

Microhabitat Use by an Assemblage of California Stream Fishes: Developing Criteria for Instream Flow Determinations

PETER B. MOYLE AND DONALD M. BALTZ

Department of Wildlife and Fisheries Biology
University of California
Davis, California 95616

Abstract

Microhabitat requirements were determined for eight species of native California stream fishes: rainbow trout *Salmo gairdneri*; Sacramento sucker *Catostomus occidentalis*; Sacramento squawfish *Ptychocheilus grandis*; hardhead *Mylopharodon conocephalus*; California roach *Hesperoleucus symmetricus*; speckled dace *Rhinichthys osculus*; tule perch *Hysterocarpus traski*; and riffle sculpin *Cottus gulosus*. Two or three size classes were evaluated for each species. Each species had a preferred microhabitat (defined on the basis of depth, velocity, substrate), as did each size class within each species, but there was much similarity in microhabitat use within and among species. The amount of microhabitat available to each species differed in three stream reaches in which availability was quantified, but the differences were not enough to explain the differences in composition of the fish assemblage found at each site. This study indicates that recommendations for instream flows should be based on microhabitat use data collected on site together with habitat availability data. Even on-site data should be used cautiously because intraspecific interactions and changes in a stream's physical characteristics, especially in its temperature regime, may cause unexpected shifts in microhabitat use.

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The determination of flow regimes necessary to support stream fish populations is a major problem in the western United States. Various methods have been developed for this purpose, but the most widely used is probably the instream flow incremental methodology of the Instream Flow Group (IFG), U.S. Fish and Wildlife Service (Bovee and Milhous 1978; Stalnaker 1979; Orth and Maughan 1982). These methods concentrate on developing hydraulic and habitat simulation models for each stream. The construction of these models, however, depends on the availability of preference or utilization criteria for each fish species for the major microhabitat variables (depth, velocity, substrate, temperature, cover, etc.). The data presently available to describe these criteria are limited and are mainly for salmonids. Preference data are needed for other fishes, especially nongame fishes, because (1) maintenance of native fish populations of all types is an important management goal in itself; (2) choice of microhabitat by each species can be affected by the presence of competitors (Fausch and White 1981; Baltz et al. 1982) and predators (Cerri and Fraser 1983; Power and Matthews 1983); and (3) in a fish community made up of species with slightly different envi-

ronmental optima, small changes in flow may result in major changes in relative abundances of species. Thus it is important to understand the effects of changed flow regimes on fish communities. This is especially true in the western U.S. where fish communities typically contain less than ten species and appear to be fairly predictable in composition (Moyle and Li 1979; Moyle et al. 1982; Moyle and Vondracek 1985).

In this paper, we examine the use of microhabitat (as characterized by depth, velocity, and substrate) by an assemblage of native fishes in a California stream, taking into account distributional differences among the species within the stream and availability of microhabitat space at different flows. The questions we address are: (1) do major life history stages of each species have different microhabitat requirements? and (2) are microhabitat requirements substantially different among species? We then use the answers to evaluate the usefulness of habitat suitability curves in making instream flow recommendations.

Study Area

Deer Creek, Tehama County, California, is a tributary of the Sacramento River draining the

TABLE 1.—Composition of the fish assemblages in three reaches of Deer Creek, Tehama County, California, based on numbers encountered in microhabitat surveys.

Species	Stream reach					
	Valley		Foothill		Mountain	
	Number	%	Number	%	Number	%
Rainbow trout <i>Salmo gairdneri</i>	18	2.2	156	38.6	120	86.3
Brown trout <i>Salmo trutta</i> ^a	0	0.0	0	0.0	18	13.0
Sacramento sucker <i>Catostomus occidentalis</i>	102	12.7	60	14.9	0	0.0
Sacramento squawfish <i>Ptychocheilus grandis</i>	126	15.6	10	2.5	0	0.0
California roach <i>Hesperoleucus symmetricus</i>	148	18.4	46	11.4	0	0.0
Speckled dace <i>Rhinichthys osculus</i>	121	15.0	41	10.2	0	0.0
Hardhead <i>Mylopharodon conocephalus</i>	47	5.8	0	0.0	0	0.0
Green sunfish <i>Lepomis cyanellus</i> ^a	1	0.1	0	0.0	0	0.0
Smallmouth bass <i>Micropterus dolomieu</i> ^a	21	2.6	0	0.0	0	0.0
Tule perch <i>Hysterocarpus traski</i>	12	1.5	0	0.0	0	0.0
Riffle sculpin <i>Cottus gulosus</i>	210	26.1	91	22.5	1	0.7

