A COMMUNITY-BASED HABITAT SUITABILITY INDEX MODEL FOR SHADED RIVERINE AQUATIC COVER, SELECTED REACHES OF THE SACRAMENTO RIVER SYSTEM

by

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PREFACE

The Habitat Suitability Index (HSI) model presented in this paper is designed to aid in identifying important habitat variables for Shaded Riverine Aquatic (SRA) Cover of selected reaches of the Sacramento River system. Facts, ideas, and concepts obtained from the research literature and expert reviews are synthesized and presented in a format that can be used in impact assessments. The model is an hypothesis of community-habitat relationships, and model users should recognize that the degree of veracity of the HSI model, Suitability Index (SI) curves, and assumptions may vary according to geographical area and the extent of the database used for estimating individual SI's values.

Interest in the use of community-based models in impact assessment has increased over recent years (see Schroeder 1987), primarily as a result of ecologists' heightened awareness of the linkages between species within a community. Thus, the intent of the community-based model presented herein is to include habitat variables which we consider essential in providing the structural and functional integrity for the several regionally important fish and wildlife species which inhabit this cover-type. SRA Cover has drastically declined in area and become increasingly fragmented in the Sacramento River system over the past 30 years; the Sacramento River and the Sacramento-San Joaquin Delta have also had significant expansions of introduced species over even a longer time period, largely as a result of habitat alterations. Consequently, the Fish and Wildlife Service (Service) has concerns about the viability of all natural habitats and native species in this region. The output from this model should provide an assessment of SRA Cover's ability to provide sustainable habitat requirements for several native, regionally-important fish and wildlife species, including anadromous salmonids, birds such as belted kingfisher, wood duck, great blue heron, black-crowned night heron and snowy egret, semi-aquatic mammals such as beaver and river otter, and several amphibian and reptile species. We believe that at least one functional characteristic (productivity) of this cover-type is also essential to the functional integrity of the entire Sacramento River ecosystem; thus the model also indirectly assesses the trophic dynamic structure of SRA Cover.

This model does not attempt to include *all* important variables for its targeted species; if it did, the model would be no more useful and likely more confusing than the use of several species-based HSI models. It does, however, provide an assessment of what we have determined to be key components of SRA Cover for several species. *We view this community-based model as a synthesis of key habitat components for several fish and wildlife species which are found in SRA Cover of the Sacramento River system. The model's output should reflect native species richness and the integrity of trophic relationships.* Other components (such as water quality, suitable nest sites, etc.) which may affect some species in the system are assumed to be constant or not to affect the output of the model. Based on our Field Office's extensive experience with this cover type in the Sacramento River system, we believe that this assumption is correct in nearly all instances. However, this model should not be applied (or should be modified before use) in instances where the biologist judges that the model would not provide an accurate assessment of the habitat requirements for one or more species of special focus.

The primary purpose in developing this model was to provide a mechanism of impact assessment for streambank protection projects in the Sacramento River system. Rock revetment (riprapping) construction on the Sacramento River has resulted in the loss of over 60 percent of the river's SRA Cover. Partially as a result of these losses, the Service's Sacramento Field Office has recently determined that this unique cover type is to be classified as Resource Category 1 (USFWS 1992a) under the Service's Mitigation Policy (Federal Register, January 23, 1981) relative to impacts caused by the U.S. Army Corps of Engineers' ongoing Sacramento River Bank Protection Project.

The Service encourages users of this model to provide comments, suggestions, and test results that may help us to increase the utility and effectiveness of this community-based approach to impact assessment. Please send any comments to:

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HABITAT DESCRIPTION

We define Shaded Riverine Aquatic (SRA) Cover as the unique, nearshore aquatic area occurring at the interface between a river (or stream) and adjacent woody riparian habitat. Key attributes of this aquatic area include (a) the adjacent bank being composed of natural, eroding substrates supporting riparian vegetation that either overhangs or protrudes into the water, and (b) the water containing variable amounts of woody debris, such as leaves, logs, branches and roots, often substantial detritus, and variable water velocities, depths and flows. Often, much of the instream vegetation consists of dead woody debris that has fallen from the overhanging riparian vegetation. However, whole trees, which periodically become dislodged from the adjacent eroding banks, often also contribute to the instream structure of SRA Cover. More thorough descriptions of SRA Cover may be found in documents by the U.S. Fish and Wildlife Service (1992a) and DeHaven (1989).

The size of any occurrence of SRA Cover is defined by the length and width of the aquatic area. The length is the distance along the riverbank; the width can be expressed as the average perpendicular distance from the shoreline during mean high water flows to the outermost (i.e., towards the center of the river) extension of either the vegetative canopy overhanging the water or the living and/or dead vegetation within the water, whichever is greater. Widths can range from as little as 1 or 2 feet to as great as 50 or 60 feet.

