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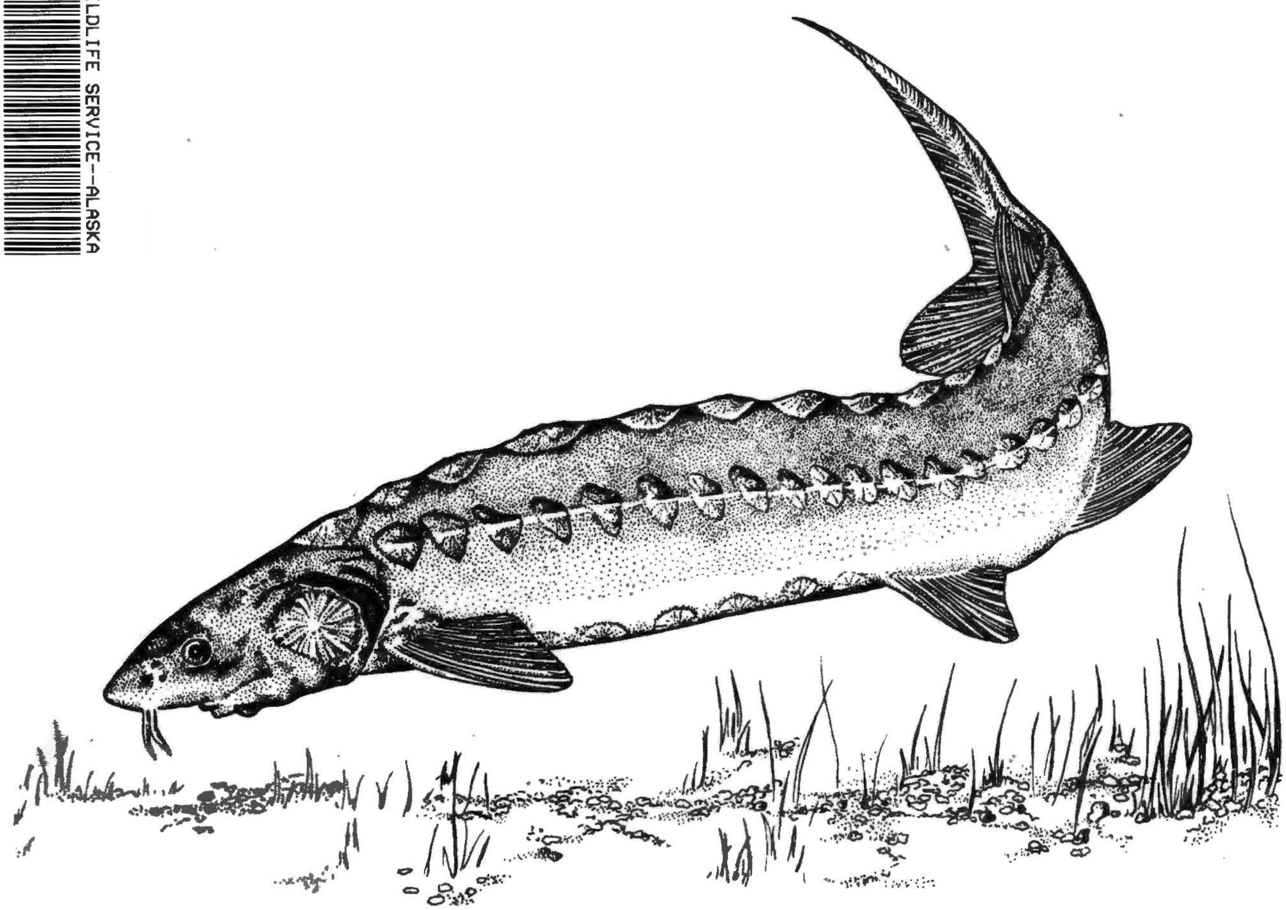
# HABITAT SUITABILITY INDEX MODELS: AND INSTREAM FLOW SUITABILITY CURVES: SHORTNOSE STURGEON







nd Wildlife Service
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# MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
or
Instream Flow Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ______________ Geographic Location ______________________________

Habitat or Cover Type(s) ______________________________

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other ______________________________

Variables Measured or Evaluated ______________________________
______________________________
______________________________
______________________________

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed? ______________________________
______________________________
______________________________
______________________________

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________

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______________________________________________________________________

Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? ______________

______________________________________________________________________

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Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? __________________________________

______________________________________________________________________

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______________________________________________________________________

Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ______________________

______________________________________________________________________

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Additional references or information that should be included in the model:

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Model Evaluator or Reviewer ____________________________ Date ______________

Agency ______________________________________________________________

Address _____________________________________________________________

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Telephone Number Comm: ________________________ FTS ________________________

Biological Report 82(10.129)
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# HABITAT SUITABILITY INDEX MODELS AND INSTREAM FLOW SUITABILITY CURVES: SHORTNOSE STURGEON

by

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## PREFACE

Information presented in this document is for use with the Habitat Evaluation Procedures (HEP) and the Instream Flow Incremental Methodology (IFIM). The information also should be useful for impact assessment for the shortnose sturgeon using methodologies other than HEP or IFIM. The comparison and recommendations for use of HEP and IFIM presented by Armour et al. (1984)[1] should help potential users of these two methodologies determine the most efficient way to utilize the information in this publication.

The Suitability Index (SI) curves and graphs and Habitat Suitability Index (HSI) models presented in this report for use with HEP are based primarily on a synthesis of information obtained from a review of the literature concerning the habitat requirements of the species. The SI curves and graphs for use with IFIM are based primarily on the results of a Delphi exercise conducted during July 1984 to August 1985 by the author. Seven shortnose sturgeon experts participated as panelists in the Delphi exercise. The HSI models and SI curves are scaled to produce an index between 0 (unsuitable habitat) and 1 (optimal habitat). Assumptions used to transform habitat use information into an index are noted, and guidelines for application of the curves and models are described. A discussion of IFIM and shortnose sturgeon SI curves available for use with IFIM is included.

The SI curves and HSI models are starting points for users of HEP or IFIM to develop their own curves and models. Use of the SI curves and HSI models within project-specific applicational constraints is likely to require modifications of the SI curves or graphs and HSI models to meet those constraints and to be applicable to local habitat conditions. Users of the SI graphs and/or HSI models with HEP should be familiar with the standards for developing HSI models (U.S. Fish and Wildlife Service 1981)[1] and the guidelines for simplifying HSI models and recommended measurement techniques for model variables (Terrell et al. 1982; Hamilton and Bergersen 1984).[1] Users of the SI curves with IFIM should be familiar with the guide to stream habitat analysis (Bovee 1982)[1] and the guide to the Physical Habitat Simulation System (Milhous et al. 1984).[1]

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[1]Citation included in References.

The HSI models and SI curves are hypotheses of species-habitat relationships, not statements of proven cause and effect relationships. The curves and models are based on the literature and professional judgment. They have not been applied in the field. For this reason, the U.S. Fish and Wildlife Service encourages model users to convey comments and suggestions that may help increase the utility and effectiveness of this habitat-based approach to fisheries planning. Please send comments to:

Habitat Evaluation Procedures Group

or

Instream Flow and Aquatic Systems Group
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
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CONTENTS

ACKNOWLEDGMENTS

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The SI curves for use with IFIM are based on information obtained from the results of a Delphi exercise. Gratitude goes to the following persons who were panelists for the Delphi exercise: Douglas Beach, National Marine Fisheries Service, Gloucester, MA; Mike Dadswell, Canada Fisheries and Oceans, St. Andrews, NB, Canada; Ronnie Gilbert, University of Georgia, Athens, GA; Tom Hoff, Mid-Atlantic Fisheries Management Council, Dover, DE; Ted Smith, South Carolina Marine Resources Research Institute, Charleston, SC; Tom Squiers, Maine Department of Marine Resources, Augusta, ME; and Byron Young, New York Department of Environmental Conservation, Stony Brook, NY.

Readers should not construe the reviews or participation in the Delphi exercise by the people named above as an endorsement of the publications' content or of the use of the model or suitability index curves to evaluate habitat.

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SHORTNOSE STURGEON (Acipenser brevirostrum)

## HABITAT USE INFORMATION

### General

The shortnose sturgeon, Acipenser brevirostrum, inhabits large tidal rivers along the Atlantic coast of North America from the Saint John River, New Brunswick, Canada, to the Saint Johns River, Florida (Vladykov and Greeley 1963; Scott and Crossman 1973). The species is generally considered to be anadromous, but it has been described as intermediate between fully anadromous and potamodromous (Dadswell 1979; Buckley and Kynard 1985a). A reproducing population of shortnose sturgeon is landlocked in the Holyoke Pool of the Connecticut River (Taubert 1980a, 1980b). Dadswell et al. (1984) prepared a synopsis of published and unpublished biological data available on the species up to 1984, including riverine and estuarine systems that shortnose sturgeons have been known to occur in since 1818. Rulifson et al. (1982) summarized the status of the species in river systems within Region 4 of the U.S. Fish and Wildlife Service.

Spawning sites are in freshwater. Maturing fish generally migrate to spawning grounds during spring, when they spawn, or some migrate to spawning sites during fall, overwinter in the area, and spawn during spring. Studies in South Carolina indicate maturing fish move to spawning sites in January-February and spawn shortly thereafter (T. I. J. Smith, South Carolina Wildlife and Marine Resources Department, Charleston; pers. comm.).

