Instream Flow and Habitat Suitability Criteria

Habitat suitability criteria (HSC) are streamflow management tools that link species and life stages to their physical environment (Bovee 1986). The HSC incorporate the behavioral response of a species to the variability in microhabitat (e.g., depth, velocity, substrate). Put simply, HSC are mathematical relationships that describe a species response to a habitat attribute (Allen 2018). HSC are used in hydraulic habitat models (like PHABSIM[1] and SEFA[2]) to predict how the quantity and quality of habitat changes under different flows, and the models are used to develop flow criteria. Habitat versus flow relationships must be integrated with species life history knowledge which can be collected through fish observation surveys (Figure 1).

HSC Definitions

Fish Observations:
Microhabitat data collected where fish were observed during snorkel surveys; these points represent a sample of habitat that is occupied by the focal species and life stage

Habitat Availability:
Microhabitat data collected using a systematic randomized approach in each sampled mesohabitat unit; these points represent a sample of habitat that is also available to fish

Mesohabitat:
A section of habitat with similar characteristics (e.g., slope, channel shape, and structure) that is distinct and separate from adjacent mesohabitat sections (e.g., riffle, pool, glide, run) found in a stream

Microhabitat:
Small discrete areas within a mesohabitat occupied by an organism that is described using habitat components such as depth, velocity, substrate, or cover

Figure 1. IFP scientists snorkel a stream habitat unit in Hollow Tree Creek as a means of direct fish observation.

[1] US Geological Survey's Physical Habitat Simulation System
[2] System for Environmental Flows Analysis

HSC Categories

HSC categories describe the method used to develop HSC (Bovee et al. 1998).

Category I

Category I HSC involve professional opinion and personal experience. Category I considerations:

- Developed during discussions with interested stakeholders knowledgeable about target species habitat requirements
- Must remain neutral and objective with respect to criteria and their potential to affect the study outcome
- Discussions typically start with pre-existing HSC curves and the development of a new composite curve that is more representative of target species needs in the study watershed
- No fieldwork

Category II

Category II HSC are developed from field observations of species habitat use without accounting for habitat availability. Category II considerations:

- Locations where the target species was observed (Figure 2)
- Represents conditions that were occupied by the target species
- Uses fish observations only; habitat availability is not accounted for

Figure 2. An IFP scientist reaches out with a grabbing tool to place a weighted fish marker directly under a fish's location. The scientist keeps a short distance downstream to observe the fish without startling it.

Category II ½

Category II½ HSC are developed from field observations of species habitat use and accounts for habitat availability using an equal-area sampling approach or a proportional-area sampling approach. Category II ½ considerations:

- Surveys equal areas for each habitat type (e.g., 5,000 ft^2 of riffles, pools, runs, and glides)
- Uses fish observations (Figure 3) and accounts for habitat availability

Category III

Category III are also developed from field observations of species habitat use but this category adjusts for limited habitat availability by using a mathematical index (e.g., forage ratio). Category III considerations:

- Uses fish observations and accounts for limited habitat availability

Figure 3. A juvenile steelhead in Hollow Tree Creek lingers near the weighted fish markers.

HSC Data Collection

> According to Bovee (1986), a minimum of 150 fish observations are needed to construct an HSC curve.

HSC data collection can be completed through various methods depending on HSC category and stream limitations (e.g., high water depth). HSC Categories II, II½, and III require field data collection of fish observations. Methods of collecting these fish observations include, but are not limited to, observations from the streambank, snorkeling, SCUBA, underwater video, and electrofishing. Observations from the streambank, snorkeling, and SCUBA are the preferred methods by field biologists because they are the least intrusive and allow for direct observation of the fish's focal position and activity (Bovee 1986). Channel width, water clarity, and fish densities are taken into consideration when determining the appropriate method and resources needed for data collection.

When fish observation data are collected through direct observation, weighted numbered markers are placed where undisturbed juvenile salmonids are observed (Figure 4; purple areas). Data collection during the fish survey includes fish marker number, fish species, fork length, number of fish, fish activity, and fish focal position. When developing Category III HSC, habitat availability markers (Figure 4; green Xs) are placed throughout the unit using a stratified random sampling design after the fish survey is completed. At the location of each fish marker and each habitat availability marker, depth and velocity are recorded. Other microhabitat features like cover and substrate are also typically documented at each marker (Gephart et al. 2020; Holmes et al. 2014).

