers (Eddy and Surber 1947; Hubbs and Lagler 1947; Beckman 1953; Cleary 1956; Koster 1957; Minckley and Deacon 1959; Pflieger 1971, 1975; Minckley 1973; Moyle 1976; Trautman 1981) and reservoirs (Koster 1957; Minckley and Deacon 1959; Gholson 1971; Pflieger 1975; Moyle 1976). Based on limited information provided by Buck (1956), Brown (1960), Cross (1967), and Moyle (1976), flathead catfish populations are higher in turbid than in clear water bodies. In large rivers, Trautman (1981) found that flathead catfish were most abundant in large, sluggish, deep pools located in low-gradient sections. Although the species inhabits extremely turbid streams, it is significant that in such streams flatheads are usually found over hard bottoms; when they are found over silt bottoms, it is in areas where silt deposition is low (Trautman 1981). Pflieger (1975) stated that the flathead catfish inhabits a variety of stream types, but avoids streams with high gradients or intermittent flow. The term "high gradient" was not defined.

Adults usually are found associated with submerged logs or other cover (Pflieger 1975; Smith 1979). In Texas, Gholson (1975) reported that flathead catfish were most abundant near rocks, shoals, log jams, brush tops, ledges, submerged trees, and other structures that afford cover and also are associated with current. Minckley and Deacon (1959) found that debris piles ≥3 m and ≤12 m in diameter each yielded two or three large flathead catfish. Fish were absent from areas out of the main current and having soft, silty bottoms, even when these areas afforded cover. Few catfish were found in slack-water habitats such as backwaters and the upper ends of coves. In reservoirs, Layher and Boles (1980) suggested that the availability of rock rip-rap, rather than the amount of forage fish, limited flathead catfish populations. The rip-rap was used by flathead catfish for cover, spawning, and feeding on small gizzard shad that were grazing on rip-rap periphyton.

Based on selection and avoidance of thermal zones in the Wabash River, Indiana, the preferred temperature range of 100- to 200-mm flatheads is 31.5 to 33.5 °C (Gammon 1973). Stauffer (1975) studied the ichthyofauna of the New River, Virginia, to determine the effects of a fossil fuel plant on fish behavior, condition, community structure, and distribution. He found flatheads in water of 21.7 to 30 °C (71 to 86 °F), with highest abundance at 27.2 °C. The temperature range (21.7 to 30 °C) at which flathead catfish were found probably also is the range where adult growth occurs.

HABITAT SUITABILITY INDEX (HSI) MODELS

Two types of habitat models for flathead catfish are developed below for assessing different types of habitat impacts. Since flathead catfish are often closely associated with cover, both for spawning and other activities, a riverine cover model is presented for assessing general adult cover requirements. In conjunction with general habitat requirement information obtained from the literature and stream standing crop data from Dr. W.G. Layher (Kansas Fish and Game, Box 54A, Route 2, Pratt, Kansas 67124; pers. comm.), a macrohabitat model was developed for quantifying impacts of changes in macrohabitat variables other than cover, using suitability index (SI) graphs.

Model Applicability

Geographic area. The riverine cover model was designed for use throughout the flathead catfish's range. However, the model assumption that growing seasons and nutrient levels of compared habitats are similar, would likely be violated if the model was used to compare habitats from very different geographical areas. The macrohabitat model should be useable throughout the species range, even though the SI graphs are derived primarily from Kansas data. The habitat area to which the models are applied should be representative of the entire habitat that is being evaluated.

Season. The riverine adult cover model provides a rating for riverine habitat based on its ability to support adult flathead catfish through all seasons of the year. Supplemental information is described for estimating the quantity of spawning habitat but reproductive requirements are not rated with the model. The macrohabitat model provides a rating assumed to represent the ability of the habitat to support adult and juvenile flathead catfish on a year-round basis, based on habitat variable measurements collected during average summer flow.

Verification level. The riverine cover model produces an index between 0 and 1 that is assumed to represent the upper limit to adult population densities on a ratio scale. The cover model has not been evaluated in the field, and its ability to describe population limits has not been tested. The relationship of the macrohabitat SI graphs to Kansas stream mean standing crops is presented with each graph. The ability of the graphs to predict population limits in other areas has not been tested. Reviewer comments on model assumptions and interpretations of the cited literature have been incorporated, but reviewers did not necessarily believe that the models would be accurate predictors of the upper limits to adult population densities.

Model Description - I. Riverine Adult Cover

Overview. The riverine cover model attempts to condense habitat use information into a manageable set of habitat evaluation criteria and is structured to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat) for adult flathead catfish habitat. A positive relationship between HSI and number of adults that the habitat could support is assumed. The flathead catfish HSI determined by the use of the cover model is not assumed to represent the existing population of flathead catfish because existing population size is not totally determined by the presence of cover. If the model represents actual adult cover requirements, then adult flathead catfish populations should not exceed the limits imposed by cover requirements on a year-round basis. The proper interpretation of the cover-based HSI is one of comparison. If two riverine habitats have different HSI's, the one with the higher HSI should be able to support more flathead catfish per unit area than the one with the lower HSI, given the model assumptions have not been violated and there are no limiting effects of variables not included in the model. The assumptions for using the riverine cover-based model are presented below. If any assumption cannot be met, the model should not be used. The model makes extensive use of flathead catfish densities reported by Minckley and Deacon (1959) from only six individual debris piles. Model users should use different densities in the model to estimate the maximum number of adults likely to be associated with debris piles and other forms of cover if more extensive data on use of debris are available.

Assumption 1. Growing season and nutrient levels of compared habitats are similar. The cover model does not contain a food component. Therefore, it should only be used to compare habitats with similar nutrient levels and growing seasons. We assume that, if nutrient levels and growing seasons are similar, the food-induced population limits will be the same in the compared habitats and that comparisons of the habitat variables listed in the model can lead to a realistic comparison of population limits.

Assumption 2. The streams to be compared have an average width ≥9.3 m and a low gradient. Trautman (1981) suggested that flathead catfish occur most abundantly in sluggish, long, deep pools of the low gradient portions of large streams. We assume that a river with an average width ≥9.3 m (Table 2) meets Trautman's (1981) size criteria for a large stream. The model also uses variables such as number of debris piles >12 m in diameter, which may be inappropriate for small streams. Therefore, we recommend that streams with average widths <9.3 m not be evaluated with the cover model.

The class boundaries defining "low" gradient shown in Table 2 were developed for Ohio streams by Trautman (1981). If the stream gradient is determined to be greater than "low" by the above criteria, we recommend that the stream not be evaluated with the cover model.