Fertilized eggs of shortnose sturgeon are adhesive and demersal (Meehan 1910). Larvae and juveniles are generally benthic and nonmigratory (Dadswell 1979; Taubert 1980a). Juveniles may remain in freshwater areas year-round until they reach 45 cm fork length (FL) or 2 to 8 years of age (Dadswell et al. 1984). Biotelemetry studies with juveniles in South Carolina suggest that they moved rapidly down river and into brackish water or the freshwater-saltwater interface (T. I. J. Smith, pers. comm.). Adults and some older juveniles overwinter in halocline regions in the lower estuary or in deep freshwater areas upriver. During summer, adults forage in shallow areas generally located midestuary where salinities range from about 0.5 to 3 ppt (Dadswell et al. 1984).

The shortnose sturgeon is listed as an endangered species in the United States (Miller 1972; Anonymous 1973), and the species is on the list of rare or endangered Canadian fishes (McAllister 1970; Scott and Crossman 1973). Rulifson et al. (1982) listed factors possibly important or very important to the decline of certain populations of shortnose sturgeon within Region 4 of the U.S. Fish and Wildlife Service. Because of its endangered status in the United States, no commercial or recreational exploitation of the species is allowed in any State, and the species is often a serious concern in evaluating proposed developments that may jeopardize its well-being. The main limitations to the abundance of shortnose sturgeon are probably slow growth, late maturation, past overharvesting, and the availability of suitable habitat. The largest existing population of the species is probably in the Saint John River, Canada, where harvest of shortnose sturgeon >122 cm total length (TL) is permitted during all months except June (Dadswell et al. 1984).

Age, Growth, and Food

Shortnose sturgeon grow slowly. Immature fish began to resemble adults by the time they are 20 to 30 mm long, but they remain juveniles until about 45 cm FL or age 3 to 10, depending on sex of fish and latitude (Dadswell et al. 1984). Cultured fish in South Carolina, however, weighed 3 to 5 lbs when 17 months old (T. I. J. Smith, pers. comm.). Age at first spawning varies from about 2 to 3 years for males in the Altamaha River, Georgia, to 15 years for females in the lower Connecticut River, Connecticut and Massachusetts, and the Saint John River, Canada (Table 1). The maximum age and size for shortnose sturgeon on record is a 67 year-old female from the Saint John River, Canada; it weighed 23.6 kg and was 143 cm TL (Dadswell 1979). At hatching, shortnose sturgeon are about 9 to 12 mm long (Taubert and Dadswell 1980; Buckley and Kynard 1981; Smith et al., in press). Ages and TL's reported for older larvae and juveniles are: 2 to 5 days, 8 to 10 mm (Washburn and Gillis Associates, Ltd, n.d.); 12 days, 15 mm (Buckley and Kynard 1981); 14 days, 13 to 14.7 mm (Taubert and Dadswell 1980); and 35, 150, and 225 days, and 29, 175, and 325 mm, respectively (Smith et al., in press). Shortnose sturgeon attained a fork length of 50 cm after 10 years, 90 cm after 25 years, and 100 cm after 35 years in the Saint John River, Canada (Dadswell 1979). In the Holyoke Pool, the average weight and length of shortnose sturgeon were 1,522 g and 579 mm FL at age 10, and 3,166 g and 747 mm at age 18 (Taubert 1980a). Dadswell et al. (1984) presented length-weight relationships for various populations of the species.

The available data on feeding habitat and feeding behavior of shortnose sturgeon was summarized by Dadswell et al. (1984). The protrusible tube mouth adapts the species to feeding off the bottom. All feeding by adults seems to be either benthic or off plant surfaces. Adults appear to eat mostly molluscs (Dadswell 1979, 1984) or benthic crustaceans and insects (Taubert 1980b). Dadswell (1979) found that females ceased feeding about 8 months before spawning. Pottle and Dadswell (1979) reported that juveniles eat benthic crustaceans and often feed extensively on cladocerans. Dadswell (1984) reported that the juvenile diet consisted of insect larvae and crustaceans. Laboratory-hatched larvae absorbed the yolk sac within 8 to 13 days (Buckley and Kynard 1981; Smith et al., in press). At 12 days after hatching, fry fed on zooplankton (Buckley and Kynard 1981), and various soft-moist rations and natural foods (Smith et al., in press).

Table 1. Age at first spawning of shortnose sturgeon.[a]

| Location | Age (years) at first spawning: Males | Age (years) at first spawning: Females | Reference |
|---|---|---|---|
| Altamaha River, GA | 2 to 3 | 6 | Heidt and Gilbert (1978) |
| Delaware River, NJ | - | 7 to 10 | Hoff (1965), Hastings (1983) |
| Hudson River, NY | 3 to 4 | 6 to 8 | Greely (1937) |
| Lower Connecticut River, CT | 10 | 15 | Buckley (1982) |
| Holyoke Pool, Connecticut River, MA | 8 | 9 | Taubert (1980b) |
| Saint John Estuary, Canada | 11 | 15 | Dadswell (1979) |

[a]Adapted from Dadswell et al. (1984).

Reproduction

Male shortnose sturgeon can be reliably distinguished externally from females only during the final stages before spawning, males by abdominal pressure, which causes milt to flow, and females by the black eggs apparent through the abdomen (Dadswell et al. 1984). Adult females are generally larger than adult males of the same age and gravid females have a distinct swollen appearance (Dadswell 1979).

Spawning occurs in freshwater, usually upstream within areas of tidal influence, during spring when water temperature is 9 to 14 °C (Heidt and Gilbert 1978; Dadswell 1979; Taubert 1980a; Buckley and Kynard 1981, 1985b). Adults either arrive on spawning grounds in the fall and spawn the next spring, or migrate to spawning sites during spring when water temperature and river flow are increasing (Buckley and Kynard 1985a). Shortnose sturgeon spawned in the Connecticut River over a 3- to 5-day period during decreasing river discharge and rising water temperature between 11.5 and 14.0 °C (Buckley and Kynard 1985b). Spawning is generally associated with deep areas where the predominate substrate type is a combination of gravel, rubble, and cobble

(Dadswell 1979; Taubert 1980a; Buckley and Kynard 1982, 1985b; Squiers 1983) and water velocities are between 36 and 125 cm/s (Taubert 1980a; Buckley and Kynard 1985a). The ratio of males to females on spawning grounds was reported to be 1:1 by Buckley (1982) and 3.5:1 by Taubert (1980b). Males may migrate to the spawning grounds first (Dovel 1981). Buckley (1982) found the ratio of males to females to be 1:1 for fish overwintering on spawning grounds. Smith (in press) reported that 22 of the 25 adults captured by gill nets during spawning migrations in the Savannah were males.

Information summarized by Dadswell et al. (1984) indicates that first spawning by male shortnose sturgeon occurs at age 2 to 3 and about 45 cm FL, and age 6 by females at about 52 cm FL. Some males may not spawn until age 11 (Dadswell 1979) and some females may not spawn until age 15 (Dadswell 1979; Buckley 1982). Males probably spawn at a maximum every other year (Dadswell 1979). Females probably spawn at a maximum of once every 3 years and the time between spawnings may be as long as 5 to 11 years (Dadswell 1979).

The association of several males with one female during spawning has been inferred (Buckley and Kynard 1985a). The eggs are separate when spawned and fertilization is external. In laboratory tests, eggs became adhesive within 5 minutes after fertilization and sank at a rate of about 5.2 cm/s (Washburn and Gillis Associates, LTD, n.d.). Fecundity is directly related to total body weight. The number of eggs per adult female has been reported to range from 27,000 to 208,000 (Dadswell et al. 1984). Eggs artificially fertilized and incubated in the laboratory hatched in 5 to 6 days at temperatures of 18 to 20 °C (Smith et al., in press), 13 days at a mean water temperature of 11.7 °C (Meehan 1910), and 8 days at 17 °C (Buckley and Kynard 1981).

Specific Habitat Requirements

Shortnose sturgeons may be found in riverine (Dadswell 1979; Taubert 1980a; Brundage and Meadows 1982), estuarine (McCleave et al. 1977; Heidt and Gilbert 1978; Dadswell 1979), and near inshore marine waters (Schaeffer 1967; Holland and Yelverton 1973; Brundage and Meadows 1982). They are probably more commonly found in productive mesohaline environments with salinities between 1 and 2 ppm, usually in and around the salt-wedge portion of estuaries (Squiers and Smith 1978; Dadswell 1979). Dadswell et al. (1984) summarized population estimates and average densities for adult shortnose sturgeon in rivers in eastern North America. The largest populations probably exist in the Hudson River, New York, and the Saint John River, Canada, while the highest densities occur in the Hudson River, New York, and the Kennebec River, Maine. Estimates of the average density of adult shortnose sturgeon in the Holyoke Pool of the Connecticut River, Massachusetts, were about the same or higher than in most other stream systems where estimates of population density for the species have been made. Estimates of shortnose sturgeon population numbers and density in southern river systems have not been made.

The lifetime movements and patterns of use of discrete habitats in rivers and bays by the species may be complex and may vary depending on life stage, season, and, to some extent, latitude. Nevertheless, distinct migration and habitat use patterns by several populations of shortnose sturgeon have been identified (Heidt and Gilbert 1978; Dadswell 1979; Taubert 1980a; Brundage and Meadows 1982; Buckley 1982; Dadswell et al. 1984; Buckley and Kynard 1985a,b). Dadswell et al. (1984) concluded that the normal pattern of migration of the species conforms to the model of Harden-Jones (1968) in which fish move between feeding, wintering, and spawning areas.

In summer, shortnose sturgeon adults and older juveniles are found on feeding grounds in shallow midestuary areas. In fall, they migrate to overwintering sites. Overwintering sites are generally located in deep, halocline areas of the lower estuary (Dadswell 1979); but some adults in some populations overwinter in deep freshwater sites located upstream at or near the spawning site (Dadswell 1979; Buckley 1982; Buckley and Kynard 1985b). In spring, shortnose sturgeon from all wintering sites probably spawn together (Buckley and Kynard 1985a).