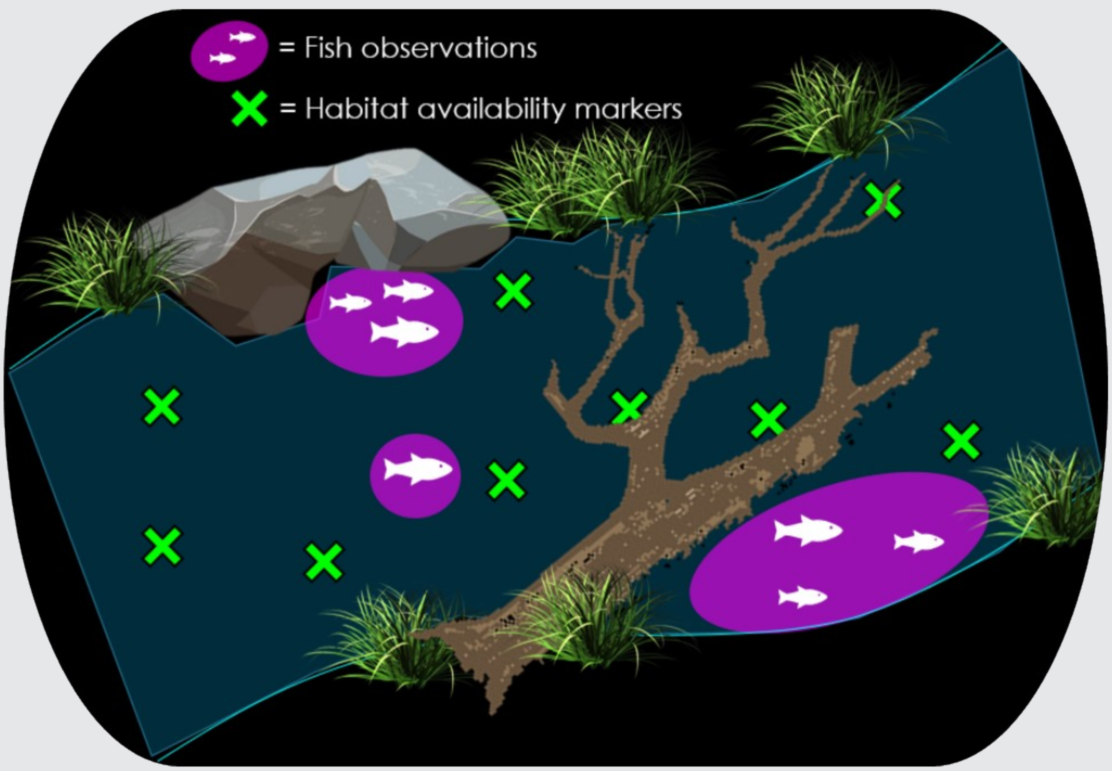

Figure 4. Schematic of a stream segment with fish observations circled in purple and randomized habitat sampling locations shown by green Xs.

Other methods used to account for habitat availability that do not use a mathematical index to account for limited habitat availability (e.g., the forage ratio (Jowett and Davey 2007; Manly et al. 1993)) include density sampling (Rubin et al. 1991) and presence/absence sampling (Gard 2010).

The IFP has created watershed-specific HSC curves in Hollow Tree Creek (within the South Fork Eel River watershed) and in the Big Sur River. Snorkel surveys were conducted to collect fish observation data in these studies (Figures 5 and 6; Gephart et al. 2020; Holmes et al. 2014).

Figure 5. This stream section in Hollow Tree Creek contains weighted markers where fish were directly observed by IFP surveyors (the visible pink flagging is tied to each marker).

Figure 6. IFP scientists snorkel a stream habitat unit in the Big Sur River, placing markers where fish are observed.

HSC Curves

HSC curves show the relationship between a microhabitat feature and its relative suitability for a specific fish species and life stage. The HSC results will vary depending on which category of HSC was selected for the study. Microhabitat suitability is assigned based on fish observations and may be adjusted for habitat availability if it is required for the category of HSC being developed. Microhabitat features are given a suitability index between 0 and 1, where 0 is least suitable and 1 is most suitable. The shape of the habitat suitability curve and location of peak suitability can vary based on fish species and life stage. For example, we could expect a fry salmonid to occupy different water depths and velocities than a spawning adult. Similarly, different fish species will utilize the habitat in diverse ways specific to their needs or adaptations, resulting in different suitability curves.

