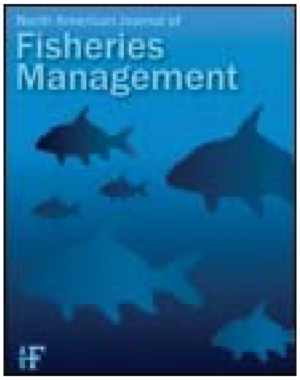

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Habitat Sequencing and the Importance of Discharge in Inferences

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Habitat Sequencing and the Importance of Discharge in Inferences

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Abstract.—We constructed stream maps for a low-gradient trout stream in southwestern Virginia during autumn (base flow) and spring (elevated flows) to compare spatial and temporal variation in stream habitats. Pool–riffle sequencing and total area occupied by pools and riffles changed substantially depending on the level of discharge: reduced discharge resulted in an increase in total pool surface area with more numerous but smaller pools than during spring. In contrast, total surface area of riffles decreased with decreasing discharge as did total wetted surface area. These findings suggest caution should be exercised when comparing seasonal or annual surveys, applying habitat guidelines for assessment or management, evaluating fish standing crop potential from predictive habitat models, or predicting availability of habitat or biological information at times other than when stream surveys are conducted. We demonstrate the potential dangers by intentionally applying biological sample results taken at one discharge level to the same stream reach at a different discharge level. Our results clearly illustrate the importance of acquiring physical and biological information during similar discharges.

The majority of field studies involving North American streams are conducted during the summer months when they are typically at or near base flow conditions. This timing is influenced in part by the observation that streams are often best studied at base flows (e.g., Simonson et al. 1994; Thurow 1994) and because universities are in summer recess, making large numbers of technicians and graduate students available. Repeated sampling within streams during the same field season is often not possible for stream surveys because of limited time. However, changes in stream discharge may result in substantial changes in habitat availability through time (Hogan and Church 1989), even between the beginning and end of a field season (Fallau 1995; Herger et al. 1996). The lack of repeated sampling produces a large storehouse of snapshots of streams upon which we sometimes, out of necessity, base assumptions for the season (e.g., fish distributions, densities, and production) or the year (e.g., microhabitat studies and their application in instream flow applications, but see Moyle and Baltz 1985; Baltz et al. 1991), or use temporal extrapolations to make predictions about suitable conditions during other times of the year (e.g., availability of spawning substrates for spring and fall spawning salmonids from one-time surveys; state and federal habitat guidelines such as the Pacific Salmon Conservation Strategy [PACFISH; USDA et al. 1995] and its inland salmonid habitat equivalent [INFISH]). We have not cited the above examples because it is neither our place nor desire to point out studies where this occurs.

Fisheries professionals do not intentionally misapply data, but many applications implicitly require some sort of extrapolation in space or time. Extrapolation in space from one or several representative reaches may lead to inaccurate predictions due to spatial variability (Hankin and Reeves 1988; Dolloff et al. 1993, 1997). However, techniques designed to eliminate representative reach extrapolation may fall victim to temporal variability in many systems. For example, Herger et al. (1996) reported substantial differences in pool and riffle area during different portions of the field season, and they cautioned against comparisons made from data collected at differing flows. Fallau (1995) also found changes in habitat amounts due to differences in discharge among various gradient classes. Similarly, base flows may differ among years, making both seasonal and annual comparisons possibly suspect. Some state and federal habitat guidelines (e.g., PACFISH) use features such

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as pool frequency or area of pools and riffles to judge adequacy of stream habitats for fish. Similarly, many models used to predict standing crops of stream fishes also use variables such as surface area, percentage of pools and riffles, pool width, and cover attributes (reviewed in Fausch et al. 1988). However, these physical attributes may change in configuration and abundance with changes in discharge (Fallau 1995; Herger et al. 1996).

During research aimed at evaluating the effectiveness of experimentally added large woody debris (LWD) in habitat restoration (Hilderbrand et al. 1997, 1998), we constructed stream maps in a low-gradient stream at two discharge levels: base flow and elevated flows occurring during spring. The purpose of this management brief is to report the substantial changes that occurred in pool–riffle pattern and surface area between the two flow regimes and to discuss the implications of these changes for extrapolations based on point-in-time habitat estimates.