^a Introduced species.

northern end of the western Sierra Nevada. Typical summer flows range from 3 to 6 m³/s (USGS 1950). Deer Creek was chosen for the study because it is one of the least modified (by dam or diversion) sizable streams in the Sacramento River drainage and retains the complete assemblage of Sacramento–San Joaquin stream fishes (Moyle 1976). Three study sites were chosen, based on ease of access, representing major habitat types. The lowermost site (“valley reach,” elevation 9–120 m) is located where the creek flows onto the valley floor; the gradient is about 11 m/km and summer temperatures range from 19 to 32°C (Baltz et al. 1982). The middle site (“foothill reach,” elevation 510–530 m) is located in a deep canyon and consists mainly of deep bedrock pools connected by short, high-gradient riffles; the gradient averages almost 20 m/km and summer temperatures are typically 14 to 20°C. The uppermost site (“mountain reach,” elevation 1,010–1,060 m) consists mainly of riffles and runs shaded by dense pine forest; the gradient is 27 m/km and summer temperatures typically are 13 to 18°C. Ten species are present in the valley reach, six in the foothill reach, and three in the mountain reach (Table 1). An additional species, chinook salmon *Oncorhynchus tshawytscha*, spawns in the creek and juveniles may overwinter on occasion (Alley and Reed, in press), but few were observed during this study.

Methods

Microhabitat observations were made at various dates during the months of June through October, 1979 through 1982. Undisturbed fishes

to be observed were located principally by one or two observers snorkeling in an upstream direction. If two observers were used, they were widely separated. Usually a kilometre or more of stream was covered by the observers in a day of observations, although the actual distance depended on the abundance of fishes. Measurements were made on all undisturbed individuals encountered, regardless of species. Because of the morphological distinctness of each species (Moyle 1976), the clarity of the water, and the experience of the authors in working with these fishes, underwater identification was not generally a problem. Once located, the standard length of each fish was estimated by comparing the fish to a painted iron measuring bar carried by each observer. In some deep pools fishes were observed from the bank and their position noted on a map. In swift or shallow riffles locations of small benthic fishes were determined by systematically electrofishing at widely spaced intervals (Baltz et al. 1982).

For each fish observed, the following microhabitat measurements were recorded: (1) total depth of the water column; (2) focal point elevation, the distance between the snout of the fish and the bottom; (3) focal point velocity, the water velocity at the fish's snout; (4) mean water column velocity; (5) surface water velocity; and (6) substrate composition. Total and focal point depths were read directly from a top-setting wading rod. A third depth variable, relative depth, was calculated by subtracting focal point elevation from total depth and then dividing by total depth. Velocity measurements were made with a Marsh-McBirney Model 201 flow meter. Mean

TABLE 2.—Means \pm SDs of microhabitat measurements for eight species of Deer Creek fishes. Size classes are young of year (Y), juvenile (J), and adult (A).