Although we define SRA Cover as an aquatic area, the area which comprises SRA Cover may include several terrestrial components such as overhanging terrestrial vegetation and riverbanks. Thus, this cover type may be of value to both terrestrial and aquatic species.

HABITAT SUITABILITY INDEX (HSI) MODEL

MODEL APPLICABILITY

Geographic Area: This model pertains to specific areas of SRA Cover (as defined above) existing along the following major riverine channels of the Sacramento River system within the Sacramento Valley, California: (1) the Sacramento River, from Colusa (River Mile 144) downstream to Rio Vista (River Mile 13); and (2) the Sacramento River's four primary distributary channels--Steamboat, Miner, Sutter, and Georgianna sloughs--which branch off the main river downstream of the city of Sacramento, roughly between the towns of Clarksburg and Walnut Grove.

Although the model has been designed for a specific ecoregion, it may be applicable for use in other rivers and streams of the western United States. However, before using this model in other areas we recommend that its assumptions be carefully reviewed, and any necessary modifications be made to "fine tune" the model to the particular study area.

Season: This model has year-round applicability for the geographical area listed above. However, sampling procedures are most easily and effectively carried out by boat and during relatively low water stages. To maintain consistency in measurements, we recommend that sampling be done under mean summer flow conditions in years of average precipitation and runoff.

Minimum Habitat Area: There is no minimum area which should be applied to the model. However, we suggest that, for impact assessments, the habitat be delineated both in terms of area *and* lineal feet along the river's edge.

Verification Level: The model has been verified under computer simulation and methodologies have been field-tested. No empirical data has been collected to test model output versus actual habitat quality (i.e., native species diversity). Thus, this model is an hypothesis of community-habitat relationships and not a statement of proven cause-and-effect relationships.

Expert review has been provided by:

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Their review comments and suggestions have been incorporated into the model.

MODEL DESCRIPTION

Overview: This model is divided into three components, each representing a key feature of SRA Cover structure (key species composition) and function (trophic dynamics). These are: Cover, Depth, and Substrate Composition. Within the Cover Component are four sub-components: Overhanging Cover, Instream Cover Area, Instream Cover Composition, and an Instream/Overhead Cover Interaction Factor. A total of six variables are included in the model. Each is discussed below.

Cover Components (V1-4):

Overhanging cover (V1), consisting of overhanging vegetation and, in some areas, overhanging banks, provides shade, a form of cover important to the survival of many aquatic organisms, including fish. Overhanging vegetation moderates water temperatures, which is an important factor for all life stages of salmonid fishes (Reiser and Bjornn 1979). Recent studies by the Fish and Wildlife Service (USFWS 1990, 1992b) have demonstrated (by sampling of abundance) the deleterious effect of elevated water temperatures on juvenile salmon outmigration success through the Sacramento River system into the San Francisco Bay. River productivity is also increased at all trophic levels by the allochthonous materials and energy input from terrestrial vegetation. The vegetation provides food and habitat for both terrestrial and aquatic invertebrates, which in turn serve as food for numerous bird species and several fish species including chinook salmon and steelhead trout (Hydrozoology 1976; Sekulich and Bjornn 1977).

Overhanging vegetation also provides shaded escape cover for fish. Wampler (1986) found that 86 percent of holding chinook salmon in the Wind River, Washington, were found in full or partial shade. Similar results were found for juvenile chinook salmon in the South Fork Salmon River, Idaho (Meehan *et al*. 1987). The value of overhanging vegetation has also been indirectly demonstrated by various studies which have compared juvenile salmon abundance along riprapped banks as compared to natural banks along the Sacramento River. For example, a Department of Fish and Game (CDFG 1983) study between Red Bluff (River Mile 244) and Ord Bend (River Mile 184) found about two-thirds fewer juvenile chinook salmon along riprapped than along natural riverbanks. From 1984 through 1988, annual surveys by the Service (Michny and Hampton 1984; Michny and Deibel 1986; Michny 1987, 1988, 1989) on the Sacramento River between roughly Chico Landing (River Mile 193) and Red Bluff found that only about 10-20 percent as many juvenile salmon were present along riprap as along natural riverbanks, and the highest densities of juveniles always occurred in areas with characteristics of SRA Cover. A similar, preliminary survey by the Service in 1988 along the lower Sacramento River (downstream of Sacramento) and distributaries failed to detect such population differences during spring when low-to-moderate water temperatures prevailed. However, during early summer when the Sacramento River warmed to over 70° F, juvenile salmonids were found exclusively in SRA Cover; none were captured in nearby riprapped areas (DeHaven 1989).

