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GENERAL MANAGEMENT CONCEPTS

The Incremental Method of Assessing Habitat Potential for Coolwater Species, with Management Implications

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Abstract

The IFG incremental method assesses the effects of stream flow regimes on fish communities. It utilizes one or more hydraulic simulation procedures to determine the distribution of depth, velocity, and substrate within a channel at different discharges. A composite probability of use for each combination of depth, velocity, and substrate is determined for each life stage of each species under study. A weighted usable area, roughly equivalent to the physical carrying capacity of the stream reach, is then determined for each month of the year. The weighted usable area may then be used to interpret changes in both standing crop and species composition due to changes in the hydraulic features of the stream.

At first glance, there appear to be few common features among various riverine habitat alterations such as stream dewatering, flow augmentation, channelization, bank stablization, habitat improvement, or sedimentation. Each appears to be a unique problem, requiring a unique solution. However, each of these problems involves some alteration of river hydraulics, and the responses of different aquatic species to those changes. Thus, it is possible to utilize a standard methodological approach in the solution of any of these problems.

The Incremental Method was developed by personnel of the Cooperative Instream Flow Service Group, U.S. Fish and Wildlife Service, Fort Collins, Colorado. The IFG incremental method allows quantification of the amount of potential habitat available for a species and life history phase, in a given reach of stream, at different streamflow regimes with different channel configurations and slopes.

This method is composed of four components: (1) simulation of the stream; (2) determination of depths, velocities, substrates, and cover objects, by area; (3) determination of a composite probability of use for each combination of depth, velocity, substrate, and cover (where applicable) found within the stream reach, for each species and life history phase under investigation; and (4) the calculation of a *weighted usable area* (roughly a habitat's carrying capacity based on physical conditions alone) for each discharge, species, and life history phase under investigation.

Stream Reach Simulation

Several hydraulic simulation techniques, with varying input data requirements and levels of accuracy, are routinely used in assessment of instream flow requirements. However, the family of hydraulic simulations most promising in the assessment of channel manipulation is generally termed "backwater curve" calculation.

Several computer programs are available, which can predict the hydraulic parameters of depth, velocity, width, and stage for different discharges. The version utilized by the Bureau of Reclamation (Anonymous 1968) is termed "Pseudo," while the Corps of Engineers (Anonymous 1976) has a series of backwater curve programs titled "HEC."

Regardless of the title, all backwater curve or "water surface profile" calcula-

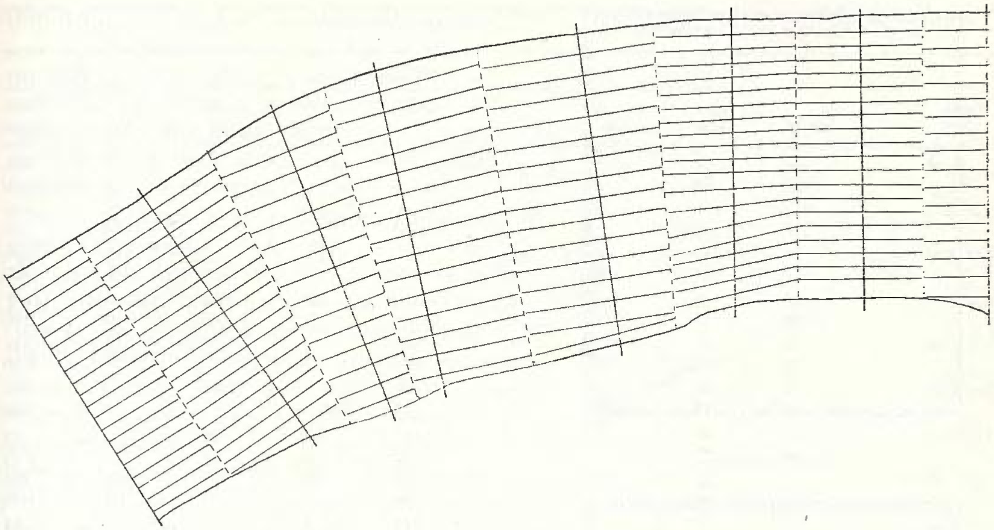

FIGURE 1.—*Computer conceptualization of a simulated stream reach. Hydraulic parameters of depth, velocity, and substrate for each major transect subdivision are assigned to the area of each subdivision block.*

tions utilize Manning's equation,

$$Q = N^{-1}R^{2/3}S^{1/2}A,$$

where

Q = discharge (m^3/s);

R = hydraulic radius (m), or cross-sectional area divided by the wetted perimeter of the stream (roughly equivalent to mean depth);

S = energy gradient, assumed parallel to slope of the water surface;

A = cross-sectional area (m^2);

N = roughness coefficient, which may be calculated from stream measurements, or estimated from a description of bed materials, channel uniformity, and channel shape.