Spawning sites are generally located upstream of the salt wedge in or near areas of deep water (Hoff 1965; Heidt and Gilbert 1978; Taubert 1980a; Dovel 1981; Buckley and Kynard 1982, 1985a,b; Squiers et al. 1982). Environmental conditions suitable for spawning may be available for only 3 to 6 days (Taubert 1980b; Buckley and Kynard 1985b). Postspawning fish generally migrate downstream to summer feeding grounds (Dadswell et al. 1984; Buckley and Kynard 1985b). Hoff et al. (1982) presented data that indicated a downstream migration of shortnose sturgeon soon after spawning.

Little is known about preadult life stages of the species. Eggs become adhesive within a few minutes after fertilization and then sink rapidly (Washburn and Associates, LTD, n.d.). This indicates that the eggs probably sink and become attached to substrate within a few hundred feet, depending on water temperature (Meehan 1910; Buckley and Kynard 1981; Smith et al., in press). Based on laboratory observations of a few shortnose sturgeon larvae by Buckley and Kynard (1981), larvae probably drift downstream for the first 1 to 2 days of life, aggregate in concealment on the bottom for the next 3 to 10 days, and then begin feeding and movement. Juvenile shortnose sturgeon probably confine their movements to riverine areas upstream of the salt wedge until they are about 45 cm long (Pottle and Dadswell 1979; Brundage and Meadows 1982).

Water velocity, temperature, and streambed substrate appear to be important variables that affect movement, distribution, and abundance of shortnose sturgeon and the suitability of their feeding and spawning habitats. The models included in this paper are restricted to these variables and to the life requisites for feeding and reproduction. Water depth and salinity are discussed but the effects of these two variables on habitat suitability for shortnose sturgeon are unclear and neither variable is included in the models.

Water temperature. The preferred temperature range and upper and lower lethal temperatures for shortnose sturgeon are unknown (Dadswell et al. 1984). Adults have been found where the temperature was as high as 34 °C (Heidt and Gilbert 1978) and as low as 2 to 3 °C (Dadswell et al. 1984). Unpublished information cited by Dadswell et al. (1984) indicated that "young" shortnose sturgeon experienced distress or rapid mortality at temperatures over 25 °C.

Shortnose sturgeon 2+ inches long are typically cultured in water that is 24 to 27 °C (T. I. J. Smith, pers. comm.). Other temperatures reported to be associated with various life stages and activities of the species are presented in Table 2.

Feeding by adult shortnose sturgeon in freshwater portions of Saint John River, Canada (Dadswell 1979), is confined largely to periods when water temperature exceeds 10 °C. A temperature decline of 2 to 3 °C during fall stimulated downriver migration to overwintering sites in the Pee Dee River, South Carolina (Dadswell et al. 1984), and a decrease in temperature from 19 to 11 °C stimulated fall migration in the Connecticut River (Buckley and Kynard 1985a). Movement onto spawning grounds during spring appears to be initiated by water temperature rising above 8 °C (Pekovitch 1979; Taubert 1980a; Dadswell et al. 1984). Spawning was reported to occur when water temperature ranged from 10 to 12 °C (Dadswell 1979; Taubert 1980a), 12 to 15 °C (Taubert 1980a) and 11.5 to 14.0 °C (Buckley and Kynard 1985b).

Water velocity. Summer feeding areas of adult shortnose sturgeon generally have little or no current (McCleave et al. 1977; Dadswell 1979; Taubert 1980b). Estuarine overwintering sites are generally deep (>10 m) with moderate tidal currents (Dadswell 1979).

Prespawning shortnose sturgeon in the Connecticut River preferred areas of reduced velocities (between 30 and 70 cm/s) and spawned in an area where mean water column velocities ranged from 36 to 120 cm/s during the spawning period (Buckley and Kynard 1985b). Other water velocities reported for probable spawning sites of shortnose sturgeon during the spawning period are: 37 to 56 cm/s and 104 to 125 cm/s in the Holyoke Pool of the Connecticut River (Taubert 1980a), 60 to 120 cm/s in the Hudson River (Pekovitch 1979), and 100 to 300 cm/s in the Saint John River, Canada (Washburn and Gillis Associates, LTD, n.d.). Buckley and Kynard (1982, 1985b) postulated that the release of eggs in the proper velocity is critical to successful egg deposition and survival:

> If eggs are released when the velocity is too high, the eggs may not adhere to the substrate before losing adhesiveness. Spawning in insufficient velocity may cause clumping of eggs which would increase mortality from respiratory stress, fungus growth, and possibly increased egg predation. Spawning in sufficient water velocity would also be important to survival of larvae. Buckley and Kynard (1981) described newly hatched shortnose sturgeon embryos as active and engaging in a series of vertical swimming bouts. Presumably this is an adaptation for downriver transport and, if hatching does not occur in an area of sufficient velocity, the hatching fish would not be transported downstream.

Buckley and Kynard (1985b) also noted that:

> Water temperature and water velocity may affect the reproductive process in a stepped manner. Rising temperatures would cause the final maturation of oocytes and the appropriate water velocity may cue the female to deposit eggs.

Table 2. Water temperatures associated with various life stages and activities of shortnose sturgeon.

| Life stage or activity | Temperature (°C) | Location | Reference |
|---|---|---|---|
| Adults summer movement | 14 to 23 | Montsweag Bay, ME | McCleave et al. (1977) |
| Adults leaving summer foraging area | decreased from 19 to 11 | Lower Connecticut River, CT | Buckley and Kynard (1985a) |
| Adults leaving summer foraging area | decrease of 2 to 3 | Pee Dee-Winyah System, SC | Dadswell et al. (1984) |
| Adults overwintering | 2 to 13 | Saint John River, Canada | Dadswell (1979) |
| Adults overwintering | 5 to 10 | Pee Dee-Winyah System, SC | Dadswell et al. (1984) |
| Adults initiate spring spawning migration | increase above 8 | Various locations | Pekovitch (1979); Taubert (1980a); Dadswell et al. (1984) |
| Ripe males captured | 9.9 to 12.3 | Delaware River, NJ | O'Herron and Able (1985) |
| Ripe males and females captured | 7.2 to 13.2 | Cooper River, SC<br>Savannah River, SC & GA | Smith et al. (in press) |
| Ripe males and females captured | 6.0 to 14.4 | Saint John River, Canada | Washburn and Gillis Associates, LTD (n.d.) |
| Spent males captured | 15.2 | Savannah River, SC & GA | Smith et al. (in press) |
| Spawning | 10 to 12 | Saint John River, Canada | Dadswell (1979) |
| Spawning | 12 to 15 | Connecticut River, MS | Taubert (1980a) |
| Spawning | 11.5 to 14 | Connecticut River, CT | Buckley and Kynard (1985b) |
| Hatching, 13 days | 7.8 to 12.2 | Indoors, aquaria | Meehan (1910) |
| Hatching, 12 to 16 days | 9.8 to 14.0 | Indoors, incubator | Washburn and Gillis Associates, LTD (n.d.) |
| Hatching, 11 days | 18.0 | Indoors, aquaria | Smith et al. (in press) |
| Hatching, 9 to 10 days | 20.0 | Indoors, aquaria | Smith et al. (in press) |
| Hatching, 8 days | 17.0 | Indoors, aquaria | Buckley and Kynard (1981) |
| Larvae, reared indoors | 17 to 23 | Indoors, aquaria | Smith et al. (in press) |

Buckley and Kynard (1985b) found that shortnose sturgeon had a compressed spawning period, perhaps no more than 3 to 5 days, and environmental conditions suitable for spawning may have been available for only a short period. The departure of shortnose sturgeon from the spawning area before they spawned suggested to Buckley and Kynard (1985b) that a spawning threshold is defined by the duration and magnitude of water velocity.

Larval shortnose sturgeon are apparently benthic and presumably occupy deep channel areas where water velocity is strong (Dadswell 1979; Taubert 1980a; Washburn and Gillis Associates, LTD, n.d.). Juveniles (fish <45 cm mean length) appear to prefer living in deep channel regions with currents 10 to 40 cm/s (Pottle and Dadswell 1979; Dadswell et al. 1984).

Substrate type. Dadswell (1979) noted that foraging areas of shortnose sturgeon in saline areas were over gravel-silt bottoms, and in freshwater over shallow, muddy bottoms with abundant macrophytes. McCleave et al. (1977) found shortnose sturgeon in Montsweag Bay, Maine, feeding over mud flats during June and July 1971-1974.

Substrate of spawning sites was reported to be cobble and rubble (Dadswell 1979; Taubert 1980a); gravel, rubble, and large boulders (Squiers 1983), and rock and rubble, and sand and gravel (Washburn and Gillis Associates, LTD, n.d.). The widespread availability of suitable shortnose sturgeon spawning substrate throughout an area of the Connecticut River studied by Buckley and Kynard (1982, 1985b) indicated that water velocity and depth may be more critical than substrate factors in determining the specific spawning location by the species. Some adults have been known to overwinter in or near spawning sites that had gravel, cobble, and rubble substrate (Buckley and Kynard 1985b).

Experiments by Pottle and Dadswell (1979) indicate that juvenile shortnose sturgeon prefer a sand-mud or gravel-mud substrate.

Water depth. Water depth preferences of shortnose sturgeon, if any, are unknown. It is assumed that a water depth of about 0.6 m is needed for unimpeded swimming by adults. Water depths associated with summer feeding and overwintering sites and spawning areas may be related to temperature, velocity, and substrate, or a combination of these and other variables.