Overhanging vegetation also serves as feeding perches for fish-eating birds such as the belted kingfisher (CDFG 1990) and nesting and resting areas for birds such as herons, egrets and wood ducks (CDFG 1990). Hehnke and Stone (1978) found that bird species diversity on riprapped banks of the Sacramento River was 71 percent lower than on natural banks. Wood ducks prefer aquatic areas, including the Sacramento River and its sloughs (Small 1974), sheltered by riparian vegetation (Grinnell and Miller 1944; Small 1974) for feeding, courtship, and roosting (CDFG 1990). Their diet consists of terrestrial invertebrates, and terrestrial and aquatic plants (Bent 1923). Preferred nesting sites are cavities in trees (Palmer 1975) near or over the water (Bent 1923; Gilmer *et al*. 1978); nearly immediately after hatching, the young wood ducks jump or are carried by their parents into the adjacent waters (Bent 1923).

An overabundance of overhanging vegetation in small streams and ponds may *inhibit* feeding by belted kingfishers, which prefer isolated, overhanging branches (Bent 1940) from which they dive into the water to catch fish and aquatic invertebrates. However, in large, open streams such as the Sacramento River, suitable perch sites probably are not limiting (Prose 1985) and hence, these streams have been shown to be preferred by kingfishers in the Maritime Provinces (White 1953).

Streamside riparian vegetation also helps to prevent rapid streambank erosion (Buer *et al*. 1984), thus reducing water quality problems and rapid habitat losses.

Variable V1 is the percent of SRA Cover area which is covered by either overhanging vegetation or streambanks. We assume that value increases linearly as the percent cover increases. Maximum values are assumed to be achieved at 75 percent cover; at this point full or partial shading would be present over most of the site. The model does not distinguish the height of vegetative canopy. For the model, both high (relative to the water surface) and low cover are considered of equal value to fish and wildlife species.

In-water cover (V2 and V3) features occur in the form of either (a) woody vegetation from overhanging or fallen trees or branches, (b) aquatic vegetation, (c) variable substrate types and sizes, or (d) irregular or undercut banks. In-water cover provides habitat necessary for a wide range of regionally important fish and wildlife species. Orientation and size of woody debris enhances channel and habitat heterogeneity by altering flow direction and velocity (Everest and Meehan 1981; Shields and Smith 1992). The diversity of microhabitats present allows for high species diversity and abundance (Angermeier and Karr 1984; Bisson *et al*. 1987; Sedell and Swanson 1984).

Vegetative debris also provides a food source for instream invertebrates, which in turn are eaten by several fish species, including anadromous salmonids. Aquatic stream invertebrate productivity is usually highest in these nearshore areas at depths between 0.15 and 0.9 meters (Hooper 1973). Thus, a broad food base and extensive cover and habitat niches are supported by in-water cover. These values in turn create high fish and wildlife diversity and abundance at all trophic levels.

Instream cover along the stream banks also increases the physical complexity of the river channel (e.g., Shields and Smith 1992); the numerous debris dams and slack flow areas accumulate allochthonous organic matter and anaerobic conditions can develop. Dahm, Trotter and Sedell (1987) and others have shown that in these natural bank areas the concentrations of several important organic and inorganic nutrients are much greater than in channelized streams; thus, overall channel productivity may be enhanced by the greater nutrient availability in the natural areas. Woody instream cover increases aquatic productivity to a greater extent than rocks, probably because the woody cover also serves to provide organic materials and food for aquatic productivity.

Instream cover of the channels identified in this model is important to various life stages of salmonids, but is probably most important to juveniles. It provides them with abundant food resources, protection from predators, and an abundance of nearshore water conditions for their various growth stages and needs (Reiser and Bjornn 1979). Removal of instream structures can also cause disorientation of fishes, and disrupt their territorial behaviors which are often associated with feeding and reproduction. Nearshore vegetation also provides spawning substrate for several other fish species.

Logs, branches and large boulder masses provide a variety of microhabitats for aquatic organisms, by breaking up part of the relatively smooth, high-velocity flows associated with channelized streams. The composition of instream structures appears to have different values to individual species and their life stages (Olsen and West 1989). House and Boehne (1986) found a positive correlation between the amount of large woody debris and salmonid density in Tobe Creek, Oregon. Wampler (1986) determined preferences of cover types by adult chinook salmon in the Wind River, and found that large woody debris was about seven times more preferred than rock cover. The Service's instream flow SI curve for chinook salmon (Raleigh *et al.* 1986), which is based upon empirical data from Suchanek *et al.* (1984), records SI values of 1.0, 0.9, and 0.2 for undercut banks, woody debris, and rubble/cobble/boulders, respectively. Hampton (1988) found the same order of preference for these three instream cover types by all life stages of anadromous salmonids in the Trinity River; however, undercut banks were even more highly preferred (relative to the other two types) than in Suchanek *et al.*'s (1984) study.