Size class	Number of fish	Total depth (cm)	Focal point elevation (cm)	Relative depth	Mean water column velocity (cm/s)	Focal point velocity (cm/s)	Surface velocity (cm/s)	Substrate
<i>Rainbow trout</i>								
Y	70–82	35.5 \pm 16.7	8.1 \pm 8.8	0.76 \pm 0.20	13.0 \pm 17.5	7.3 \pm 8.6	21.1 \pm 24.9	6.2 \pm 0.8
J	82–108	63.3 \pm 29.4	20.3 \pm 20.5	0.69 \pm 0.21	24.2 \pm 19.3	19.4 \pm 16.1	40.8 \pm 33.1	6.4 \pm 0.8
A	96–108	81.7 \pm 32.9	27.2 \pm 19.4	0.67 \pm 0.21	35.5 \pm 19.5	28.6 \pm 18.0	48.0 \pm 26.3	6.4 \pm 0.6
<i>Sacramento sucker</i>								
Y	60–63	52.2 \pm 31.0	3.6 \pm 8.1	0.90 \pm 0.21	9.9 \pm 9.3	4.2 \pm 5.5	12.0 \pm 11.9	5.8 \pm 1.2
J	31–32	56.4 \pm 30.9	0.4 \pm 1.0	0.99 \pm 0.03	19.2 \pm 18.4	4.8 \pm 7.4	22.0 \pm 23.9	6.0 \pm 1.3
A	40–41	102.1 \pm 41.5	5.0 \pm 18.8	0.95 \pm 0.18	28.0 \pm 17.8	14.6 \pm 13.6	48.0 \pm 38.0	6.2 \pm 0.9
<i>Sacramento squawfish</i>								
J	141–149	57.4 \pm 35.0	14.6 \pm 20.1	0.79 \pm 0.19	19.4 \pm 18.4	12.1 \pm 13.0	22.9 \pm 20.5	5.8 \pm 1.3
A	46–49	115.6 \pm 38.4	31.4 \pm 28.5	0.74 \pm 0.21	36.4 \pm 26.8	18.3 \pm 14.5	33.2 \pm 27.8	6.3 \pm 0.9
<i>Hardhead</i>								
J	74–81	91.2 \pm 32.1	36.4 \pm 30.8	0.64 \pm 0.25	17.0 \pm 15.8	14.0 \pm 14.0	19.6 \pm 18.3	5.5 \pm 1.2
A	49–57	107.7 \pm 35.5	33.7 \pm 29.5	0.70 \pm 0.21	23.5 \pm 17.0	21.7 \pm 17.9	25.3 \pm 19.5	5.9 \pm 1.2
<i>California roach</i>								
J	77–79	37.5 \pm 25.7	9.1 \pm 16.0	0.80 \pm 0.24	8.3 \pm 9.1	3.3 \pm 4.4	11.1 \pm 11.9	5.8 \pm 1.2
A	140–147	42.1 \pm 26.7	10.0 \pm 15.8	0.80 \pm 0.22	20.0 \pm 18.5	10.4 \pm 11.1	25.6 \pm 21.9	6.1 \pm 1.1
<i>Speckled dace</i>								
J	65–66	31.9 \pm 27.1	1.5 \pm 6.3	0.96 \pm 0.10	22.8 \pm 22.0	6.2 \pm 8.4	32.1 \pm 27.7	6.3 \pm 0.5
A	242–271	29.9 \pm 17.5	0.9 \pm 4.4	0.98 \pm 0.08	40.4 \pm 35.3	12.3 \pm 15.9	49.3 \pm 37.0	6.3 \pm 0.5
<i>Tule perch</i>								
J	10–12	74.0 \pm 25.7	19.0 \pm 13.2	0.71 \pm 0.20	8.9 \pm 5.9	7.4 \pm 6.0	13.0 \pm 13.6	5.1 \pm 1.2
A	16–19	76.2 \pm 29.5	20.9 \pm 21.3	0.74 \pm 0.21	11.0 \pm 8.1	6.1 \pm 5.8	21.3 \pm 20.8	6.0 \pm 1.4
<i>Riffle sculpin</i>								
J	234–292	38.2 \pm 18.7	0.8 \pm 6.0	0.99 \pm 0.10	41.7 \pm 41.1	8.7 \pm 14.8	50.1 \pm 40.6	6.3 \pm 0.6
A	220–226	39.5 \pm 20.1	0.2 \pm 1.5	1.00 \pm 0.05	43.9 \pm 38.7	7.8 \pm 12.8	53.8 \pm 42.5	6.4 \pm 0.8

water column velocity was the velocity at 0.6 of the total depth if the water was less than 75 cm deep or the mean of the velocities at 0.2 and 0.8 of the total depth in deeper water, but for measurements where flows were disturbed by upstream objects, a weighted mean was calculated from all three proportional depths (Bovee and Milhous 1978). The substrate composition (percentages) in an area 0.25 m on a side beneath each fish was based on a modified Wentworth particle size scale in which codes ranged from 1 for plant detritus to 8 for bedrock (Bovee and Cochnauer 1977). A single numeric score for adjacent substrate codes was generated by weighting the percentages of the two dominant substrates. Thus a section containing 60% cobble (code 6) and 40% boulder (code 7) would be coded 6.4 indicating a dominance of cobble and a lesser proportion (0.4) of the adjacent larger class.