Table 2. Average stream width (m) and corresponding values (m/km) for low gradient as defined by Trautman (1981).

Average stream width (m) at normal summer flow	Low gradient (m/km)
9.3 - 13.8	0.20 - 1.0
13.9 - 30.6	0.10 - 0.8
30.7+	0.02 - 0.2

Assumption 3. Temperature range allows for adult growth and reproduction; temperature fluctuations do not reduce embryo survival. Use the information in the narrative, personal experience, and other available information to determine if a given temperature regime is likely to be limiting populations. We have not developed specific criteria to meet assumption 3. Numerous combinations of harmful ranges in fluctuation and duration of temperature change are possible. The purpose of this assumption is that if temperatures are likely to be limiting populations, habitat comparisons based on cover may not describe the actual population limits, and thus model ratings might not be very useful.

Riverine Adult Cover Model Application

The riverine adult cover model requires measurement of five classes of cover: debris piles over a hard bottom (e.g., substrate other than silt), debris piles over silt, surface area of pools ≥12 m in length or width at mean summer flow, number of isolated logs, and linear extent of undercut banks (Figure 2). The maximum number of adults that are likely to be supported by each class of cover is estimated as described below. The sum of the individual estimates of maximum number of adults likely to be supported by each class of cover is converted to an HSI by dividing the sum by the number of adults that are assumed to occur in optimum habitat. The model is based primarily on a study by Minckley and Deacon (1959), which described numbers of adult flatheads found associated with six debris piles of varying size and shape.

Habitat variables	Life requisite	Estimated parameter
Number of debris piles ≥3 m and <12 m in diameter over a hard bottom		
Area (m^2) of debris piles ≥12 m in diameter over a hard bottom		
Number of debris piles ≥3 m and <12 m in diameter surrounded predominantly by silt substrate		
Area (m^2) of debris piles ≥12 m in diameter surrounded predominantly by silt substrate		
Area (m^2) of pools ≥12 m in length or width with no debris that could serve as cover and deep enough at mean summer flow to obscure >50% of the bottom		
Number of "isolated" (≥12.6 m distant from other logs) logs ≥3 m and ≤12.6 m in length and ≥0.3 m in diameter	Adult cover	Maximum number of adults likely to occupy the area sampled
Average length (m) of "isolated" (≥12.6 m distant from other logs) logs >12.6 m in length and ≥0.3 m in diameter		
Number of "isolated" (≥12.6 m distant from other logs) logs >12.6 m in length and ≥0.3 m in diameter		
Total length (m) of each undercut bank that is ≥12.6 m in length and ≥0.3 m in diameter		
Number of "isolated" (>12.6 m from other cover objects) undercut banks ≥3 m and <12.6 m in length and ≥0.3 m in diameter		

Figure 2. Habitat variables in the riverine adult cover model for flathead catfish.

The potential number of adults associated with debris piles is calculated by classifying debris piles into two size classes: (1) ≥3 m and <12 m in diameter and (2) ≥12 m in diameter. The assumptions for the calculations are based on the statements of Minckley and Deacon (1959) who found that a pile of debris about 3 m in diameter was occupied by one large (>40.6 cm) individual, whereas debris ≥3 m and ≤12 m in diameter yielded two or three large individuals. We developed the model from this statement by assuming that a debris structure ≥3 m and <12 m in diameter is likely to support two adult flathead catfish. The area of a round debris pile 12 m in diameter is 113 m^2, or about 38 m^2 per adult catfish (assuming a maximum of three fish). Therefore, the total area of large (≥12 m diameter) debris piles divided by 38 m^2 should yield a reasonable estimate of the number of adults associated with large debris piles. Trautman (1981) reported that flatheads are usually found over a hard bottom; when they are found over a silt bottom it is in areas where silt deposition is slow. Hence, we assumed that if the debris structure is over a hard substrate, the debris structure should support the maximum number of adults, but if the substrate is silt, fewer individuals would use the structure. In equation form:

$$FC_{DH} = 2(DH) + AH/38 \qquad (1)$$

where FC_{DH} = potential number of adult flathead catfish associated with debris piles, over a hard bottom, in the area sampled

DH = number of debris piles ≥3 m and <12 m in diameter located over a hard bottom

AH = total area (m^2) of debris piles ≥12 m in diameter located over a hard bottom

38 = the area (m^2/catfish) of debris piles required to provide cover for one adult catfish

To quantify the assumed reduced suitability of debris overlying a silt substrate, we suggest modifying the above equation by multiplying by a factor of two-thirds. In equation form:

$$FC_{DS} = 2/3[2(DS) + AS/38] \qquad (2)$$

where FC_{DS} = potential number of adult flathead catfish associated with debris piles, over a predominantly silt substrate, in the area sampled

DS = number of debris piles ≥3 m and <12 m in diameter located over a silt bottom

AS = total area (m^2) of debris piles ≥12 m in diameter located over a silt bottom

38 = the area (m^2/catfish) of debris piles required to provide cover for one adult catfish

Minckley and Deacon (1959) collected adult flatheads in open pool areas away from cover. We assumed that fish would use pools without object or cavity cover if the pools were deep enough so that >50% of the bottom was normally obscured during the mean summer flow and if the pools met some minimum size criteria. There were no specific data addressing minimum pool size criteria. We assumed that a pool with a width or length of at least 12 m (near the midrange of the average stream width for the smallest stream size class (Table 1) to which the model should be applied) would be large enough to be used as cover by adult flatheads. Data describing flathead catfish densities in pools without cover were lacking, so we selected a density (one 3-kg fish/ha of pools without cover) that was much lower than the average standing crop (9 kg/ha) of flathead catfish in Kansas streams reported by Layher (pers. comm.). In equation form:

$$FC_p = P/10,000 \qquad (3)$$

where FC_p = potential number of adult flathead catfish associated with pools ≥12 m in length or width, with no debris that could serve as cover, and deep enough at mean summer flow to obscure >50% of the bottom, in the area sampled

P = total area (m^2) of pools meeting the above criteria

10,000 = the area (m^2/catfish) of open pools required to support one adult catfish