Several birds (e.g., herons, egrets, belted kingfisher, wood duck) and mammals (e.g., beaver, mink and river otter) utilize emergent instream structures for resting, cover, and as access for feeding in the productive nearshore areas (Melquist and Hornocker 1983; CDFG 1990). Muskrats rely upon emergent nearshore vegetation as a food source (Mitch and Gosselink 1986), whereas many other vertebrate species feed on fishes and invertebrates which are concentrated within areas of instream cover. The western pond turtle basks on partially submersed logs on riverbanks (Stebbins 1985). Bullfrog survival has been shown to become reduced where vegetative cover and woody debris are lacking (Brown 1972); they and other herpetofauna often hibernate in submerged nearshore muddy, debris-covered substrates, and also use woody debris and leaf litter which washes up on river shorelines as cover (Hawkins *et al.* 1983; Jones 1988; Jones and Glinski 1985; Willis *et al.* 1956).

Variable **V2** is the percent of SRA Cover area which has any in-water cover features. Its SI curve assumes a correlation between the amount of cover at the site and its value to fish and wildlife. This correlation is positive between 0 and 40 percent; however, in areas of extremely dense cover (>75 percent), conditions for fish and wildlife are assumed to decrease slightly due to extremely impaired flows, limited access for some aquatic species, and reduced feeding success by fish-eating birds.

Variable **V3** refers to composition of instream structures that provide cover. Relative values of different instream cover components were determined based on the information summarized in this section. Sites with undercut banks and a high percentage of woody cover are given the highest habitat values, with lesser values for cover composed of boulders and cobbles.

Overhead cover/instream cover interaction (V4) refers to the synergistic effect of occurrences of overhead cover and instream cover in the same location, or conversely, the negative effect of providing as mitigation only one of the two forms of cover. A California Department of Fish and Game study

(Brown 1990) in the upper Sacramento River found that chinook salmon fry and juveniles have high preferences for areas containing both overhead and instream cover. Mean preference ratios determined from that study are shown in Table 1. It is likely that similar preferences may be found for some other fish species, as well as beaver, muskrat and wood duck, but we know of no studies which have attempted to determine such information. Some other species, such as the kingfisher, probably would not be affected by the absence of instream cover, but would be affected by the loss of overhead cover.

Variable V4 is a multiplicative factor designed to reflect the value of the synergistic effect of the presence of both cover types at one location. The sharp preferences which were found in the California Department of Fish and Game study (Brown 1990) formed the general basis for the Variable V4 SI curve. However, we increased the low values for the presence only of either instream or overhead cover, based on the likelihood that for many animals, relative habitat values would be higher than what Brown (1990) determined for juvenile salmon.

TABLE 1. Mean habitat preferences for chinook salmon fry (less than or equal to 2.6 inches total length) and juveniles (greater than 2.6 inches) in the upper Sacramento River. Data taken from Brown (1990).

COVER CATEGORY	RELATIVE PREFERENCE RATIO	
	FRY	JUVENILES
NO COVER PRESENT	0.01	0.00
INSTREAM COVER ONLY	0.17	0.04
OVERHEAD COVER ONLY	0.57	0.26
INSTREAM AND OVERHEAD COVER	1.00	1.00

Substrate Composition Component (V5):

Natural, often eroding banks, composed of soil, sand, gravel, silt, or clay often have cavities, depressions or vertical faces which provide substrate required by certain bank-dwelling birds (e.g., bank swallows, rough-winged swallows, and belted kingfisher), mammals (e.g., muskrat, mink, beaver, and river otter) and fish (e.g., channel catfish) for feeding, cover, and shelter. Many species utilize these areas as access and egress points from shore to water, or as nesting or burrowing areas (CDFG 1990, 1992). Natural erosion of natural bank substrates also replenishes instream spawning substrates for numerous aquatic species, including anadromous salmonids (Buer et al. 1984). Furthermore, erosion of riparian vegetation also replenishes the instream woody debris in the aquatic system, and contributes other allochthonous materials and energy to the riverine system.

River banks consisting of a uniform layer of rock (e.g., riprap) are of little or no value for several species, such as burrowing mammals and bank-dwelling birds. These species prefer eroding banks with primarily sand or clay soils (Garrison 1991; CDFG 1990). Kingfishers also prefer sandy soils for burrowing in vertical faces along the river (White 1953; Cornwell 1963), as do muskrat (CDFG 1990) and several other burrowing mammals.

Although the bank swallow does not exclusively require SRA Cover areas, the majority of suitable nesting sites for these birds are located in areas that include SRA Cover or its components. The bank swallow nests in colonies in eroding banks, usually composed of loamy, friable soils of sand, clay, silt and gravel (Garrison 1991). Colonies are found on the Sacramento River, mainly upstream of Sacramento, and on the lower Feather and Yuba rivers. Existing SRA Cover sites which are presently unsuitable for bank swallow nesting may be suitable sites in future years, during more advanced stages of erosion. Thus, riprapping of areas with SRA Cover eliminates future nesting areas for this State-listed threatened species.