Data collection was stratified among the reaches to compensate for differences in species richness. Observations were usually made as each

fish was encountered, regardless of species. Therefore, the number of observations per species listed on Table 1 is proportional to their abundance in each reach. However, for the analyses of microhabitat use, data also were included that had been collected as part of another study (Baltz et al. 1982).

The microhabitat data for each species were analyzed by size classes that approximated major life history stages. For Sacramento sucker and rainbow trout, three size classes were used: young of year (≤ 50 mm standard length, SL), juveniles (51–119 mm SL), and adults (≥ 120 mm SL). Most young of year were between 20 and 50 mm SL. Two size classes were used for Sacramento squawfish (separated at 160 mm SL), hardhead (160 mm SL), California roach (40 mm SL), riffle sculpin (40 mm SL), tule perch (40 mm SL), and speckled dace (30 mm SL). The introduced species (green sunfish, smallmouth bass, brown trout) were not treated because of small sample sizes. The effect of site and fish size on microhabitat

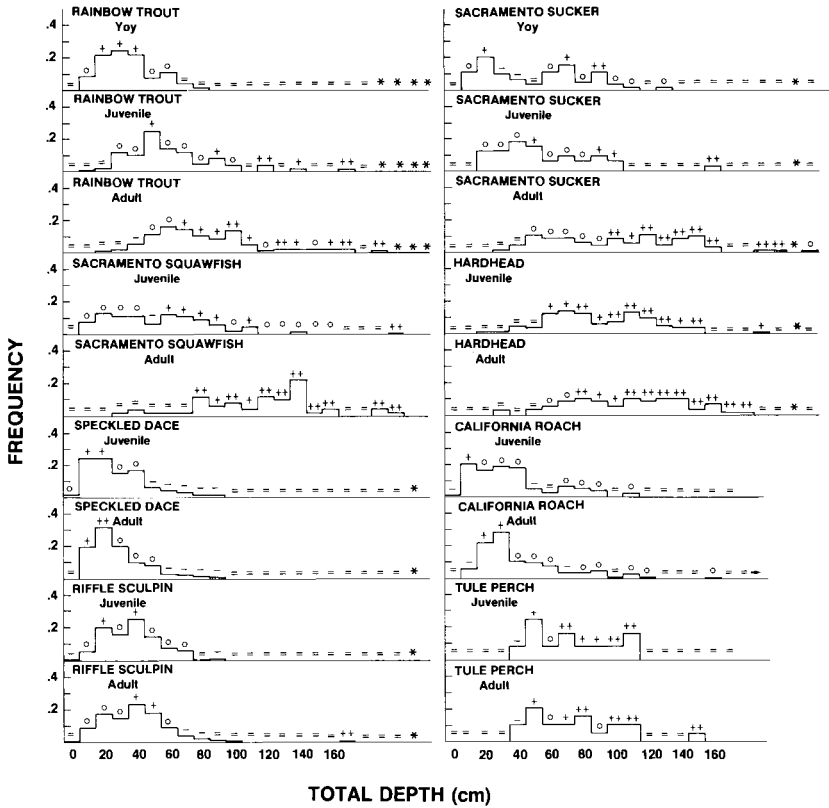


FIGURE 1.—Frequency distributions of total water column depths used by native Deer Creek fishes. Midpoints of intervals are in centimeters. Electivities are indicated ++ (≥ 0.50 , strong preference), + (> 0.25 but < 0.50 , moderate preference), o (± 0.25 , no preference), - (> -0.50 but < -0.025 , moderate avoidance), and = (≤ -0.50 , strong avoidance). Asterisks indicate lack of availability data and undefined electivity. Yoy is young of year.

use was tested by a two-way analysis of variance on $\log_{10}(x + 1)$ -transformed data where x is any variable. Because sample sizes between reaches and size classes were highly variable, Levene's test for equal variances was performed to check the validity of the analyses of variance (Dixon and Brown 1977). Analysis of variance was not performed on hardhead or tulle perch observations because all were made in the valley reach.