Water depths of summer foraging areas used by shortnose sturgeon are generally shallow. Radio-tagged adults were tracked during summer in areas where water depths ranged from 1 to 27 m; the fish made extensive use of quiet shallow water and, on many occasions, were tracked in water <1 m deep (McCleave et al. 1977). Concentrations of shortnose sturgeon were found in an area of the Connecticut River where average water depth was 3 m (Buckley and Kynard 1985a). Squiers et al. (1982) found that shortnose sturgeon concentrated during summer in midestuary in the Kennebec River system where water depth was <1 m deep.

Overwintering sites of shortnose sturgeon are generally deep areas. Dadswell (1979) reported that overwintering sites are generally >10 m in the Saint John River, Canada. The most likely overwintering sites in the Kennebec

River, Maine, were deep saline regions of the lower estuary (Squiers et al. 1982). Shortnose sturgeon overwintered in riverine areas of the Connecticut River where water depths ranged between 0.5 and 7 m; the fish did not concentrate in the deepest available areas of the river (Buckley and Kynard 1985a). This possibly indicates a depth preference by these shortnose sturgeon, assuming that other factors were not responsible for their location.

Water depths for shortnose sturgeon spawning or suspected spawning sites were reported to be 6.3 to 7.3 m by Squiers (1983), about 2 m by O'Herron and Able (1985), and 2 to 4 m by Buckley and Kynard (1985a).

Water salinity. Shortnose sturgeon use water ranging from freshwater (Taubert 1980a; Taubert and Dadswell 1980) to salinity of 30 ppt or higher (Holland and Yelverton 1973; Squiers and Smith 1978). Adults moved freely through waters of widely differing salinities, sometimes encountering salinity changes of 10 ppt in less than 2 hours (McCleave et al. 1977).

Summer foraging grounds are generally located midestuary where salinities range from about 0.5 to 3.0 ppt (Dadswell 1979; Dadswell et al. 1984). However, the landlocked population of shortnose sturgeon in Holyoke Pool feeds in freshwater (Taubert 1980a), and McCleave et al. (1977) found adults feeding during summer where salinities ranged from 18 to 24 ppt.

Overwintering sites have been reported to be in freshwater areas (Taubert 1980b), freshwater and estuarine areas (Dadswell 1979; Buckley and Kynard 1985a), and areas where salinities averaged 20 ppt (Dadswell 1979).

All known or suspected spawning sites are located in freshwater.

## HABITAT SUITABILITY INDEX (HSI) MODELS

### Applicability of the Models

Potential users of the HSI models presented here for shortnose sturgeon should be familiar with guidelines for riverine application of fish HSI models with HEP (Terrell et al. 1982).

Geographic area. The HSI models were designed to apply to shortnose sturgeon riverine habitat along the Atlantic coast of the United States. They may also have application to the shortnose sturgeon population in the Saint John River, Canada, however, because the models are generalized to reflect the life cycle and requirements of the species throughout its range. Generalized statements about habitat requirements are unlikely to be precisely applicable to all shortnose sturgeon habitats. Therefore, information pertaining to a particular habitat should be evaluated with regard to model criteria.

Season. The HSI models are designed to evaluate food (summer foraging), and reproduction (spawning and incubation) habitats of shortnose sturgeon. The time of year these occur may vary slightly depending on latitude. Spawning generally occurs between February and May (Dadswell et al. 1984). Ripe and spent females were present in the Altamaha River, Georgia, during February

(Heidt and Gilbert 1978). Ripe and running-ripe females were present during the first 2 weeks of May in the Connecticut River (Taubert 1980a; Buckley 1982), and during late April through mid-May in the Androscoggin River, Maine (Squiers 1983). The season for application of the model for evaluating summer foraging habitat is about April-October, or depending on the location, when the water temperature is normally above 10 °C.

Habitat types. The models are applicable to riverine (lotic) habitat of shortnose sturgeon. It is assumed that some of the riverine areas used by the species for summer foraging may be freshwater or estuarine, whereas spawning habitat is always freshwater.

Minimum habitat area. The minimum habitat area is defined as the minimum area of contiguous suitable habitat that is required by a species to live and reproduce. No minimum habitat size for shortnose sturgeon has been established. Dadswell et al. (1984) estimated the areas of habitat used by adult shortnose sturgeon populations in rivers in eastern North America. The smallest habitat area was 800 ha, used by the shortnose sturgeon population in the lower Connecticut River.

The area of habitat reported to be used by shortnose sturgeon in various river systems varies considerably. The spawning site in the Holyoke Pool of the Connecticut River (Taubert 1980a) and the spawning area in the Connecticut River below the Holyoke Dam (Buckley and Kynard 1985b) extend over about 2 km or less of the river. The suspected spawning site for shortnose sturgeon in the Hudson River extended from rkm 184 to 223 (Dovel and Bonavist 1979). Locations of spawning sites and the approximate areas where shortnose sturgeon were concentrated during summer (assumed to be summer foraging grounds) are shown for some major river systems by Dadswell et al. 1984, Figure 35.

Verification level. These HSI models represent my interpretation of how specific environmental factors determine the ability of a habitat to support a reproducing population of shortnose sturgeon. The SI curves and HSI models were synthesized from information available in the literature and opinions of biologists familiar with habitat uses by shortnose sturgeon. The curves and models are conceptual and are open to modification. Each curve and model should be interpreted with caution. They have not been tested against habitats of known quality to determine their validity. The suitability index varies from 0 (unsuitable habitat) to 1 (optimum habitat).

## Model Descriptions

The shortnose sturgeon HSI model consists of two components: food ($C_F$) or summer feeding habitat, and reproduction ($C_R$) or spawning and incubation habitat. Each component contains habitat variables specifically related to that component. Each habitat variable is considered to be capable of being measured in the field, but significant effort may be required to measure some variables. The assumed relationship of the habitat variable included in the HSI model to life requisites of the species in riverine habitat is illustrated in Figure 1. All habitat-related variables that can potentially affect shortnose sturgeon populations (e.g., toxic wastes, food availability, competitors) are not included in the model because of insufficient information on the

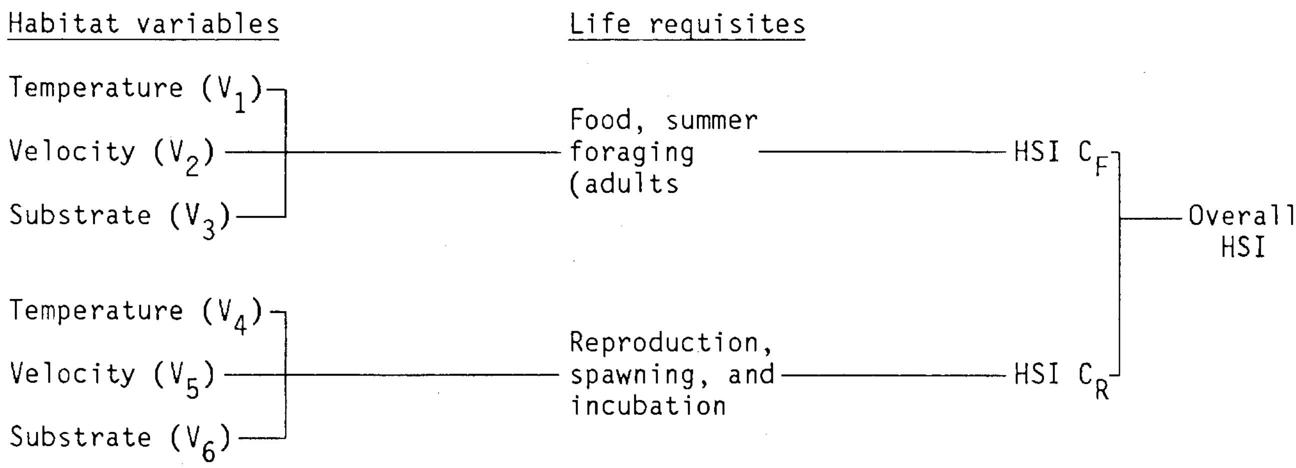



Figure 1. The relationship of habitat variables and life requisites in the riverine (lotic) HSI model for shortnose sturgeon.

relationship of the variables to habitat suitability or the difficulty in measuring the variables in the field. The variables selected for the SI's will likely interact, but I did not attempt to predict variable interrelationships.

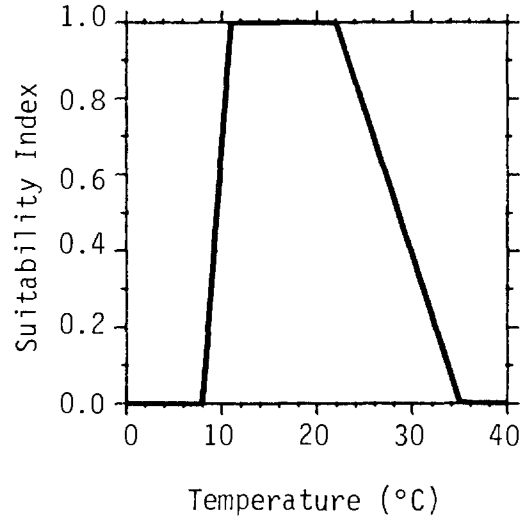
Food component. Water temperature ($V_1$), velocity ($V_2$), and predominate substrate type ($V_3$) were chosen as indicators of summer feeding habitat suitability for adult shortnose sturgeon. Adults feed primarily on benthic organisms. Feeding is heaviest during summer and is confined largely to periods when water temperature exceeds 10 °C. Summer feeding habitat is further characterized as shallow areas with little or no water velocity and a substrate of predominantly silt, sand, and gravel with abundant growths of macrophytes. Depths of summer foraging areas are generally shallow (2 to 5 m deep) but tend to be deeper during late summer. The fish probably select summer feeding areas because of the availability of food, but adults are stimulated to leave summer foraging areas as water temperature decreases during fall.