Bank substrates vary in suitability for various life stages of salmonids. Several studies (CDFG 1983; Michny and Hampton 1984; Michny and Deibel 1986; Michny 1987, 1988, 1989) show that Sacramento River banks which have been riprapped with large quarry rock support fewer juvenile salmon than natural banks. Chinook salmon fry and juveniles often prefer habitats where fine sediments (< 4 mm diameter) are predominant (Hampton 1988; Brown 1990), probably because of the low current velocities associated with fine sediment deposits. Juvenile salmon also prefer gravel sediments (4 to 75 mm) and, to a lesser extent cobbles, likely because of the increased insect productivity in these substrates (Reiser and Bjornn 1979). Boulder substrates are least preferred by salmonids, although boulders are of value as a *subdominant* substrate (Hampton 1988; Brown 1990); in these instances, the boulders function as instream (object) cover for fishes.

Variable **V5** refers to the composition of the dominant (in terms of area covered) substrate type present at a site. Relative values of different substrate types were determined based on the information summarized in this section. Fine and gravel substrates provide the highest habitat values for the key fish and wildlife species inhabiting SRA Cover. Cobble substrates provide intermediate habitat values, and boulders are of the lowest value as the dominant substrate.

Depth Component (V6):

Generally, shallow nearshore areas are of higher values to fish and wildlife than are deeper nearshore areas. For semi-aquatic and amphibious species, access and egress to and from the water is facilitated in shallow areas. Several bird species, such as the belted kingfisher (White 1953) and herons (Kushlan 1976), usually feed in water less than 24-inches-deep, although kingfishers may also feed in the upper water column of deeper areas. Nearshore shallow areas of streams are typically highest in insect productivity (Hooper 1973). Studies in the Sacramento River (Brown 1990) and in other northern California rivers (Hampton 1988; Aceituno 1990) show that salmonid juveniles and fry typically inhabit shallow, nearshore areas which are between 1- and 3-feet-deep.

Variable **V6** is the average depth of SRA Cover at a distance of 5 feet from the water's edge. Optimal SI values are given for depths ranging between 1 and 3 feet. SI values decrease at depths outside this optimal range.

SI CURVES / METHODOLOGIES

Sampling of SRA Cover is best carried out from a boat. Two to three people are necessary to make measurements, drive the boat, and record data.

Site Length: Length of SRA Cover is best measured from aerial photographs, if available. Planimetry of the shoreline, making curvilinear lines, should provide accurate determinations of the length of the study site.

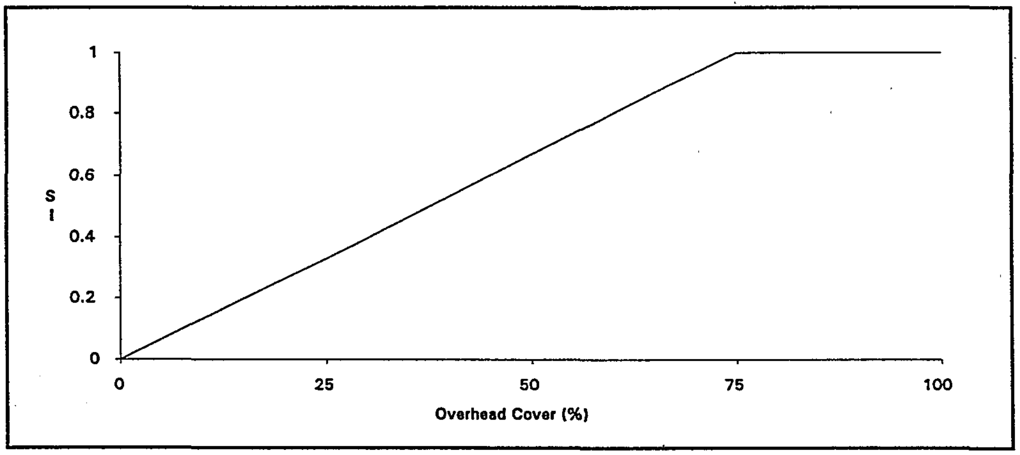
Site Width: Width of SRA Cover is defined as the *average* distance from *the estimated mean summer water line during years of average precipitation and runoff* to the average distance perpendicular to the shoreline that either overhead or instream cover (whichever is greater) occurs. Thus, width would be determined during measurements of Variables **V1** and **V2** (see below).

Variable V1 - ***Overhead cover***: Percent of SRA Cover area which has overhanging vegetation or streambanks.

Over-water canopy density refers to the amount of vegetative canopy and/or overhanging bank which actually hangs over the water surface, thus providing shade, woody vegetation, detritus and insect drop to the river.