Electivities (D) for mean water column velocity, total depth, and substrate were calculated from the formula of Jacobs (1974),

$$D = \frac{r - p}{(r + p) - 2rp}$$

where r is the proportion of the resource used by each species and p is the proportion available in the environment. Availability was determined by establishing ten transects at sites representa-

tive of each study reach and chosen according to the criteria of Bovee and Milhous (1978). Measurements of mean water column velocity, total depth, and substrate were made at 10 to 25 equally spaced points on each transect. These measurements were made at three flows for the valley and mountain reach, and two flows for the foothill reach. None of the flows represented either extreme high- or low-flow conditions, but were typical of the spring, summer, and fall seasons when the microhabitat data were gathered. Rainbow trout electivities were calculated from combined availability data from the foothill and mountain reaches at all flows. Electivities for Sacramento squawfish, hardhead, and tulle perch were based on availability data from the valley reach at all flows, because squawfish were rare in the foothill reach and the other species were absent from it. For the remaining species, California roach, Sacramento sucker, speckled dace,

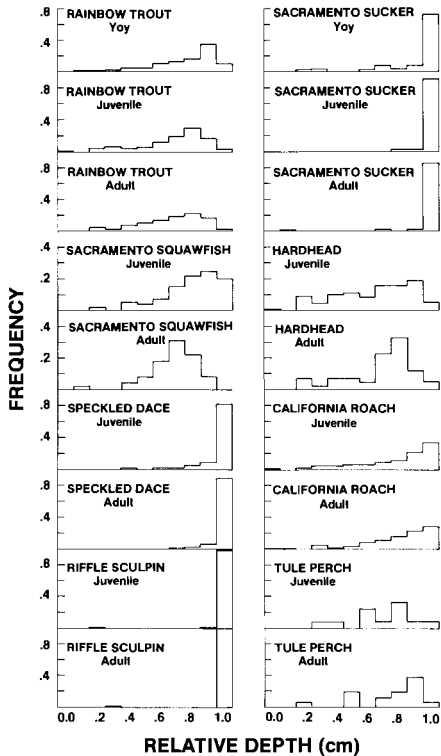


FIGURE 2.—Frequency distributions of relative depths used by native Deer Creek fishes. Relative depth is the difference between total depth and focal point elevation divided by the total depth. A value of 0.0 indicates a fish at the surface; 1.0 indicates a fish in contact with the bottom. Yoy is young of year.

and riffle sculpin, availability data from the valley and foothill reaches were combined, as they were abundant in both reaches but absent from the mountain reach. Electivities were not determined for focal point velocity and relative depth because of the difficulty of obtaining meaningful availability data.

Results

Habitat Availability

The availability data for total depth, velocities, and substrate indicated that a wide range of habitats were available in each reach, but the reaches also differed in important ways. Mean total depths (± 1 SD) for each reach were similar (53 ± 45 , 51 ± 36 , 59 ± 34 cm for the valley, foothill, and mountain reaches, respectively), but the valley reach had more shallow habitat (61% less than 50 cm deep, as compared to 46% and 52% for the foothill and mountain reaches, respectively)

and was the only reach with pools deeper than 180 cm, ranging to over 300 cm deep. This deep water covered only about 2% of the total area. Mean water column velocities were also similar for the three reaches (45 ± 34 , 32 ± 26 , 36 ± 36 cm/s, respectively) but only the mountain reach had mean water column velocities over 150 cm/s. Substrates were also similar (6.6 ± 0.5 , 6.3 ± 0.7 , 6.8 ± 0.7 , respectively).

Species Distribution

Species composition differed considerably among the three reaches (Table 1). Rainbow and brown trout predominated in the mountain reach and riffle sculpin were rare. The valley reach was dominated by the typical warmwater fish assemblage of Sacramento Valley streams (Moyle 1976) and contained ten species. The foothill reach had six species.