Reproduction component. Water temperature ($V_4$), velocity ($V_5$), and predominate substrate type ($V_6$) were selected as indicators of spawning and incubation habitat suitability for shortnose sturgeon. Spawning generally occurs at temperatures ranging from 10 to 15 °C. The incubation period is temperature dependent. Spawning sites are associated with relatively deep, freshwater areas of streams having substrate consisting primarily of gravel, cobble, and rubble suitable for egg attachment. The magnitude and duration of water velocity is assumed to be critical to spawning, successful incubation, and survival of larvae. A combination of environmental conditions suitable for spawning is likely to be available for only 3 to 5 days. Adults may abandon the spawning site before spawning if the duration and magnitude of water velocity are not suitable.

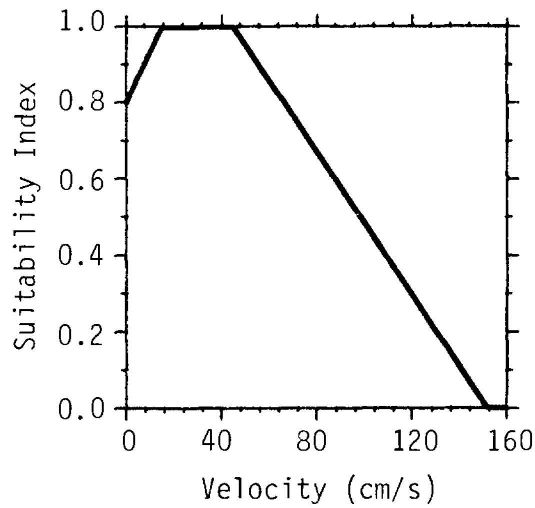
Suitability Index (SI) Graphs for Model Variables

The SI graphs for $V_1$ - $V_6$ were constructed by converting available information (including informed and expert opinion) on the habitat of shortnose sturgeon into an index of suitability ranging from 0 (unsuitable) to 1 (optimum). The sources of information and rationale used for developing the suitability indices for the variables used in the two components of the shortnose sturgeon HSI model are presented in Table 3.

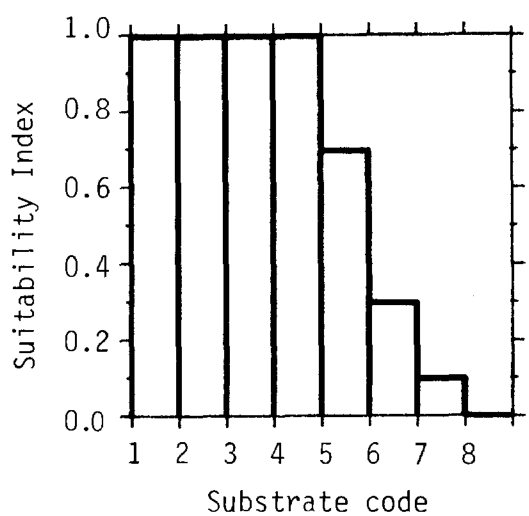
| Variable | | Coordinates x | y | Suitability graph |
|---|---|---|---|---|
| $V_1$ | Mean water temperature during summer. Foraging site, adults | °C | SI | |
| | | 8 | 0.0 | |
| | | 11 | 1.0 | |
| | | 22 | 1.0 | |
| | | 35 | 0.0 | |




| Variable | | cm/s | SI |
|---|---|---|---|
| $V_2$ | Mean water column velocity during summer. Foraging site, adults | 0.0 | 0.8 |
| | | 15.0 | 1.0 |
| | | 45.0 | 1.0 |
| | | 152.0 | 0.0 |



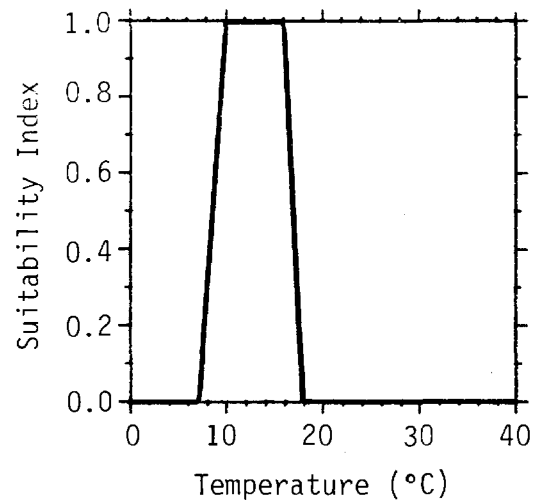

| Variable | | Code | Substrate | SI |
|---|---|---|---|---|
| $V_3$ | Predominant substrate type during summer. Foraging site, adults | 1 | macrophytes | 1.0 |
| | | 2 | mud/clay | 1.0 |
| | | 3 | silt | 1.0 |
| | | 4 | sand | 1.0 |
| | | 5 | gravel | 0.7 |
| | | 6 | cobble/rubble | 0.3 |
| | | 7 | boulder | 0.1 |
| | | 8 | bedrock | 0.0 |



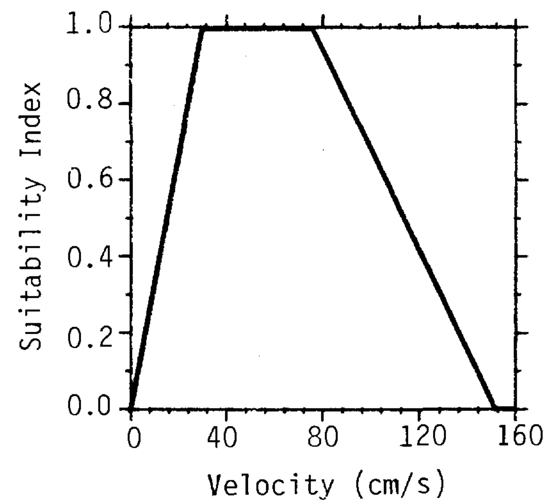
| Variable | | | Suitability graph |
|---|---|---|---|

**Coordinates**

| | | x | y |
|---|---|---|---|
| $V_4$ | Mean water temperature during spawning season | °C | SI |
| | | 7.2 | 0.0 |
| | | 10.0 | 1.0 |
| | | 16.0 | 1.0 |
| | | 18.0 | 0.0 |




| | | cm/s | SI |
|---|---|---|---|
| $V_5$ | Mean water column velocity during spawning season | 0.0 | 0 |
| | | 30.0 | 1 |
| | | 76.0 | 1 |
| | | 152.0 | 0 |




| | | Code | Substrate | SI |
|---|---|---|---|---|
| $V_6$ | Predominant substrate type during spawning season | 1 | macrophytes | 0.2 |
| | | 2 | mud/clay | 0.0 |
| | | 3 | silt | 0.1 |
| | | 4 | sand | 0.5 |
| | | 5 | gravel | 1.0 |
| | | 6 | cobble/ rubble | 1.0 |
| | | 7 | boulder | 0.8 |
| | | 8 | bedrock | 0.7 |

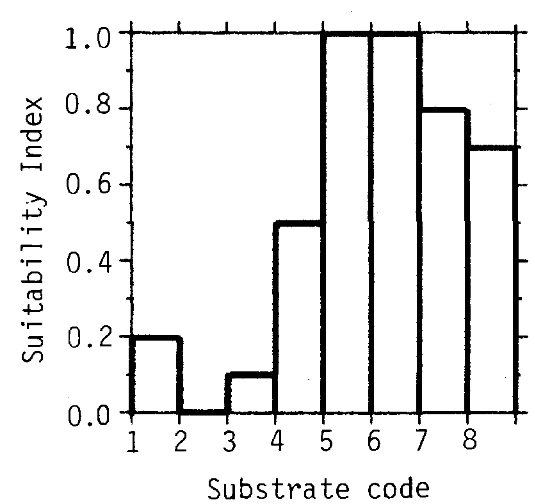


Table 3. Rationale and information sources used in the construction of the suitability index graphs for the shortnose sturgeon HSI models.

| Variable | Rationale, assumptions, and sources of information |
|---|---|
| $V_1$ | Judgments and opinions were relied upon to a significant degree because specific information correlating water temperature with maximum feeding, growth, and survival of adult shortnose sturgeon are lacking. All feeding seems to be either benthic or off plant surfaces (Dadswell et al. 1984). Summer feeding grounds tend to be shallow (1 to 5 m) areas, and feeding by adults is confined largely to periods when water temperature exceeds 10 °C (Dadswell 1979). During late summer, feeding areas tended to be in deeper water (5 to 10 m), perhaps in response to higher temperature in shallows (Dadswell 1979). Surface water temperature over 21 °C appeared to stimulate movements to deeper water (Dadswell et al. 1984). In the northern part of their range, shortnose sturgeon are seldom found in shallow water once temperature exceeds 22 °C (Dadswell 1975; Dovel 1978). Heidt and Gilbert (1978) captured two shortnose sturgeons in a tidal section of the Altamaha River, Georgia, during July, when water temperatures averaged 34 °C, but it is unknown whether or not the fish were on preferred feeding grounds. |
| $V_2$ | Summer feeding areas for adult shortnose sturgeon generally have little or no current (McCleave et al. 1977; Dadswell 1979; Taubert 1980b). Buckley and Kynard (1985a) reported that two summering areas in the Connecticut River were associated with a decrease in water velocity. In the absence of specific informating correlating water velocity with summer foraging habitat suitability, I used a velocity SI curve developed for nonspawning adult shortnose sturgeon by the Delphi technique. |
| $V_3$ | The predominant substrate types reported to be associated with summer foraging grounds (McCleave et al. 1977; Dadswell 1979; Dadswell et al. 1984) were considered optimal. I assumed other substrate types to be suboptimal. |
| $V_4$ | Temperature is probably the major factor governing spawning (Dadswell et al. 1984). Spawning has been reported to occur when the water temperature averaged about 10.5 °C (Gilbert and Hiedt 1979) and at temperatures from 10 to 12 °C (Dadswell 1979; Taubert 1980a), 12 to 15 °C (Taubert 1980a), and 11.5 to 14 °C (Buckley and Kynard 1985b). The average ranges of water temperatures reported for shortnose sturgeon and the opinions of experts who served as Delphi panelists to develop SI curves for the species were considered in selecting the optimal range and suboptimal values for water temperature. |