Minckley and Deacon (1959) reported that an isolated log ≥3 m in length and ≥0.3 m in diameter provides cover for one adult flathead catfish; however, minimum distance criteria for defining "isolated" were not provided. We estimated a minimum distance to define "isolated" from Minckley and Deacon's (1959) statement that as many as three adult flatheads will occupy a debris structure with a diameter of 12 m. Assuming a debris structure is roughly circular in shape, there would be approximately 12.6 m of circumference (but not straight line distance) between each individual fish located in the debris structure. Therefore, to be classified as "isolated" a log must be at least 12.6 m away from other logs. Scattered logs closer than 12.6 m from one another, would be evaluated as a single "isolated" log. In equation form:

$$FC_{SL} = SL \tag{4}$$

where FC_{SL} = potential number of adult flathead catfish associated with small (≥3 m and ≤12.6 m in length and ≥0.3 m in diameter), "isolated" (≥12.6 m distant from other logs) logs in the area sampled

SL = number of isolated logs meeting above criteria

If a single isolated log were long enough, we assumed that more than one catfish could use the log at the same time. In this case, we assumed that a log must be at least 18.6 m long to provide cover for two adult flathead catfish (i.e., 9.3 m per adult catfish). The value 18.6 m was determined by multiplying the minimum length (3 m) necessary for a log to be used as cover, by two, and adding the result to the minimum distance requirement (12.6 m) derived for catfish in debris piles. Thus, we assumed that 3 m of distance was needed for each flathead catfish to move about freely at the end of a log, without encroaching on the 12.6 m space requirement of the other fish. To determine the potential number of adult flathead catfish associated with large (>12.6 m in length) "isolated" logs in the study area, the following equation was developed from the above assumptions:

$$FC_{LL} = (L)(N)/9.3 \tag{5}$$

where FC_{LL} = potential number of adult flathead catfish associated with large (>12.6 m in length and ≥0.3 m in diameter), "isolated" (≥12.6 m distant from other logs) logs in the area sampled

L = average length (m) of "isolated" logs >12.6 m in length and ≥0.3 m in diameter

N = number of "isolated" logs >12.6 m in length and ≥0.3 m in diameter

9.3 = length (m/catfish) of log required per adult catfish

There are some theoretical problems with the above equation, when applied to logs with an average length <18.6 m, because by the above reasoning, a mean length between 12.6 and 18.6 m would only support one fish, although individual logs ≥18.6 m in length would support two fish and could be present if the mean was in this range. However, given the imprecise nature of the original data, we believe the estimate of potential number of fish based on the <u>average</u> length of many logs will be useful for comparative purposes.

Flatheads also use undercut banks for cover, and we assumed that an undercut bank must be as long as a log qualifying as cover (≥3 m) to qualify as suitable cover. We used the proposed 12.6 m minimum distance requirement, and assumed that the ends of an undercut bank would provide isolation from neighboring fish on one side, in order to estimate the potential number of adults associated with undercut banks. Thus, an undercut bank must have a minimum length of 25.2 m to accommodate three flathead catfish (one fish at each end, each of which is isolated by the end of the undercut plus one fish in the middle), and a minimum length of 37.8 m to hold four, etc. We assume that one catfish could occupy an undercut bank ≥3 m but <12.6 m in length if the undercut bank meets the minimum dimension requirements (≥0.3 m diameter, same as a log) and is separated from other undercut banks or cover objects by a minimum spatial requirement to qualify as isolated. We selected 12.6 m as the distance criteria for isolated. In equation form:

$$FC_{UB} = \sum_{i=1}^{n} \left(\frac{B_i}{12.6} + 1 \right) + NU \qquad (6)$$

where FC_{UB} = potential number of adult flathead catfish associated with undercut banks ≥3 m in length and ≥0.3 m in diameter, in the area sampled

B_i = total length (m) of each undercut bank (i) that is ≥12.6 m in length and ≥0.3 m in diameter

NU = the number of fish per isolated undercut bank (1 fish/isolated bank) times the number of "isolated" (>12.6 m from other cover objects) undercut banks ≥3 m in length and ≥0.3 m in diameter, but <12.6 m in length

12.6 = the minimum distance (m/catfish) between catfish occupying undercut banks

In all of the above equations, we suggest that any "fractions of fish" <.75 should be dropped and fractions ≥.75 rounded up if it is necessary to estimate the number of fish likely to be associated with a single cover class.

Fractions of fish for individual classes of cover would not be rounded off in calculations involving several classes of cover, in order to avoid accumulating rounding errors.

Simplified version of the model. The above model is based on a detailed field inventory, including size classification of undercut banks, logs, and debris piles, and measuring distance between logs. This type of inventory is difficult and time consuming, even in clear water. Turbid conditions would likely necessitate the use of electronic sensing devices, which might not provide dimension measurements for objects. Classification of objects into the various classes of cover and measurement of object dimensions would be more difficult without easy visual verification. A simplified version of the model would be useful for turbid conditions or when application time is limited. The following simplification uses the logic described for the detailed model, but requires less identification of size classes and no distance measurements between cover objects.

Assume 1 adult per 38 m^2 of object cover, where object cover equals any debris pile, log, rip-rap, or other cover material.

Assume 1 adult per 12.6 m of undercut bank.

Assume 1 adult per 10,000 m^2 of pool area where >50% of the bottom is not visible at average summer flow, and the pool area does not have any object cover as defined above.

Area (m^2) estimates of cover classes can be derived by multiplying the estimated percent cover along a linear transect times the area represented by the transect. The estimated number of adults per hectare for the simplified model would be converted to an HSI using the same standard of comparison described in the following section for the complete model.

Riverine adult cover model HSI calculation. Add the potential number of adults estimated to be associated with each class of cover and divide the sum by the size (hectares) of the area to which the estimate applies. The quotient is the potential number of adults per hectare. Divide the quotient by the assumed optimum number (6) of adults per hectare (inverse equals 0.17 ha/fish) to convert the potential number of adults per hectare to a 0 to 1 HSI scale. In areas of abundant cover, this division could result in a number >1, in which case 1 (the maximum allowable value for an HSI) should be selected as the HSI. In equation form:

$$HSI = \frac{FC_{DH} + FC_{DS} + FC_{P} + FC_{SL} + FC_{LL} + FC_{UB}}{\text{number of hectares represented}} \times 0.17 \text{ ha/fish} \qquad (7)$$

or HSI = 1, whichever is lower

where 0.17 = the quotient (ha/fish) of 1 ha per 6 fish

other variables = defined earlier for equations 1-6

To obtain the average HSI for two or more areas, calculate the area weighted mean HSI.

The number of adults per hectare for a large area of optimum habitat was estimated as follows:

1. Kansas stream survey data provided by Layher (pers. comm.) indicated an average stream standing crop of 9 kg/ha, with a standard error of 5 kg/ha.