Methods

We mapped stream channel features in Stony Creek, a low-gradient (1%) trout stream in southwestern Virginia. Stony Creek is a first-order stream with an average stream width of approximately 5 m during spring and approximately 3.5 m during late summer and fall. Stream discharges are typically elevated during winter and spring due to increased precipitation, and they decrease to base flows during late summer and fall because of lower precipitation. The stream was mapped once during spring 1993 when discharges were seasonally elevated by typical spring weather and again during fall 1993 when the stream was at base flow conditions. A permanent reference stake was secured in the riparian zone at the lower boundary of the study area. From this stake, we strung a measuring tape upstream and roughly parallel to the stream for as far as was possible and anchored its end with another stake. This procedure was repeated 30 times to map the entire length of the 870-m study reach. At zero distance and wherever the channel width changed more than approximately 1 m, the perpendicular distance from our tight line to the active channel edges and bank full edges was measured. Any measures to the left of the line were recorded as negative whereas any to the right were positive. The tight line represented the *y*-axis of a coordinate system and the perpendicular distances represented the *x*-axis, where the stake furthest downstream represented the coordinate origin 0, 0. Given the compass bearing of the tight line, the *y* distance, and the *x* distance, the stream's features were represented in a Cartesian grid. We defined pools and riffles by following descriptions in Bisson et al. (1982) and classified glides as pools and runs as riffles. Pool and riffle boundaries were mapped throughout the 870-m stream reach.

After transforming our data into grid coordinates, we constructed digital stream maps to scale with ARC/INFO, a GIS (geographic information system) software package. These maps enabled us to examine pool–riffle sequencing at different sampling periods and provided measurements of area occupied by each individual riffle or pool. We then applied information gathered on leaf detritus and benthic macroinvertebrates collected during spring 1993 (described in Hilderbrand 1994; Hilderbrand et al. 1997) to form estimates at the scale of the stream reach.

Results and Discussion

Seasonal differences in discharge resulted in substantial changes both in pool–riffle sequencing (Figure 1) and in number, total area, and mean area occupied by each channel unit type (Table 1). At base flow conditions, Stony Creek contained almost twice as many pools that were on average 23% smaller than pools existing in the elevated discharge conditions. However, reduced discharge increased total pool surface area by 33% from 1,266 m^2 to 1,681 m^2. The reduction in discharge at base flow resulted in a 56% reduction in riffle area and an increase in riffle number due to pools breaking up long riffle stretches. Total stream surface area decreased from 3,833 m^2 at elevated discharges to 2,799 m^2 at base flows.

As the water surface level dropped with decreasing discharge, hydraulic controls defining pools became more easily expressed. Surface turbulence decreased and many pools occupying only a small portion of the channel width at higher flows occupied the entire channel at lower flows and formed distinct pools. Although these transient pools appear only under conditions of lower discharges, they are depositional and fish holding areas nonetheless and factor into estimates based on habitat amount and type.

Stream-wide estimates of habitat availability, riffle- or pool-dwelling fish densities, or invertebrate densities taken at periods other than those when the stream habitat was mapped could severely bias conceptions about the object's status and could alter management approaches. For ex-