Figure 7 shows an example of Category III HSC results for juvenile steelhead and Coho Salmon suitabilities at varying water velocities. Although the curves shown below are both results for juvenile fish, the shape and peak of the curves differ because the stream habitat was occupied differently by steelhead and Coho Salmon.

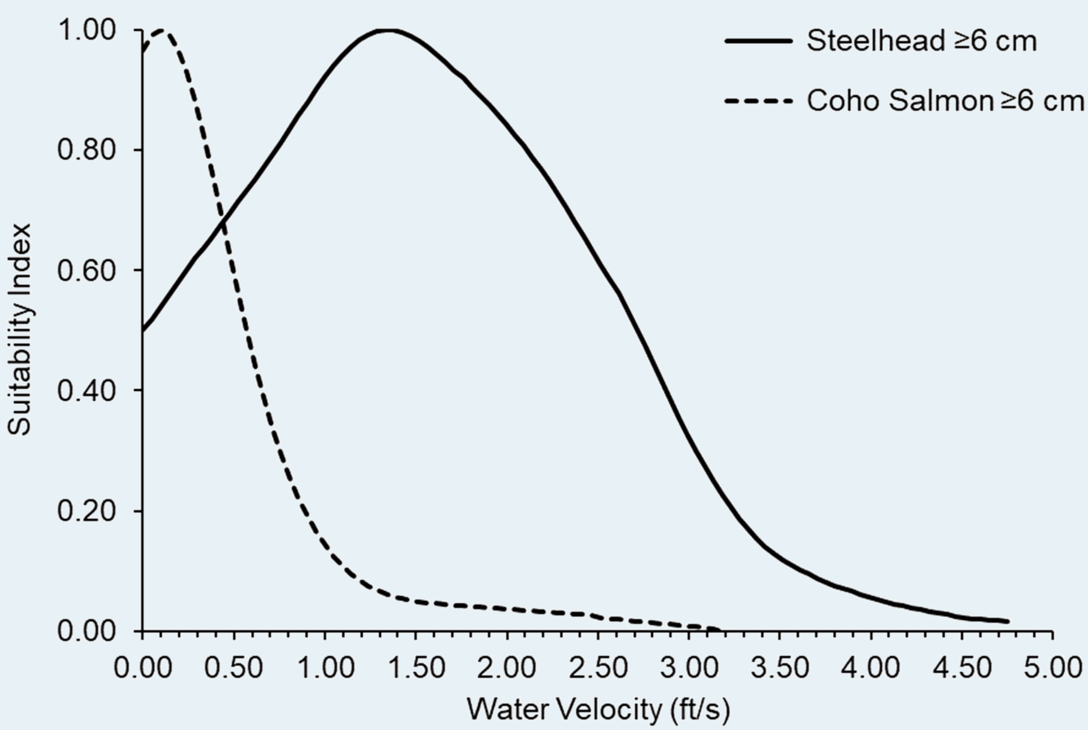

Figure 7. An example of juvenile (≥6 cm) steelhead and Coho Salmon HSC curves for water velocity based on results from Hollow Tree Creek (Gephart et al. 2020). The results from this example indicate that juvenile steelhead were found in locations with faster velocity than Coho Salmon of the same life stage.

It is important to develop region-specific HSC curves that reflect species adaptations to unique basin area attributes. However, there can be similar patterns of suitability across watersheds for a single species and life stage. Figure 8 shows a comparison of HSC curves from watersheds across the western United States (Beecher et al. 2016; Bovee 1978; Gephart et al. 2020; Hampton 1997; Hardy and Addley 2001; Holmes et al. 2014). The HSC curves for juvenile steelhead in the figure below show that the overall shape of the curves was similar between studies.

Certain considerations should be made before using HSC in a different watershed from where it was collected. These considerations include but are not limited to watershed size, stream habitat (e.g., cover, riparian vegetation), and species and life history traits (Bovee 1986; Bovee et al. 1998).