Table 3. (Concluded)

| Variable | Rationale, assumptions, and sources of information |
|---|---|
| $V_5$ | The duration and magnitude of water velocity is probably critical to the release of eggs and successful deposition of eggs (Buckley and Kynard 1985b), but specific details are lacking. For 3 years, the mean water velocities in the Connecticut River during the spawning period ranged from 36 to 120 cm/s in the spawning area (Buckley and Kynard 1985b). The majority of fish captured during the spawning period by these investigators were in water velocities from 70 to 100 cm/s, but available water velocities were 30 to 120 cm/s. Other water velocities reported to be associated with spawning sites during the spawning period were: 35 to 56 cm/s and 104 to 125 cm/s (Taubert 1980a), 60 to 120 cm/s (Pekovitch 1979), and 100 to 300 cm/s (Washburn and Gillis Associates, LTD, n.d.). These reported velocities associated with spawning and results of the shortnose sturgeon Delphi exercise were considered in selecting the optimal range and suboptimal values for water velocity. |
| $V_6$ | Predominant substrates of spawning sites have been reported to be gravel, cobble, and rubble (Buckley and Kynard 1985b), cobble, and rubble (Dadswell 1979; Taubert 1980a; Squiers 1983), and rock and rubble, and sand and gravel (Washburn and Gillis Associates, LTD, n.d.). Delphi panelists reached a consensus that gravel and cobble/rubble were optimal substrate types for shortnose spawning habitat. Substrate types with particle sizes smaller than gravel and larger than cobble/rubble were considered to be suboptimal. |

## HSI Determination

Table 4 presents hypothetical data sets that I developed to calculate and display SI scores for each component of the model. The hypothetical data are conditions assumed to represent some logical combinations of shortnose sturgeon habitat conditions. I assume that any one of the variables used on either component of this model ($C_F$ or $C_R$) may prevent maximum standing crops of shortnose sturgeon from occurring regardless of the values of the other habitat variables. I assume, therefore, that the variable with the lowest SI defines the upper potential limit for shortnose sturgeon populations in the habitat being evaluated.

$$\text{HSI } C_F = \text{minimum SI of } V_1, V_2, \text{ or } V_3.$$

$$\text{HSI } C_R = \text{minimum SI of } V_4, V_5, \text{ or } V_6.$$

$$\text{Overall HSI} = \text{minimum SI for } C_F \text{ or } C_R.$$

## Field Application of the Models

Potential problems in application of any HSI model include deciding the appropriate location, time, and procedures for measuring variables used in the model. I did not attempt to give clear-cut instructions on measuring variables used in the shortnose sturgeon models. Project scoping is the appropriate time to address and resolve these and other potential problems; set objectives that communicate the identity, nature, and depth of the problem; identify the study area; and decide the precision and accuracy required for estimating habitat variables. Terrell et al. (1982) provided guidelines for the field application of riverine HSI models. Choice of methods used for measuring habitat variables is often governed by a combination of money, purpose, available equipment, study site, experience of personnel, measuring efficiency, and standardization with previous studies (Hamilton and Bergerson 1984).

The variables used in the shortnose sturgeon HSI models should be measured or estimated during a particular time period (i.e., spawning season and summer foraging season). Dadswell et al. (1984) showed locations of spawning sites and summer foraging sites. Unpublished reports, local fishermen, and expert opinion are also potential sources of information for determining shortnose sturgeon spawning and foraging sites and the time period the areas are utilized by the species.

Field studies of several weeks or months duration may be necessary for evaluating the suitability of shortnose sturgeon habitat. Hamilton and Bergerson (1984) suggested the transect method for estimating many riverine habitat variables and described procedures for estimating mean values for variables for a study reach over a particular time period.

Table 4. Hypothetical data sets used to display SI scores for shortnose sturgeon habitat variables by life requisite.

| Model component | Data set 1 | | Data set 2 | | Data set 3 | |
|---|---|---|---|---|---|---|
| | Data | SI | Data | SI | Data | SI |
| $V_1$ | 16 °C | 1.0 | 32 °C | 0.2 | 9 °C | 0.4 |
| $V_2$ | 25 cm/s | 1.0 | 86 cm/s | 0.6 | 6 cm/s | 0.9 |
| $V_3$ | silt | 1.0 | gravel | 0.7 | cobble/rubble | 0.3 |
| $V_4$ | 15 °C | 1.0 | 17 °C | 0.5 | 9 °C | 0.0 |
| $V_5$ | 50 cm/s | 1.0 | 125 cm/s | 0.4 | 16 cm/s | 0.5 |
| $V_6$ | boulder | 0.8 | gravel | 1.0 | sand | 0.5 |
| HSI $C_{(F)}$ | | 1.0 | | 0.2 | | 0.3 |
| HSI $C_{(R)}$ | | 0.8 | | 0.4 | | 0.0 |
| Overall HSI | | 0.8 | | 0.2 | | 0.0 |

## Interpreting Model Outputs

These models are not expected to predict standing crop or annual production of shortnose sturgeon, because habitat alone does not determine the survival and success of a shortnose sturgeon population. The models should be useful tools for the preliminary evaluation of specific study sites as potential shortnose sturgeon habitat. They are designed as indicators of excellent (SI = 0.8 to 1.0), good (SI = 0.7 to 0.8), fair (SI = 0.5 to 0.6), poor (SI = 0.1 to 0.4), or unsuitable (SI=0) habitat for shortnose sturgeon. The models have not been applied in the field. Therefore, the accuracy of model-generated HSI's as descriptors of habitat quality is unknown and is likely to vary in different geographical areas. The models should be evaluated with field measurements in the proposed areas of application to determine which, if any, model variables are important and can be reasonably measured or estimated. An HSI of 0 for a site being evaluated would not necessarily mean that shortnose sturgeon were absent; it would mean that the habitat is very poor for one or more variables and that the species is likely to be scarce or absent. If the models are correctly structured, a high HSI score would indicate near optimal habitat conditions for shortnose sturgeon production for those variables included in the models. Interactions of one variable with another are unknown.

## ADDITIONAL HABITAT MODELS

None.

## INSTREAM FLOW INCREMENTAL METHODOLOGY

The Instream Flow Incremental Methodology (IFIM) was designed to quantify changes in the amount of habitat available to different species and life stages of fish (or macroinvertebrates) under various flow regimes. Armour et al. (1984) compared the use of HEP and IFIM in aquatic analysis. Bovee (1982) presented a guide to stream habitat analysis using IFIM. The IFIM can be used to help formulate instream flow recommendations; to assess the effects of altered streamflow regimes, habitat improvement projects, mitigation proposals, and fish stocking programs; and to assist in negotiating releases from existing water storage projects. The IFIM consists of several autonomous models that are combined as needed by the user. One component of the IFIM is the Physical Habitat Simulation System (PHABSIM) model. Milhous et al. (1984) developed a user's guide to PHABSIM. The output from PHABSIM is a measure of physical microhabitat availability as a function of discharge and channel structure for each set of habitat suitability criteria (SI curves) entered into the model. The output can be used for several IFIM habitat display and interpretation techiques, including:

1. Habitat Time Series. Determination of impact of a project on a species' life stage habitat by imposing project operation curves over baseline flow time series conditions and integrating the difference between the corresponding time series.

2. Effective Habitat Time Series. Calculation of the habitat requirements of each life stage of a single species at a given time by using habitat ratios (relative spatial requirements of various life stages).

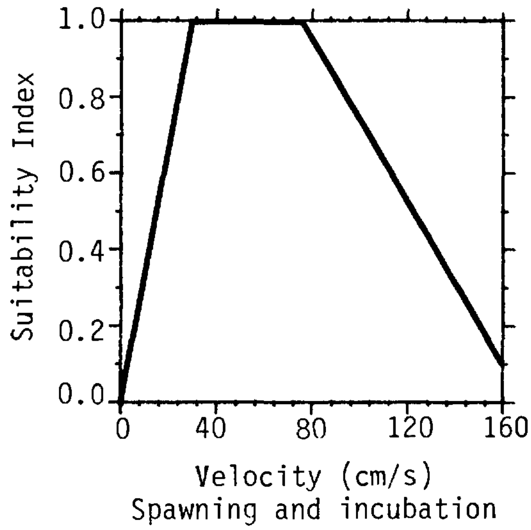
3. Optimization. Determination of flows (daily, weekly, and monthly) that minimize habitat reductions for a complex of species and life stages of interest.

### Suitability Index Curves Used in the IFIM

PHABSIM utilizes Suitability Index (SI) curves that describe the instream suitability of the habitat variables most closely related to stream hydraulics and channel stucture (i.e., velocity, depth, substrate, cover, and temperature) for each major life stage of a given fish species (i.e., spawning, egg incubation, larval, juvenile, and adult). Four categories of curves have been designated and the terminology pertaining to the curves has been standardized (Armour et al. 1984). Category one curves are based on literature sources and professional opinion. Category two (utilization) curves, based on frequency analyses of field data, are fit to frequency histograms. Category three (preference) curves are utilization curves with the environmental bias removed. Category four (conditional preference) curves describe habitat requirements as a function of interaction among variables. Armour et al. (1984) presented a more detailed discussion on the four categories of curves. The designation of a curve as belonging to a particular category does not imply that there are differences in the quality or accuracy of curves among the four categories.