Since $Q = VA$, Manning's equation may be restated as

$$V = N^{-1}R^{2/3}S^{1/2},$$

where V is mean velocity (m/s).

The stream reach simulation utilized by IFG uses several cross-sectional transects, each of which is subdivided into 9 to 20 subsections. The computer program then treats each subsection as an essentially separate channel. For any stage (water surface elevation), the mean depth and velocity of each subsection may then be calculated.

An area represented by these values of depth and velocity is calculated by multiplying the width of the subsection by half the distance to the next transect upstream and the next downstream. This representation is illustrated in Figure 1.

The output of the stream reach simulation is in the form of a multidimensional matrix showing the surface area of stream having different combinations of hydraulic parameters (i.e., depth, velocity, substrate, and cover when applicable). Table 1 illustrates a depth-velocity matrix, although the computer is not limited to two dimensions. The numeral in the upper left-hand corner of the matrix refers to 585 m^2 per km of stream having a combination of depths less than 0.3 m *and* velocities less than 0.15 m/s. This is the total summation of areas within the stream reach with that combination of depths and velocities. These areas are not necessarily contiguous.

In order to evaluate the magnitude of impacts caused by changes in stream hydraulics, it is necessary to develop an information base for each species or group of species of interest. Such an information base is termed biological criteria.

Biological criteria are primarily aimed at those parameters affecting fish distribu-

TABLE 1.—*Distribution of depth-velocity combinations, expressed as* m^2 *per km of stream, and (in parentheses) weighted usable areas* (m^2/km) *for adult smallmouth bass.*

Depth (m)	Velocity (m/s) <0.15	 0.15–0.30	 0.30–0.45	 0.45–0.60	 0.60–0.75	 0.75–0.90	 0.90–1.05	 >1.05	 Totals
<0.30	585 (22)	78 (4)							663 (26)
0.30–0.45	270 (24)	141 (15)		123 (14)	51 (5)	18 (<1)	18 (0)	279 (0)	900 (58)
0.45–0.60	87 (11)	114 (17)	96 (15)	132 (21)	324 (38)	237 (5)	114 (0)	516 (0)	1,620 (107)
0.60–0.75	18 (3)	87 (17)	69 (15)	27 (6)	333 (53)	393 (11)	429 (0)	525 (0)	1,881 (105)
0.75–0.90	18 (4)	45 (11)	165 (44)	237 (63)	123 (24)	192 (7)	123 (0)	315 (0)	1,218 (153)
0.90–1.05	27 (7)	51 (15)	45 (15)	36 (9)	96 (23)	9 (<1)	447 (<1)		711 (69)
1.05–1.20	27 (9)	60 (23)		51 (21)	141 (43)	51 (3)	246 (3)		576 (102)
1.20–1.35		60 (29)		33 (17)	150 (58)	105 (7)	51 (1)		399 (112)
1.35–1.50		33 (22)		15 (11)	345 (189)	60 (6)			453 (228)
1.50–1.65				21 (20)	69 (50)	45 (6)			135 (76)
1.65–1.80		30 (27)			93 (68)	60 (8)			183 (103)
Totals	1,032 (80)	699 (180)	375 (89)	675 (182)	1,725 (551)	1,170 (53)	1,428 (4)	1,635 (0)	8,739 (1,139)

tion which are most directly related to streamflow and channel morphology: depth, velocity, temperature, and substrate. Cover, a habitat parameter of paramount importance to many species, is also indirectly related to streamflow. Cover may be incorporated into an assessment by evaluating the usability of available cover objects in reference to the flow parameters around them.

Species for which biological criteria are being developed are roughly divided into five classes.

(1) *Management-objective species* are sport and game fishes considered important and desirable by the public, and of importance to the objectives of the state management agencies.

(2) *Indicator species* are those with narrow habitat tolerances, which inhabit areas of streams which are particularly sensitive to changes in flow. It is assumed that if conditions are suitable for the indicator species, all other species will also have suitable habitat.