2. We assumed that the mean plus two standard errors (19 kg) was a good estimate of the maximum standing crop likely to occur in a large area of optimum habitat. A few standing crop estimates in the data base provided by Layher (pers. comm.) far exceeded 19 kg/ha. We assumed that these high values represented temporary concentrations in small sample areas that could not be sustained for a long period of time or for a large area.

3. We assumed that the average weight of adult catfish was equal to the average weight (3 kg) for 4- to 7-year-old fish in Oklahoma (Carlander 1969). The "maximum" standing crop (19 kg/ha) was then divided by the average weight (3 kg) of one adult flathead catfish to arrive at six adult flathead catfish per hectare as the "standard of comparison," representing the maximum number of adults for a large area of optimum habitat.

4. The HSI cannot exceed 1 (U.S. Fish and Wildlife Service 1980). Therefore, the HSI equals 1 or the estimated potential number of adults per hectare divided by 6, whichever is smaller.

Table 3 presents a hypothetical data set for the riverine adult cover model, and Table 4 shows how to perform the calculations. Habitat variable values are provided for two subsections of a study area. In an actual study, these habitat variable values would likely be estimated from data collected along transects. The model assumptions should be met, of course, before the model is applied.

Table 3. Hypothetical data set for the riverine adult cover model.

Variable	Subsection of total study area A (9 ha)	B (7 ha)
Number of debris piles ≥3 m and <12 m in diameter over:		
hard bottom	2	3
silt bottom	1	2
Area (m^2) of debris piles ≥12 m in diameter:		
hard bottom	136	117
silt bottom	126	121
Area (m^2) of pools (≥12 m in length or width), with no debris that could serve as cover and deep enough at mean summer flow to obscure >50% of the bottom	13,100	12,300
Number of "isolated" (≥12.6 m distant from other logs) logs ≥3 m and ≤12.6 m in length and ≥0.3 m in diameter	7	2
Average length (m) of "isolated" (≥12.6 m distant from other logs) logs >12.6 m in length and ≥0.3 m in diameter	14	13
Number of "isolated" (≥12.6 m distant from other logs) logs >12.6 m in length and ≥0.3 m in diameter	9	3
Total length (m) of each undercut bank (i) that is ≥12.6 m in length and ≥0.3 m in diameter	51; 27	21
Number of "isolated" (>12.6 m from other cover objects) undercut banks ≥3 m and <12.6 m in length and ≥0.3 m in diameter.	7	3

Table 4. Sample calculations for the riverine adult cover model (based on Table 3). Subsection A = 9 ha, subsection B = 7 ha.

<u>Equation</u>

$$FC_{DH} = 2(DH) + AH/38$$

where FC_{DH} = potential number of adult flathead catfish associated with debris piles, over a hard bottom, in the area sampled

DH = number of debris piles ≥3 m and <12 m in diameter located over a hard bottom

AH = total area (m^2) of debris piles ≥12 m in diameter located over a hard bottom

38 = the area (m^2/catfish) of debris piles required to provide cover for one adult catfish

<u>Subsection A</u> $2(2) + (136\ m^2/38\ m^2) = 7.58$ adults

<u>Subsection B</u> $2(3) + (117\ m^2/38\ m^2) = 9.08$ adults

<u>Equation</u>

$$FC_{DS} = 2/3[2(DS) + AS/38]$$

where FC_{DS} = potential number of adult flathead catfish associated with debris piles, over a predominantly silt substrate, in the area sampled

DS = number of debris piles ≥3 m and <12 m in diameter located over a silt bottom

AS = total area (m^2) of debris piles ≥12 m in diameter located over a silt bottom

38 = the area (m^2/catfish) of debris piles required to provide cover for one adult catfish

(Continued)

<u>Subsection A</u> $2/3[2(1) + (126\ m^2/38\ m^2)] = 3.56$ adults

<u>Subsection B</u> $2/3[2(2) + (121\ m^2/38\ m^2)] = 4.79$ adults

<u>Equation</u>

$$FC_p = P/10{,}000$$

where FC_p = potential number of adult flathead catfish associated with pools ≥12 m in length or width, with no debris that could serve as cover and deep enough at mean summer flow to obscure >50% of the bottom, in the area sampled

P = total area (m^2) of pools meeting the above criteria

10,000 = the area (m^2/catfish) of open pools required to support one adult catfish

<u>Subsection A</u> $13{,}100\ m^2/10{,}000\ m^2 = 1.31$ adults

<u>Subsection B</u> $12{,}300\ m^2/10{,}000\ m^2 = 1.23$ adults

<u>Equation</u>

$$FC_{SL} = SL$$

where FC_{SL} = potential number of adult flathead catfish associated with small (≥3 m and ≤12.6 m in length and ≥0.3 m in diameter), "isolated" (≥12.6 m distant from other logs) logs in the area sampled

SL = number of isolated logs meeting above criteria

<u>Subsection A</u> 7 = 7 adults

<u>Subsection B</u> 2 = 2 adults

(Continued)

Equation

$$FC_{LL} = (L)(N)/9.3 \text{ m}$$

where FC_{LL} = potential number of adult flathead catfish associated with large (>12.6 m in length and ≥0.3 m in diameter), "isolated" (≥12.6 m distant from other logs) logs in the area sampled

L = average length (m) of "isolated" logs >12.6 m in length and ≥0.3 m in diameter

N = number of "isolated" logs >12.6 m in length and ≥0.3 m in diameter

9.3 = length (m/catfish) of log required per adult catfish

Subsection A (14 m x 9/9.3 m) = 13.55 adults

Subsection B (7 m x 3/9.3 m) = 2.26 adults

Equation

$$FC_{UB} = \sum_{i=1}^{n} \left(\frac{B_i}{12.6} + 1 \right) + NU$$

where FC_{UB} = potential number of adult flathead catfish associated with undercut banks ≥3 m in length and ≥0.3 m in diameter, in the area sampled

B_i = total length (m) of each undercut bank (i) that is ≥12.6 m in length and ≥0.3 m in diameter

NU = the number of fish per isolated undercut bank (1 fish/isolated bank) times the number of "isolated" (>12.6 m from other cover objects) undercut banks ≥3 m in length and ≥0.3 m in diameter, but <12.6 m in length

12.6 = the minimum distance (m/fish) between catfish occupying undercut banks

(Continued)

Table 4. (Concluded)

Subsection A $[(51 \text{ m}/12.6 \text{ m}) + 1] + [(27 \text{ m}/12.6 \text{ m}) + 1] + 7 = 15.19$ adults