The following SI curves (Figures 2-5) for IFIM analyses of shortnose sturgeon habitat are category one. Each curve resulted from a 4-round Delphi exercise conducted by correspondence during July 1984 to August 1985 to develop SI curves for the species. Seven shortnose sturgeon experts served as panelists for the exercise. When the exercise ended there was unanimous agreement among the seven experts on 10 of the 11 curves. Two panelists did not agree on the SI curve for water depth for adults during summer (Figure 3). One panelist noted that shortnose sturgeon are commonly found in shallow coves at depths less than 10 ft. Another panelist noted that it is not unusual to find sturgeon in water over 40 feet deep. Another panelist suggested that the temperature SI curve for nonmigratory juveniles and adults (Figure 5) should refer to temperature of summer feeding habitat. Potential users are encouraged to review the curves carefully and verify them before use in IFIM analyses.

| Coordinates x | x | y |
|---|---|---|
| cm/s | ft/s | SI |
| 0 | 0.0 | 0.0 |
| 30 | 1.0 | 1.0 |
| 76 | 2.5 | 1.0 |
| 152 | 5.0 | 0.2 |




| cm/s | ft/s | SI |
|---|---|---|
| 0 | 0.0 | 0 |
| 15 | 0.5 | 1 |
| 45 | 1.5 | 1 |
| 121 | 4.0 | 0 |

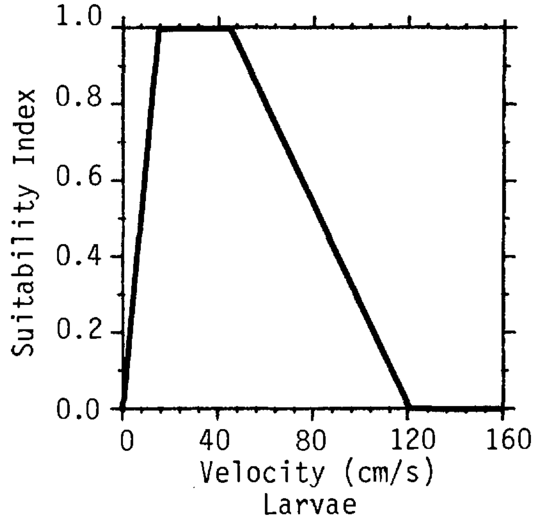
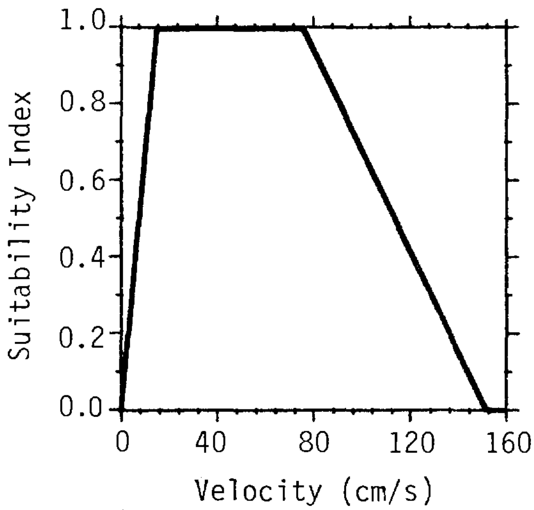


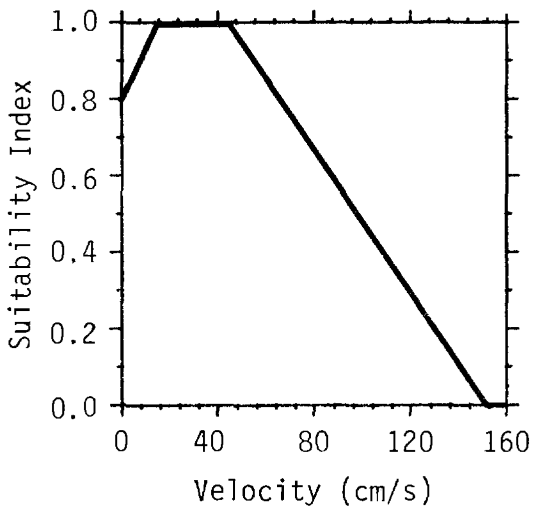

Figure 2. Category one velocity (mean water column) SI curves for shortnose sturgeon spawning and incubation, larvae, nonmigratory juveniles over 3 inches, and nonspawning adults.

| Coordinates | | |
| --- | --- | --- |
| x | x | y |
| cm/s | ft/s | SI |
| 0 | 0.0 | 0 |
| 15 | 0.5 | 1 |
| 76 | 2.5 | 1 |
| 152 | 5.0 | 0 |




Nonmigratory juveniles > 3 inches

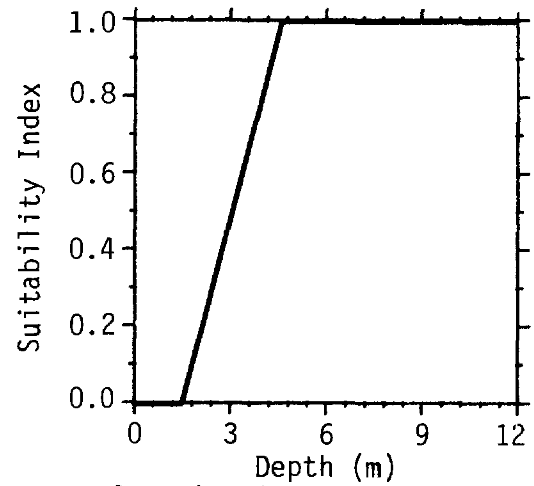
| cm/s | ft/s | SI |
| --- | --- | --- |
| 0 | 0.0 | 0.8 |
| 15 | 0.5 | 1.0 |
| 45 | 1.5 | 1.0 |
| 152 | 5.0 | 0.0 |




Nonspawning adults

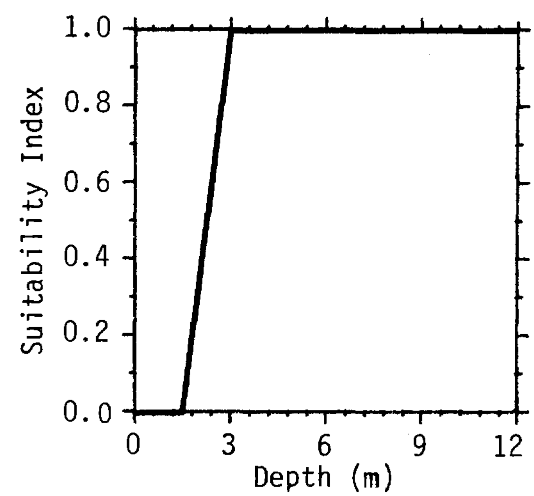
Figure 2. (Concluded)

| Coordinates | | |
| --- | --- | --- |
| x | x | y |
| m | ft | SI |
| 1.5 | 5 | 0 |
| 4.6 | 15 | 1 |
| 12.0 | 40 | 1 |
| 30.0 | 100 | 0 |




Spawning/incubation/larvae

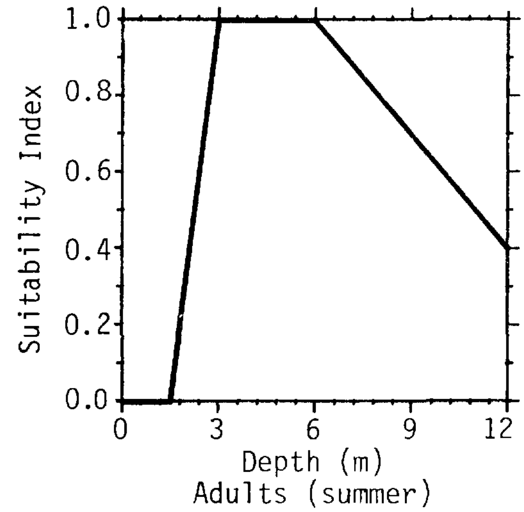
| m | ft | SI |
| --- | --- | --- |
| 1.5 | 5 | 0 |
| 3.0 | 10 | 1 |
| 12.0 | 40 | 1 |
| 30.0 | 100 | 0 |




Nonmigratory juveniles

Figure 3. Category one water depth SI curves for shortnose sturgeon spawning/incubation/larvae, nonmigratory juveniles, adults (summer), and adults (winter).

| Coordinates | | |
|---|---|---|
| x | x | y |
| m | ft | SI |
| 1.5 | 5 | 0.0 |
| 3.0 | 10 | 1.0 |
| 6.0 | 20 | 1.0 |
| 12.0 | 40 | 0.4 |
| 30.0 | 100 | 0.0 |




| m | ft | SI |
|---|---|---|
| 3 | 10 | 0 |
| 9 | 30 | 1 |
| 12 | 40 | 1 |
| 30 | 100 | 0 |