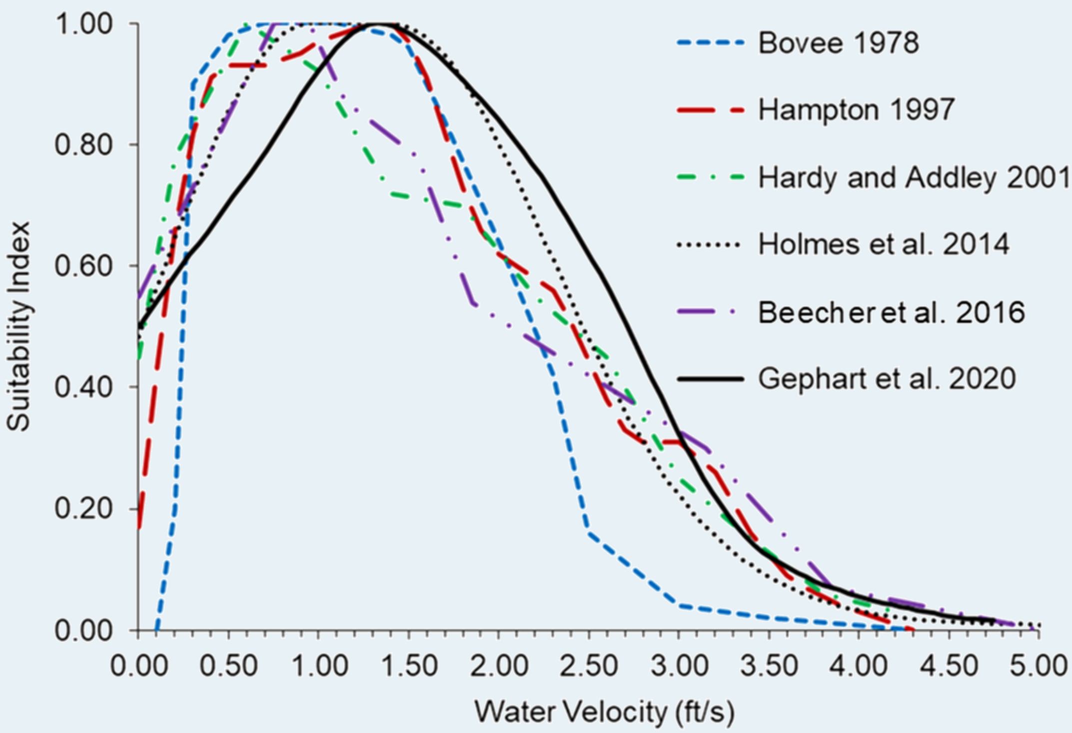

Figure 8. A comparison of juvenile steelhead water velocity HSC developed by different studies from various states and streams[3].

HSC inform area-weighted suitability (AWS; also known as weighted usable area) by providing the biological component needed to model the relationship between flow levels and physical habitat for fish. AWS is a scoring index that relates the amount of suitable habitat per unit of length (e.g., feet, yards) at a specified flow for a specific species and life stage (Payne and Jowett 2013).

[3] The curve developed by Bovee (1978) was created using data from multiple streams and states (i.e., Montana, Idaho, Utah, Washington, and Oregon). The curve developed by Beecher et al. (2016) is a combination of different streams throughout the State of Washington. The remaining curves were developed in various California streams including the Trinity River (Hampton 1997), the Klamath River (Hardy and Addley 2001), the Big Sur River (Holmes et al. 2014), and Hollow Tree Creek (Gephart et al. 2020).

Habitat index can be estimated by taking the distribution of measured depths and velocities occupied by fish and applying them to a distribution of depths and velocities surveyed in a cross-section of river. This allows instream flow practitioners to model predicted flow levels needed to protect fish species. Flows can then be identified to provide protective habitat based on unimpaired hydrologic conditions (Figure 9). The operational community (e.g., water managers) can use the modeled flow results to help guide policy and regulation to protect species and the habitats they depend on (Bovee 1986).

The IFP's fact sheet on two-dimensional modeling details the hydraulic habitat modeling process and the role of HSC in developing species-specific informed models.

Figure 9. Hollow Tree Creek is a relatively unimpaired stream in the South Fork Eel watershed that the IFP selected for an HSC study site.

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