Subsection B $[(21 \text{ m}/12.6 \text{ m}) + 1] + 3 = 5.67$ adults

		Subsection A	Subsection B
Sum (estimated number of fish for all classes of cover)	=	48.19	25.03
Subsection HSI (all units cancel)	=	$\frac{48.19 \text{ fish}}{9\text{ha}} \times \frac{1 \text{ ha}}{6 \text{ fish}} = 0.89$	$\frac{25.03 \text{ fish}}{7 \text{ ha}} \times \frac{1 \text{ ha}}{6 \text{ fish}} = 0.6$

Total study area HSI (area weighted mean) = $\frac{0.89 \ (9 \text{ ha}) + 0.6 \ (7 \text{ ha})}{16 \text{ ha (total)}} = 0.76$

or

$$\frac{(48.19 \text{ fish} + 25.03 \text{ fish})}{(9 \text{ ha} + 7 \text{ ha})} = \frac{73.22 \text{ fish}}{16 \text{ ha}} \times \frac{1 \text{ ha}}{6 \text{ fish}} = 0.76$$

Riverine Reproductive Cover Information

According to Fontaine (1944), Cleary (1956), Deacon (1961), Kansas Forestry Fish and Game Commission (1962), and Moyle (1976), flathead catfish prefer to nest in cave-like structures, e.g., natural cavities or areas near large submerged objects (Pflieger 1975), crevices in rock outcroppings, and off-shore areas with dense submerged tree stands. In equation form:

$$FC_{NS} = S \qquad (8)$$

where FC_{NS} = potential number of nest sites in the study area

S = number of "structures" (holes in banks, hollow logs, or crevices) inundated during spawning season and ≥0.4 m in diameter

Flathead catfish in reservoirs prefer to spawn at depths of 2 to 5 m (Turner and Summerfelt 1971) and use cavities ≥0.4 m in diameter (Cross 1967). However, these depth requirements may have been at least partially due to wave action and water level fluctuation and would not have to be met in a stream. We found no data describing the maximum number of nest sites that can be used per unit area of cover, but we assume that seasonal spawning concentrations of fish could be much higher than the mean standing crop present during the remainder of the year. The potential number of nest sites can be estimated using the criteria defined in equation 8 but the estimate is not converted to an HSI.

Model Description - II. Macrohabitat Suitability Index (SI) Graphs

We obtained an unpublished data set from Dr. W.G. Layher (Kansas Fish and Game Commission, pers. comm.) that displays flathead catfish mean standing crops associated with specific ranges of the same physical and chemical variables used by Layher and Maughan (1985) to develop SI curves for channel catfish. The flathead catfish data set contained an exceptionally high (1,061.1 kg/ha) standing crop estimate for one sample site. We assumed this observation represented an unusual concentration in a small sampling area. Hence, we eliminated it from the data set and calculated mean standing crop (Table 5) for the original ranges of the physical and chemical variables in the data set. Since sample sizes associated with the original variable ranges were often small and trends in mean standing crop were irregular, we calculated a weighted (by number of standing crop observations for the original ranges of each variable) mean standing crop for larger variable ranges (last column of Table 5). This produced a more consistent trend in mean standing crop between variable ranges, although with fewer groups of variable ranges the differences in standing crops were often large.

Table 5. Mean flathead catfish standing crops in Kansas streams related to increments of physical and chemical variables. (Original data from Layher (pers. comm.). All variables measured at time of fish sampling except stream gradient, which was estimated from a topographical map).

Physical or chemical variable	Range ($n_1 \geq x < n_2$)	N	Mean standing crop (kg/ha)	Weighted mean standing crop (kg/ha) for combined ranges
(V1) Stream gradient (m/km)	0 - 1	64	23.0	22.90
	1 - 2	16	22.5	
	2 - 3	1	1.0	4.00
	3 - 3.4	1	7.0	
(V2) Turbidity (JTU)	0 - 30	30	26.1	24.00
	30 - 60	9	17.0	
	60 - 90	2	1.0	
	90 - 270	1	0.1	2.65
	270 - 280	1	8.5	
(V3) Mean velocity (m/s)	0 - 0.25	52	41.0	35.76
	0.25 - 0.5	11	11.0	
	0.5 - 0.75	3	25.2	13.77
	0.75 - 1.25	4	5.2	
	1.25 - 1.5	1	5.3	6.20
	1.5 - 1.7	1	7.1	
(V4) Riffle (%)	0 - 15	49	20.0	20.84
	15 - 30	16	23.4	
	30 - 45	7	17.5	14.71
	45 - 75	3	8.2	
	75 - 88	2	5.5	5.50
(V5) Run (%)	0 - 15	25	26.1	
	15 - 30	5	25.0	24.63
	30 - 45	12	21.4	
	45 - 60	2	4.4	
	60 - 75	8	19.0	17.22
	75 - 90	5	19.5	
	90 - 100	19	12.0	12.00
(V6) Pool (%)	0 - 15	27	11.1	11.10
	15 - 30	5	30.2	
	30 - 45	11	10.1	21.56
	45 - 60	7	33.4	
	60 - 75	8	28.0	
	75 - 90	6	46.0	32.86
	90 - 100	14	30.0	

Suitability index (SI) bar graphs (e.g., Figure 3) can be derived from these weighted mean standing crop data (e.g., McMahon et al. 1984) by defining the SI as the fraction of the maximum mean weighted standing crop associated with each range of variable values. For example, for stream gradient, two SI values can be derived by dividing the weighted mean standing crop for each of the two combined ranges of gradient by 22.90 (Figure 3). However, this resulted in only two SI values. A similar loss of resolution occurs for most variables. Therefore, we used the original mean standing crop data from Table 5 and concepts described in Table 6 to derive the continuous SI graphs shown in Figure 4. These graphs represent the concept of suitability for all life stages in an entire water body even though the standing crop data are more representative of adult habitat at a sample site. The data "points" in Figure 4 represent the mean standing crop for the mean of the habitat variable ranges from Table 5. The coordinate pairs define the SI graphs. Table 6 describes the rationale and assumptions used in constructing each of these SI graphs. We did not attempt a "least squares" fit of the data points. Instead we viewed the suitability index as an estimate of the upper limits to standing crop associated with the individual variables, so most data points are on or below the limit represented by the SI graph (see Terrell 1984).