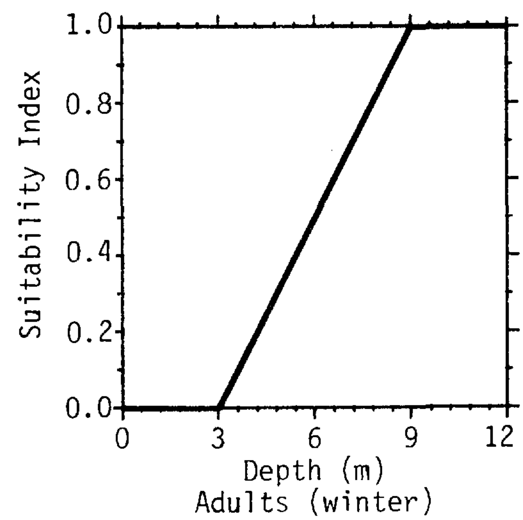
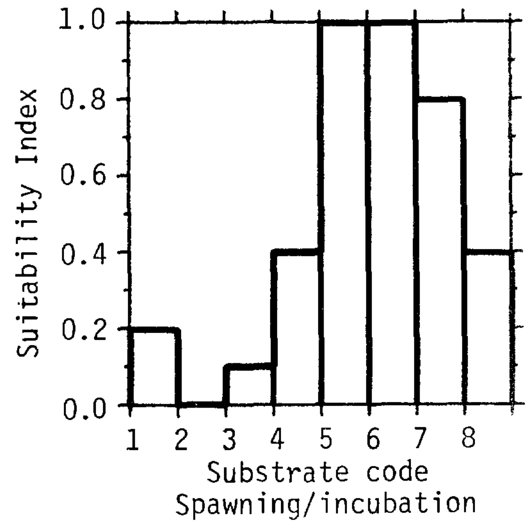
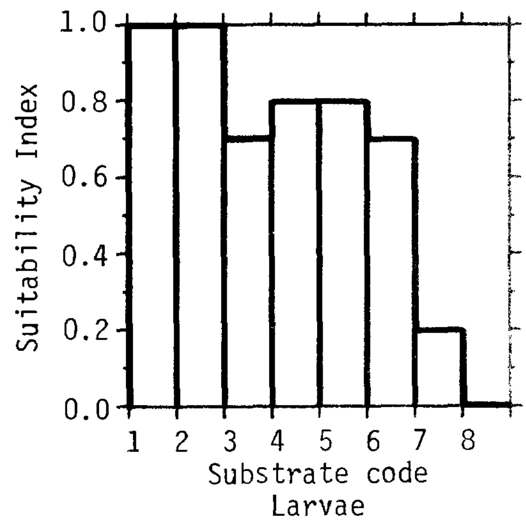



Figure 3. (Concluded)

| Code | Substrate | SI |
|---|---|---|
| 1 | Plant detritus/ organic material | 0.2 |
| 2 | mud/soft clay | 0.0 |
| 3 | silt, <0.062 mm | 0.1 |
| 4 | sand, 0.062-2 mm | 0.4 |
| 5 | gravel, 2-64 mm | 1.0 |
| 6 | cobble/rubble, 64-250 mm | 1.0 |
| 7 | boulder, 250-4,000 mm | 0.8 |
| 8 | bedrock | 0.4 |




| Code | Substrate | SI |
|---|---|---|
| 1 | Plant detritus/ organic material | 1.0 |
| 2 | mud/soft clay | 1.0 |
| 3 | silt, <0.062 mm | 0.7 |
| 4 | sand, 0.062-2 mm | 0.8 |
| 5 | gravel, 2-64 mm | 0.8 |
| 6 | cobble/rubble, 64-250 mm | 0.7 |
| 7 | boulder, 250-4,000 mm | 0.2 |
| 8 | bedrock | 0.0 |




| Code | Substrate | SI |
|---|---|---|
| 1 | Plant detritus/ organic material | 1.0 |
| 2 | mud/soft clay | 1.0 |
| 3 | silt, <0.062 mm | 1.0 |
| 4 | sand, 0.062-2 mm | 1.0 |
| 5 | gravel, 2-64 mm | 0.9 |
| 6 | cobble/rubble, 64-250 mm | 0.6 |
| 7 | boulder, 250-4,000 mm | 0.4 |
| 8 | bedrock | 0.2 |

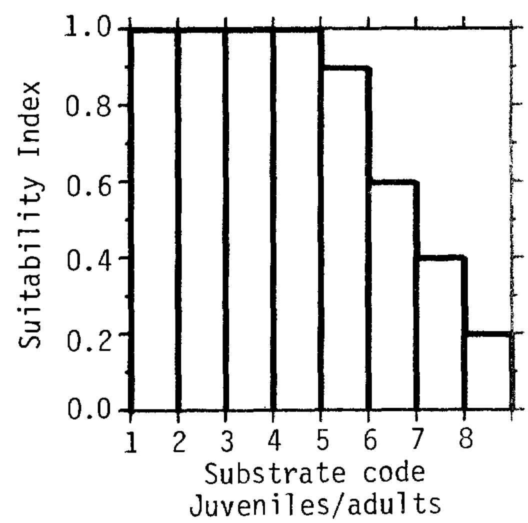
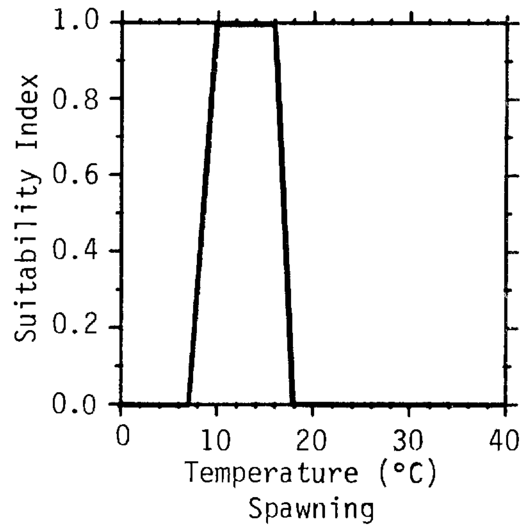



Figure 4. Category one substrate SI graphs for shortnose sturgeon spawning/incubation, larvae, and juveniles/adults.

| Coordinates x | x | y |
|---|---|---|
| °C | °F | SI |
| 7.2 | 45 | 0 |
| 10.0 | 50 | 1 |
| 16.0 | 60 | 1 |
| 18.0 | 65 | 0 |




| °C | °F | SI |
|---|---|---|
| 7.2 | 45 | 0 |
| 13.0 | 55 | 1 |
| 18.0 | 65 | 1 |
| 24.0 | 75 | 0 |

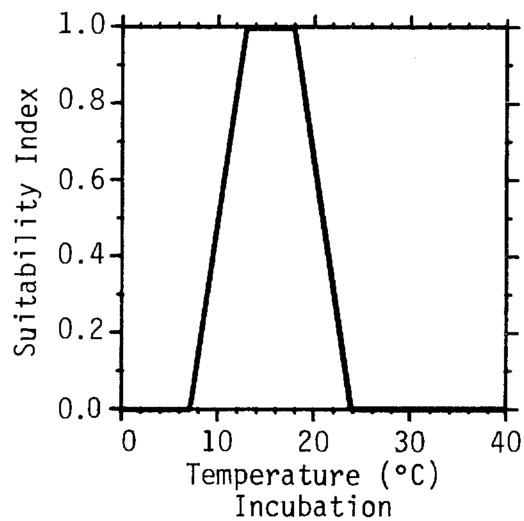
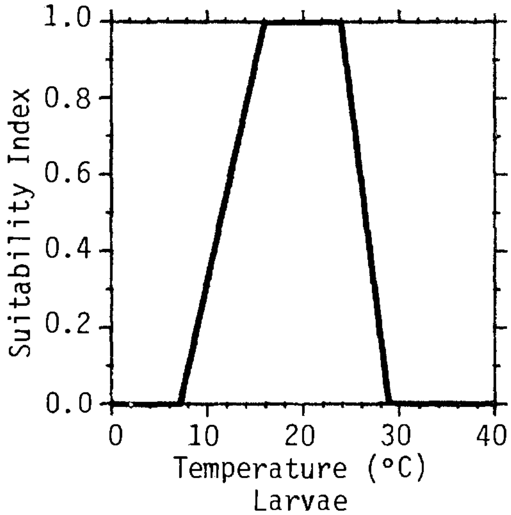



Figure 5. Category one water temperature SI curves for shortnose sturgeon spawning, incubation, larvae, and nonmigratory juveniles/adults.

| Coordinates x | x | y |
|---|---|---|
| °C | °F | SI |
| 7.2 | 45 | 0 |
| 16.0 | 60 | 1 |
| 24.0 | 75 | 1 |
| 29.4 | 85 | 0 |




| °C | °F | SI |
|---|---|---|
| 0 | 32 | 0 |
| 10 | 50 | 1 |
| 24 | 75 | 1 |
| 32 | 90 | 0 |

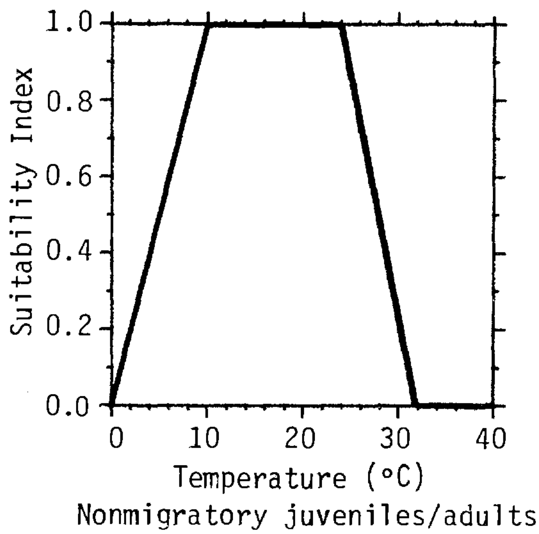



Figure 5. (Concluded)

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A review and synthesis of existing information were used to develop a Habitat Suitability Index (HSI) model and instream flow suitability curves for shortnose sturgeon (Acipenser brevirostrum). 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 the U.S. Fish and Wildlife Service.

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