MEASURED BY:
The line-intercept method (Hays *et al*. 1981). The line transects should be perpendicular to the streambank towards the center of the river, and should extend the full *width* of each occurrence of SRA Cover (i.e., the average distance perpendicular to the shoreline that either overhead or instream cover, whichever is greater, occurs). Sample with at least one transect per 50 lineal feet of SRA Cover, or a minimum of three transects for occurrences of less than 50 lineal feet. Sample sites should be determined randomly. Alternative methods: visual estimation; mapping and area determination using planimeter; GIS mapping with area determination; and other documented suitable methods (e.g., *See* Hays *et al*. 1981; Hamilton and Bergersen 1984).

SI CURVE:

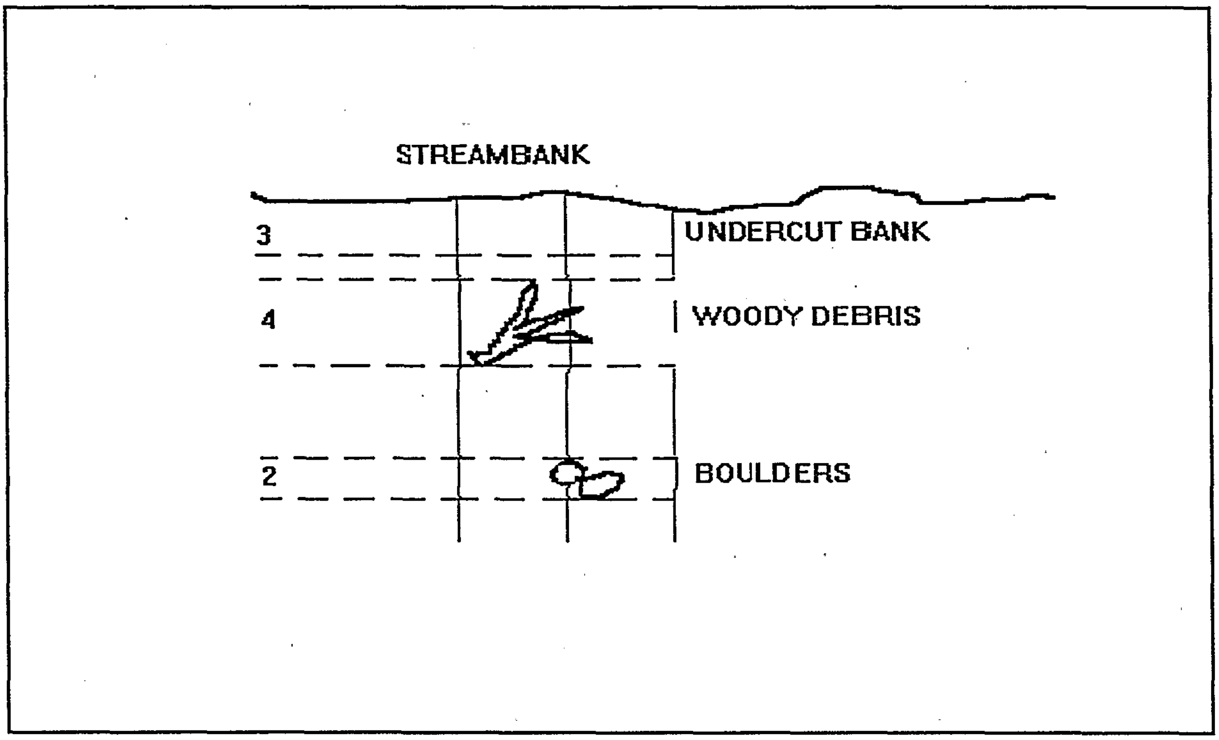


/

Variable V2 - ***Instream cover area***: Percent of SRA Cover area which has any in-water cover features. It does not include the type of substrate which is dominant at the site (See V5).

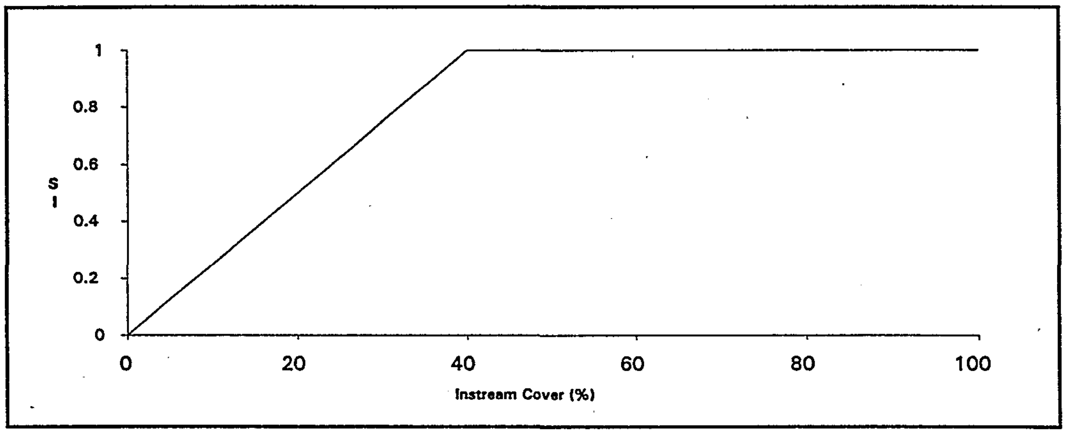
MEASURED BY:
A modification of the line-intercept method, using 10-foot-wide transect bands instead of transect lines. The transect bands are superimposed on the water's surface and any in-water cover within the band is identified. Any such cover intercepting the band is considered as if it intercepted a line transect (see example below). Numbers of transect bands, transect band locations, and length of the transect bands for each occurrence of SRA Cover are determined the same as for Variable V1. If sampling from a boat in swift currents, repeated measurements may be needed at each transect site to minimize errors due to boat drift.