(3) *Rare and endangered species* are those which may be locally abundant, but with a highly restricted distribution, or those which occupy much of their former distribution, but in greatly reduced numbers.

(4) *Important non-game species* are those which may act in direct competition with game or sport species.

(5) *Forage species* are organisms occupying intermediate positions in the food chain, including both forage fish and aquatic invertebrates.

The criteria with which this method is concerned are termed probability criteria. The assumption is that the distribution and abundance of any species are not primarily influenced by any single parameter of stream flow, but related by varying degrees to all streamflow parameters. Furthermore, it is assumed that individuals of a species will tend to select the most favorable conditions in a stream but will also use less favorable conditions, with a lower probability of use as conditions become less favorable.

Given a sufficient number of observations and measurements, it is possible to

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determine a species' preferences within a certain parameter, such as depth. Based on this information, it is also possible to calculate the relative probability that the species will utilize some positive or negative increment of that parameter which falls outside of its preferred range.

Most flow assessment methodologies in current use address only one, or occasionally two life history stages. Frequently, a particular life history stage, or a certain time period is singled out as being critical for the continued well being of a fish population. For example, spawning success is commonly considered a critical factor in the maintenance of a fish population, but habitat evaluations for fry and juvenile fish are almost universally neglected. However, under the incremental method, probability criteria are developed for all life stages (Bovee and Cochnauer 1977).

Probability of Use

The composite use probability of any combination of hydraulic conditions encountered in the study reach may be determined from the individual probability-of-use curves for each species and life stage.

Figure 2 gives probabilities of use by adult smallmouth bass for depths and velocities. For a given increment of each parameter the use probability is read directly from the curve. For example, the use probability for the depth increment of 105 cm is 0.37. The use probability for the velocity increment of 15 cm/s is 0.81. The composite use probability for adult smallmouth bass for a depth of 105 cm *and* a velocity of 15 cm/s is $0.37 \times 0.81 = 0.30$. A composite probability is similarly calculated for each stream reach subsection.

Substrate or cover may also be incorporated into this determination of composite probability following the procedure detailed above. In the preceding example, if the substrate found with that combination of depth and velocity had a probability of use of 0.90, then the composite probability of use for that combination of depth, velocity, *and* substrate would be $0.37 \times 0.81 \times 0.90 = 0.27$.

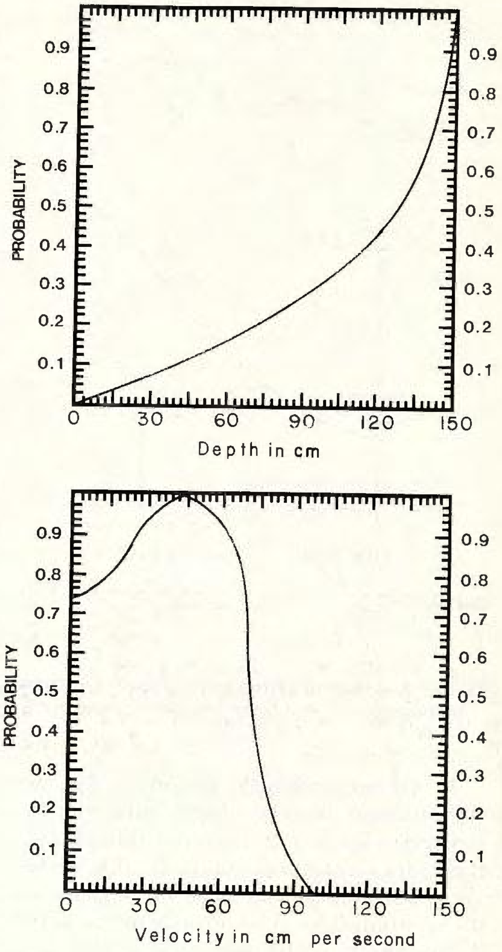

FIGURE 2.—*Probability-of-use curves for adult smallmouth bass.*

Weighted Usable Area

The weighted usable area is defined as the total surface area having a certain combination of hydraulic conditions, multiplied by the composite probability of use for that combination of conditions. This calculation is applied to each cell within the multidimensional matrix.

This procedure roughly equates an area of marginal habitat to an equivalent area of optimal habitat. For example, if 305 m^2 of surface area had the aforementioned combination of depth, velocity, and substrate it would have the approximate habitat value of only 82.4 m^2 of optimum habitat.