Bar	Coordinates ($n_1 \leq x < n_2$) X	Y
A	0.0-2.0	1.00
B	2.0-3.4	0.17

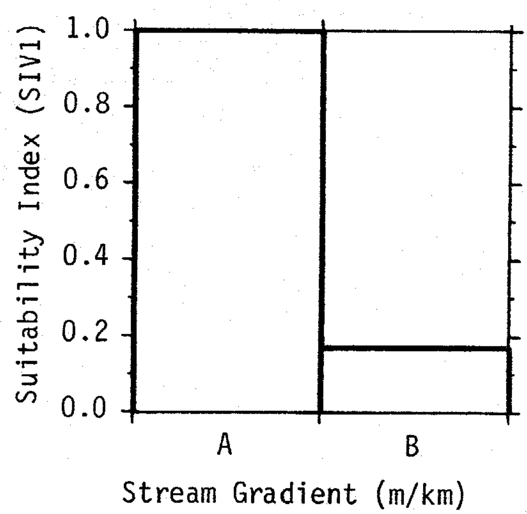


Figure 3. Example suitability index bar graph derived from weighted mean standing crop data for stream gradient in Table 5.

Table 6. Sources of information and rationale used in construction of the suitability index graphs.

Variable	Sources of information and rationale
General assumption	Relative rankings of standing crops for stream sample sites that are small relative to the size of the area a fish occupies during its life cycle do not necessarily indicate the importance of the habitat characteristics of the sample site to all life history phases of the species. Fish spawned or reared away from the sample site may occupy the site as adults. Fish may be only temporary residents of the sample site, so a great deal of judgment is required to determine if sample site characteristics reflect species habitat requirements. Because the biomass of an adult is much greater than the biomass of a juvenile, the importance of the characteristics of individual sample sites to juveniles could easily be underestimated when considering only combined biomass of adults and juveniles.
V1	Flathead catfish prefer low gradient streams (Trautman 1981). Because of this statement and the overall trend of the data points, we assumed that the suitability would decrease as stream gradient increased.
V2	Because of the general nature of the statements in the turbidity references (Buck 1956; Brown 1960; Cross 1967; Moyle 1976), stating that turbid water bodies are likely to support the most flatheads, we placed more emphasis on the data in Table 5, if sample sizes were high. Our turbidity variable is based on the turbidity exceeded more than one-half of the time during the year. We assumed this was at least roughly approximated by the turbidity measured at the time of fish sampling (usually in the summer) for the data presented in Table 5. We felt that the high standing crops and greater sample sizes at low turbidities justified a high suitability rating for low turbidity in spite of the general literature

Table 6 (Continued)

Variable	Sources of information and rationale
V2 (con't)	statements inferring clear water was not the best habitat. The very low standing crops at intermediate turbidities were accompanied by low sample sizes, so we placed more emphasis on the general statements in the literature and assumed intermediate turbidity levels were optimum and higher levels were not as limiting as the data points might indicate.
V3	Flathead catfish prefer low gradient streams. We assumed that increasing gradients are associated with increasing mean velocities, so the suitability decreases as mean velocity increases.
V4	We assumed a low SI near zero percent riffle, because young flathead catfish depend on riffles during their early life history stage (Hubbs and Lagler 1947; Koster 1957). We assumed that the biomass of an adult is much greater than the biomass of a juvenile, hence, the importance of individual sample sites to juveniles could easily be underestimated by looking only at the combined standing crop of adults and juveniles. We assumed that although riffles are important as juvenile habitat, as percent riffles increase, the habitat will, at some point, become less suitable for the entire life cycle because adult flathead catfish are usually found in pools.
V5	There were no references in the literature specifically addressing the significance of the percentage of run habitat in the life history of flathead catfish. We used the data points given in Table 5 as an estimate to population limits except when nearly 100% of the habitat was composed of runs. As referenced earlier, riffles and pools are important in the life history of flathead catfish, and we assumed lack of this habitat over a large study area would reduce standing crops. Samples from small areas of 100% run habitat might not reflect this response because the fish captured would have access to nearby riffle and pool habitat.

Table 6 (Concluded)

Variable	Sources of information and rationale
V6	Adult flathead catfish are predominantly pool dwellers (Pflieger 1975; Smith 1979). There were no data in the literature to define when lack of riffles would become limiting; however, we assumed that the relatively high standing crop (adults plus juveniles) measured at 100% pools is more representative of adult requirements than of the more riffle-oriented juveniles, and thus we show 100% pools as only fair habitat.

Variable

V1 Stream gradient of sample site.

Coordinates

X	Y
0.00	1.00
2.00	1.00
3.00	0.45
3.50	0.20

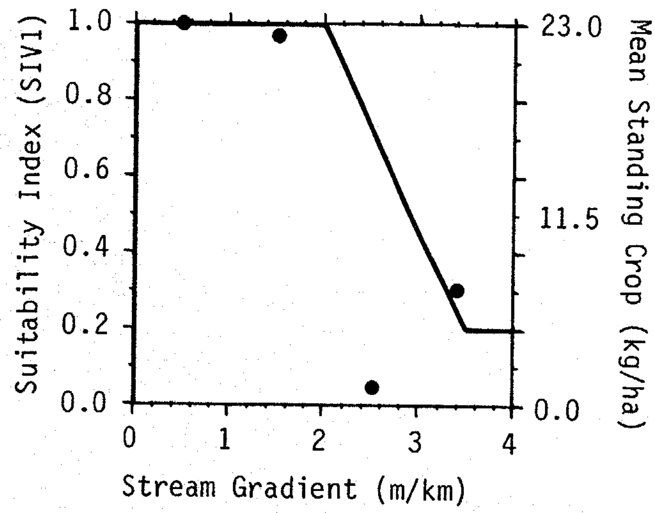


Figure 4. Suitability index graphs based on data in Table 5 and assumptions in Table 6. Data points represent the mean standing crop for the mean of the habitat variable ranges in Table 5. The coordinate pairs define the graph.

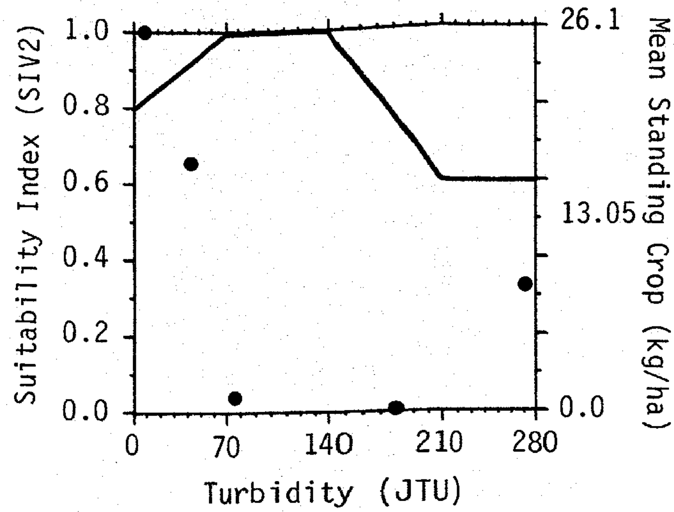
Variable

V2

Highest turbidity level exceeded more than one half time during the year.