The figure below illustrates a sample transect. Over the 18-foot width of the site, 9 feet of cover was found (which consisted of 3 feet of undercut bank, 4 feet of woody debris, and 2 feet of boulders). Thus, the sample site would have 9/18, or 50 percent, instream cover.



Alternate measurements: If visual sightings of cover are not possible, length of cover items intercepted along the transect plane can be estimated by "feeling" the bottom using a range pole. Measurements may also be made by divers using an underwater transect.

SI CURVE:



Variable **V3** - ***Instream cover composition***: Refers to the *type* of in-water cover features present.

MEASURED BY:
The band transect method as described for **V2**. Determine the length of each instream cover feature (see below) appearing within the plane of the transect band. If only one in-water cover feature predominates, determine the SI directly from the graph below. If more than one instream cover feature is present, determine the length or percent of each type, and calculate a weighted mean average SI using the graph below. For example, the sample transect depicted under Variable **V2** contained 9 feet of instream cover consisting of:

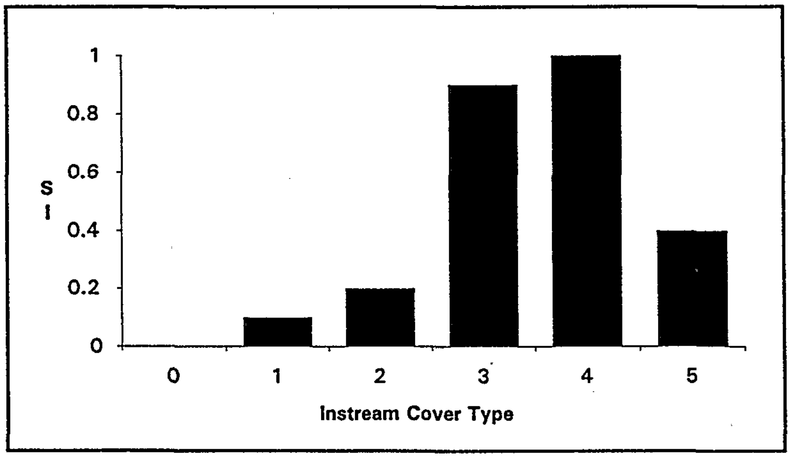
2 feet of boulders (sub-SI = 0.2),
3 feet of undercut banks (sub-SI = 1.0), and
4 feet of woody debris (sub-SI = 0.9),

Thus, the SI for Variable **V3** would be:

$$\frac{2(0.2) + 3(1.0) + 4(0.9)}{9} = 7/9 = 0.78$$

Alternate measurement: Visual estimate of relative percents of each instream cover type; if visibility is impaired, a metal range pole can be used to determine cover composition by probing the bottom.

SI
CURVE:

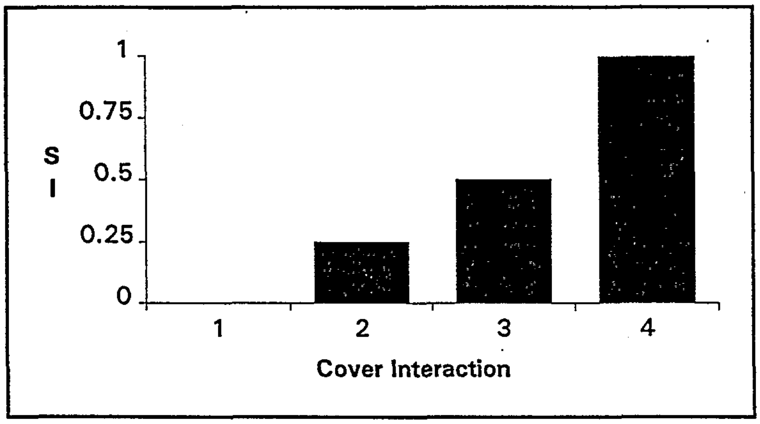


where:
0 = No cover present
1 = cobble (75 to 300 mm diameter)
2 = boulders (greater than 300 mm)
3 = woody debris
4 = undercut banks
5 = aquatic vegetation

Variable V4 - ***Instream/overhead cover interaction***: An adjustment of SRA Cover value downward when only one of the primary cover components (in-water or overhead) are present.