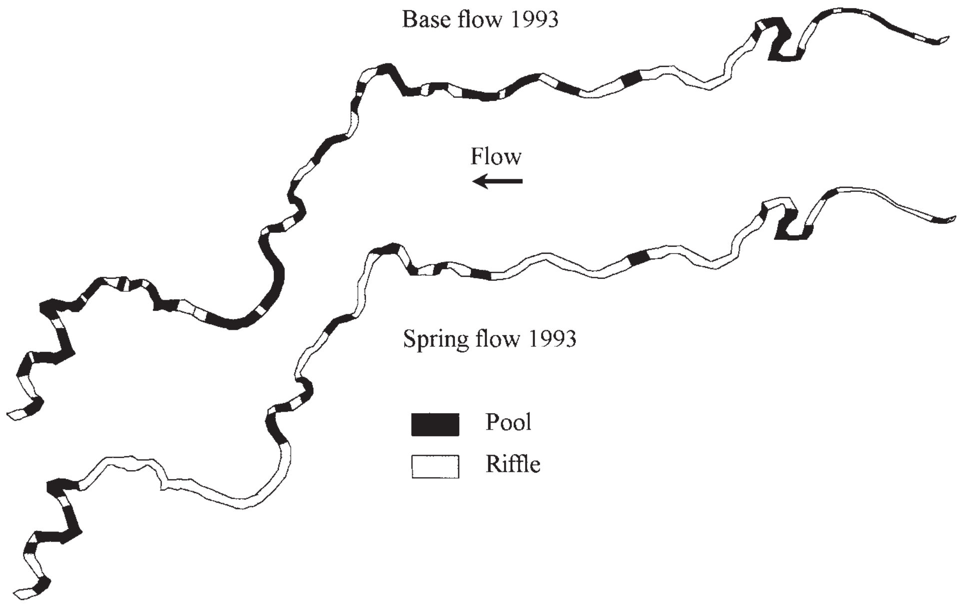

FIGURE 1.—Pool–riffle sequencing in Stony Creek during base flow and elevated spring flow conditions. The mapped section is 870 m in length. Note that the stream width was held constant between periods for visual purposes.

ample, the habitat guidelines adopted in the upper Columbia River assessment (PACFISH and INFISH) call for a minimum number of pools per mile with the number determined by a stream's wetted width. Streams not meeting this criterion are often managed differently than those meeting the standard. Our results show that the level of discharge during a stream survey could influence a stream's rating. Similarly, discharge level may affect some habitat parameter values in models (reviewed in Fausch et al. 1988) and the ultimate prediction of potential fish standing crop.

Differences in base flows between years could also produce tenuous comparisons. Herger et al. (1996) reported changes in the sizes and numbers of channel unit types within the same reach between July and August of the same year. They cautioned against making comparisons at differing flows because habitat availability changed and fish abundances increased, possibly due to seasonal fish movements. Similarly, Baltz et al. (1991) reported changes in microhabitat use of several fish species due to seasonal changes in habitat that could substantially alter results in instream flow applications.

TABLE 1.—Pool and riffle characteristics in Stony Creek at base flow and elevated spring flow conditions.

	Base flow conditions		Spring elevated flow conditions	
Measurement	Pool	Riffle	Pool	Riffle
Total area (m^2)	1,681	1,118	1,266	2,567
Mean area (m^2)	54	39	70	143
Number	31	29	18	18

The potential for problems like these is probably greatest in regions prone to frequent changes in discharge from precipitation events or regions with wet and dry seasons. Areas such as the southeastern United States experience numerous and unpredictable thunderstorm events during summer. Studies that use habitat measures over extended spatial or temporal scales may warrant special consideration when planned for this type of discharge regime. Regions like the Rocky Mountains have great seasonal variability in discharge due to snowmelt but may be more predictable later in the year because of fewer precipitation events. Identification of the type of flow regime will allow fisheries professionals to ensure maximum utility from their habitat data.

We conclude with an example predicting the distribution and abundance of possible food organisms for brook trout *Salvelinus fontinalis* inhabiting Stony Creek. Density of possible food items was greater in riffles (351/0.1 m^2) than in pools

(234/0.1 m^2) for samples collected during spring 1993 (Hilderbrand et al. 1997). Reach level estimates for spring predicted 2.56×10^6 potential food items inhabiting pools and 8.31×10^6 items from riffles for a total of 1.09×10^7 potential food items in the 870-m study reach. However, extrapolation from habitat data collected during summer base flow conditions (when stream surveys are typically done) yielded 4.97×10^6 potential food items inhabiting pools and 4.70×10^6 items in riffles for a total of 9.66×10^6 potential food items. The result is a halving in potential food items in riffles between seasons but an almost twofold increase in food production during base flow conditions for pools. If the true summer invertebrate densities were not known, this could be interpreted as evidence against summer food limitations (sensu Ensign et al. 1990) because of the sheer numbers of invertebrates. However, large decreases in total invertebrate abundance sometimes occur during summer (Giberson and Hall 1988). This could possibly result in a food-limited system although our misapplied estimates would show otherwise. We could also substitute fish production, amount of spawning habitat, or fish abundance derived from estimates using the basin-wide technique (Hankin and Reeves 1988) in place of potential food items.

Our misapplication and extrapolation of data are obvious and extreme, but we did this because many applications make more subtle spatial or temporal assumptions and we feared the point would be missed. This example illustrates the risk of using a one-time sample extrapolated in space or time. To prevent this problem, collection of biological data should coincide with stream habitat mapping or estimation.

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