Coordinates

X	Y
0.00	0.80
70.00	1.00
140.00	1.00
210.00	0.60
280.00	0.60



V3

Mean water velocity during average summer flow.

Coordinates

X	Y
0.00	1.00
0.30	1.00
0.58	0.50
0.85	0.20
1.70	0.20
1.80	0.10

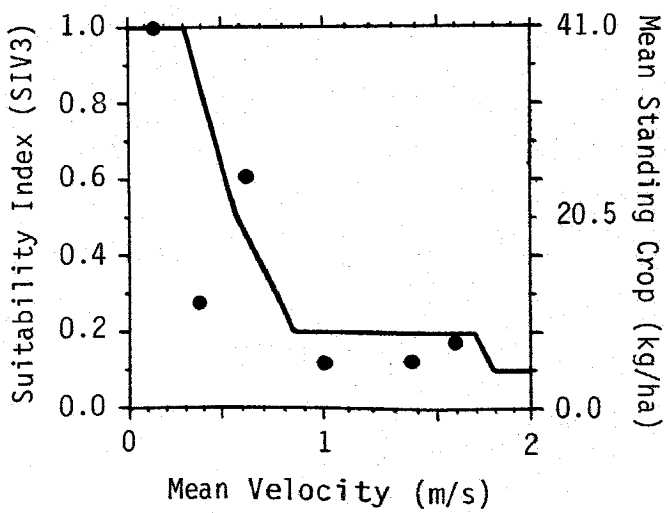


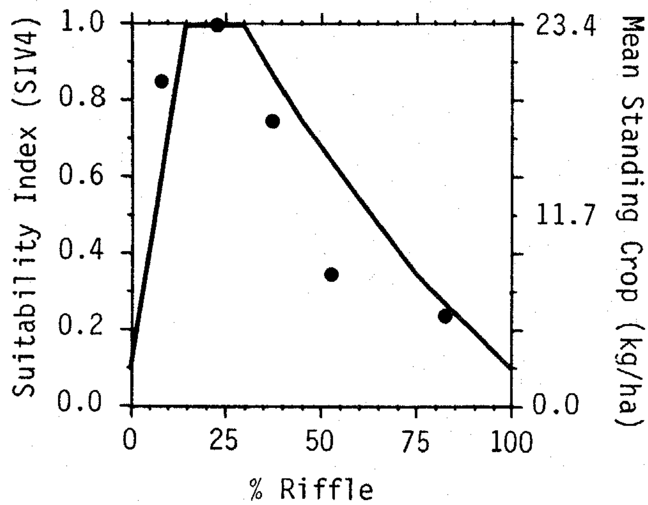
Figure 4. (Continued)

Variable

V4 Percent riffles during average summer flow.

Coordinates

X	Y
0.00	0.10
15.00	1.00
30.00	1.00
45.00	0.75
75.00	0.35
100.00	0.10



V5 Percent runs during average summer flow.

Coordinates

X	Y
0.00	1.00
25.00	1.00
90.00	0.85
100.00	0.50

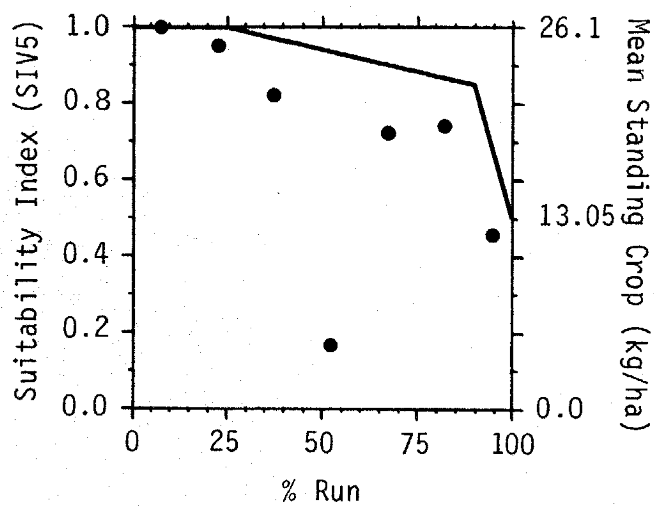


Figure 4. (Continued)

Variable

V6	Percent pools during average summer flow.		
	Coordinates		
	X	Y	
	0.00	0.10	
	60.00	1.00	
	90.00	1.00	
	100.00	0.40	

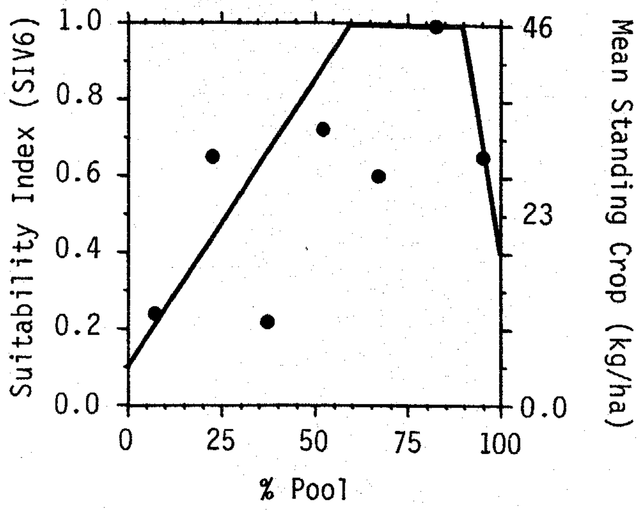


Figure 4. (Concluded)

HSI Calculation Based on Macrohabitat Suitability Index (SI) Graphs

The individual suitability indices represent estimates of the limits to average standing crop imposed by the individual habitat variables in an entire water body or sample site large enough to encompass an individual's range throughout an entire life cycle. To derive an HSI that is a conservative estimate of the standing crop limit imposed by all the model variables, define HSI as the lowest SI measured for any variable. The proper interpretation of the HSI is one of comparison. If two riverine habitats have different HSI's, the one with the higher HSI should have the potential to support more flathead catfish than the one with the lower HSI, if no unmeasured habitat variables are more limiting than the model variables. Model users who have additional standing crop data may want to revise the SI graphs and develop a statistically derived SI aggregation function based on regression analysis as described by Layher et al. (1987).