MEASURED BY:
Determining whether instream and/or overhead cover are present at the site.

SI CURVE:



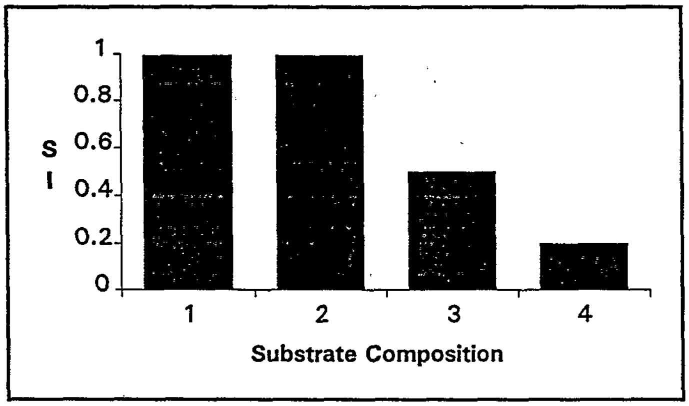
where:

1 = no cover present
2 = instream cover only
3 = overhead cover only
4 = both instream and overhead cover are present

Variable V5 - ***Substrate composition***: Refers to the composition of the dominant type of benthic substrate present.

MEASURED BY:
Characterizing surface substrate composition at sample points 5 feet from the bank. This can be done visually, with a probe of some type, or by using a benthic "grab" sampling device, as may be appropriate at a given sampling location. At least one sample per 50 lineal feet of riverbank, or a minimum of three samples, is recommended.

SI CURVE:



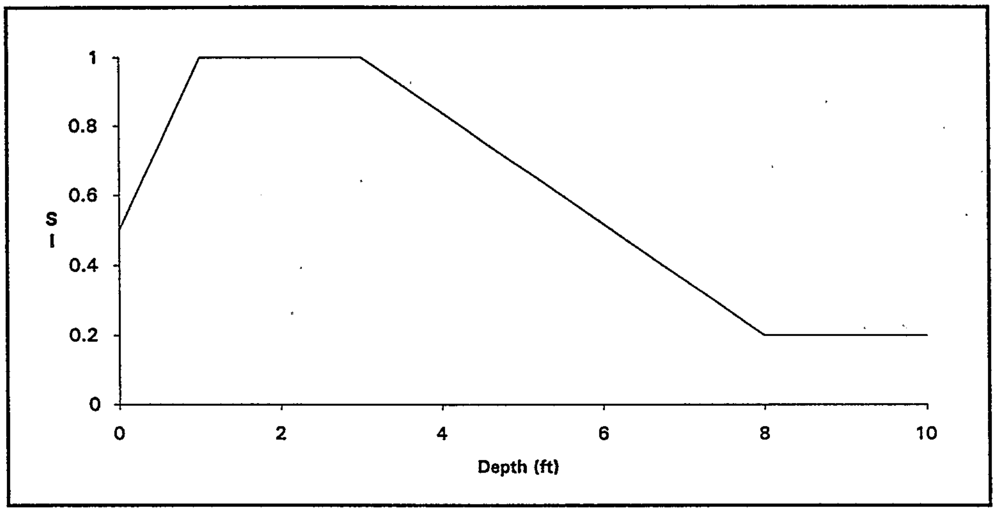
where:

1 = fine sediments (less than 4 mm diameter)
2 = gravels (4 to 75 mm)
3 = cobble (75 to 300 mm)
4 = boulders (greater than 300 mm)

Variable **V6** - ***Water depth***: Refers to the mean depth of the river 5 feet away from the bank.

MEASURED BY:
Using a range pole, visual estimate, weighted string, electronic depth finder or other method, as appropriate. Determine the average depth from at least one sample per 50 lineal feet of riverbank, or a minimum of 3 samples.

SI CURVE:



HSI DETERMINATION

The Habitat suitability index is calculated using the formula:

$$HSI = \frac{2(V1 + (V2 \times V3)) \times V4 + V5 + V6}{6}$$

This formula was determined during our verification of the above model. We determined the relative weighting factors of the cover, substrate, and depth components using sample data for various Sacramento River sites and hypothetical data. Based on these data, we determined that cover components should be weighted to receive two-thirds of the total HSI value, and that substrate composition and depth components should together contribute one-third of the total value. We compared output values to our predictions of habitat values, and this formula provided the most consistent results. The model's output, as stated above, should provide: 1) a numerical descriptor for richness of native species which rely on SRA Cover, and 2) an indicator of the overall "health" of trophic relationships. However, these have not as yet been empirically tested using this model.

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