ADDITIONAL HABITAT MODELS

Reservoir Standing Crop Models

I. Small and intermediate-sized flathead catfish. Ploskey et al. (1984) developed regression equations for predicting the effects of altering seasonal water levels in a reservoir on small (≤114 mm TL) and intermediate-sized (>114 mm and ≤318 mm TL) flatheads. Independent (Table 7) and dependent variables were converted to standard normal deviates (Z values) for the

Table 7. Regression model variables and their definitions from Ploskey et al. (1984).

Variable	Definition
Spring change in area	Difference in surface area on 28 Feb and 31 May
Summer change in area	Difference in surface area on 31 May and 31 Aug
Fall change in area	Difference in surface area on 31 July and 31 Oct (previous year)
Annual change in area	Maximum difference in area per year
Fall area	Mean of surface areas measured on 31 Aug, 20 Sep, and 31 Oct (previous year)
Spring area	Mean of surface areas measured on 28 Feb, 31 Mar, 30 Apr, and 31 May
Spring storage ratio	Mean of monthly storage ratios in Mar, Apr, and May

regression analyses. The dependent variables (biomass and density) for each of the equations were the standard normal deviations in August biomass (kilograms/hectare) or August density (number/hectare). Ploskey et al. (1984) used the following criteria to select the most appropriate regression equations: (1) level of significance of model and parameter estimates, (2) the change in mean square error (MSE), (3) the coefficient of determination (R^2), and (4) the logic of positive or negative correlations. Water exchange and areal variables must first be converted to Z scores as described by Ploskey et al. (1984) in the "Predictive Technique" section of that publication, in order to use the equations.

II. <u>Total standing crop of flathead catfish.</u> Ploskey et al. (1986) developed regression equations for predicting total reservoir standing crops and harvest of flathead catfish (all size classes combined) under various types of reservoir conditions and operations. Table 8 lists the acronyms used in the equations and their corresponding definitions. Distributions of dependent variable values are presented in Table 9. Note that the variables in the equations must be transformed to $\log_{10}$ before the calculations are performed.

Table 8. Acronyms and their definitions as used in equations 1-6 (adapted from Ploskey et al. 1986).

Acronym	Definition
AGE	Number of years since impoundment
MD	Mean depth (ft)
OD	Outlet depth (ft)
F	Fluctuation (ft)
A	Surface area (acres)
MXD	Maximum depth (ft)
TP	Total phosphorous (ppm)
N	Sample size
P	Level of significance of the F-statistic
R^2	Coefficient of determination of the regression equation

Table 9. Distribution of dependent variable values, equations 1-6. Values are expressed as pounds/acre. Mean values are in parentheses. All data and equations are from Ploskey et al. (1986).

Equation	Dependent variable	Lower quartile	Median (mean)	Upper quartile	Maximum
1	Flathead catfish - standing crop	0.5	1.5 (3.9)	4.4	76.0
2	Flathead catfish - standing crop	0.4	1.4 (2.5)	3.5	11.7
3	Flathead catfish - harvest	0.03	0.1 (0.3)	0.4	5.7
4	Flathead catfish - harvest	0.1	0.2 (0.5)	0.5	5.7
5	Flathead catfish - harvest	0.02	0.1 (0.2)	0.2	1.7
6	Flathead catfish - harvest	0.1	0.2 (0.6)	0.5	11.3

1 Regression equation for predicting flathead catfish standing crop (lbs/acre) in nonhydropower reservoirs (dominant ions: calcium and magnesium) (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = -1.0073 + 0.9397 \log(\text{AGE}) - 0.9130 \log(\text{MD}) + 0.5066 \log(\text{OD}) + 0.4830 \log(\text{F})$$

$N = 72 \quad P = 0.0037 \quad R^2 = 0.20$

2 Regression equation for predicting flathead catfish standing crop (lbs/acre) in hydropower storage reservoirs (storage ratio <0.165) (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = -2.8654 + 0.5358 \log(F) + 1.0792 \log(TDS)$$

$N = 45 \quad P = 0.0034 \quad R^2 = 0.24$

3 Regression equation for predicting flathead catfish harvest (lbs/acre) in reservoirs with surface area ≥500 acres (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = -3.0200 + 0.3274 \log(AGE) + 0.6435 \log(TDS) - 0.3479 \log(A) + 0.8063 \log(MXD)$$

$N = 116 \quad P = 0.0010 \quad R^2 = 0.15$

4 Regression equation for predicting flathead catfish harvest (lbs/acre) in reservoirs with surface areas of 500 to 4,000 acres (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = -4.4850 + 0.8037 \log(TDS) - 1.9062 \log(MD) + 2.4438 \log(MXD)$$

$N = 45 \quad P = 0.0040 \quad R^2 = 0.27$

5 Regression equation for predicting flathead catfish harvest (lbs/acre) in reservoirs with surface area ≥4,000 acres (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = -3.6125 + 0.4579 \log(TDS) + 1.4005 \log(MD) - 0.5544 \log(F)$$

$N = 71 \quad P = 0.0031 \quad R^2 = 0.19$

6 Regression equation for predicting flathead catfish harvest (lbs/acre) in reservoirs from descriptive physicochemical and National Eutrophication Survey data (Ploskey et al. 1986).

$$\log(\text{flathead catfish}) = 2.2791 + 1.1196 \log(TP) - 0.6492 \log(A) + 0.7990 \log(MD)$$

$N = 50 \quad P = 0.0034 \quad R^2 = 0.25$

INSTREAM FLOW INCREMENTAL METHODOLOGY (IFIM)

No SI curves for use with the Instream Flow Incremental Methodology (Bovee 1982) are presented because of the lack of a data base describing fish position and associated microhabitat measurements. Guidelines for collecting and analyzing data to develop SI curves for use with IFIM are presented by Bovee (1986). Orth (1987) describes assumptions and limitations on the use of habitat data generated by IFIM. Many of these cautions apply to any model where independent variables are limited to habitat characteristics.

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model for the flathead catfish (Pylodictis olivaris). The model consolidates habitat use information into a framework appropriate for field application, and is scaled to produce an index between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). HSI models are designed to be used with Habitat Evaluation Procedures previously developed by U.S. Fish and Wildlife Service.

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