Microhabitat Measures

The use of depth, velocity, and substrate by the native fishes (Table 2, Figs. 1–5) can be generalized as follows. (1) All species occurred under a wide range of conditions, so direct interactions between all species pairs were possible. (2) Young of year and juveniles of most species used water that was shallower (Figs. 1, 2) and of slower velocity (Figs. 3, 4) than adults. The analyses of variance showed that the differences among size classes for total depth and mean water column velocity were significant ($P < 0.05$) except for velocity differences between Sacramento squawfish size classes. However, Levene's test indicated that the analysis of variance for Sacramento squawfish, Sacramento sucker, and California roach may be invalid for depth, as well as those for rainbow trout and Sacramento squawfish for velocity. (3) Despite differences in depths chosen by juveniles and adults, the position in the water column (relative depth) tended to be very similar within species, regardless of size (Fig. 2). (4) The focal point velocities for all species were considerably lower than the mean water column or surface velocities (Table 2). (5) All species occupied a wide range of velocities, but adult rainbow trout, adult Sacramento suckers, adult speckled dace, and adult and juvenile riffle sculpin showed a preference for faster water (Table 2) as indicated by mean surface velocities greater than 40 cm/s. (6) Substrate use was similar among all species; most fish were found in association with cobbles and boulders (Fig. 5). (7) The deeper parts of the

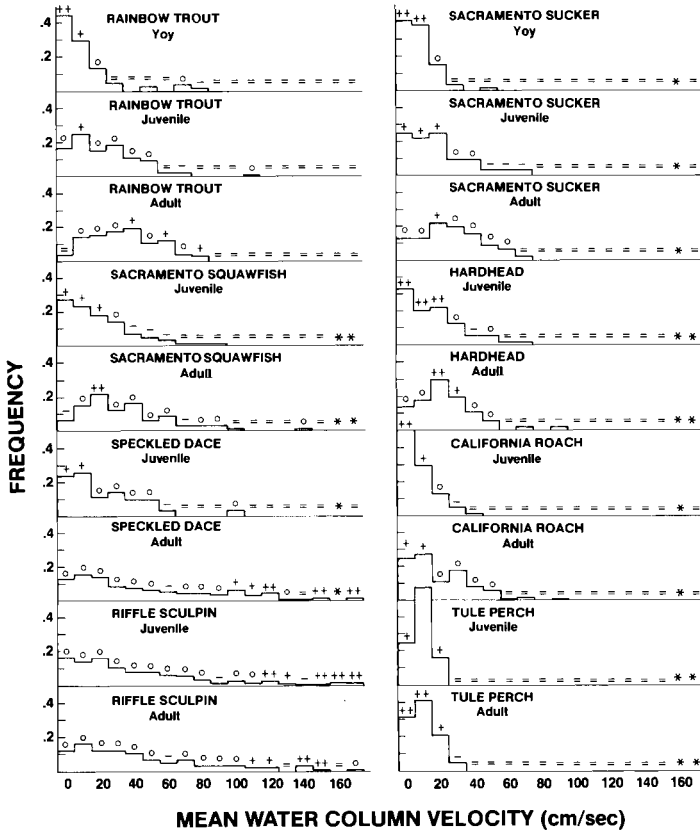


FIGURE 3.—Frequency distributions of mean water column velocities associated with native Deer Creek fishes. Electivities are indicated ++ (≥ 0.50 , strong preference), + (> 0.25 but < 0.50 , moderate preference), o (± 0.25 , no preference), - (> -0.50 but < -0.025 , moderate avoidance), and = (≤ -0.50 , strong avoidance). Asterisks indicate lack of availability data. Yoy is young of year.

stream were favored by juvenile and adult rainbow trout, Sacramento squawfish, hardhead, and tule perch, whereas shallower parts were favored by young-of-year rainbow trout, Sacramento suckers, California roach, speckled dace, and riffle sculpin (Fig. 1). (8) All species usually were found closer to the bottom than to the surface but only Sacramento suckers, speckled dace, and riffle sculpin were in nearly continuous contact with the bottom (Fig. 2). Species found highest in the water column were rainbow trout, hardhead, Sacramento squawfish, and tule perch. (9) The presence of apparently suitable habitat for each species in stream reaches from which they were absent indicates that other factors (see Discussion) may be preventing fish from using otherwise suitable areas.

Electivities

The electivity indices demonstrated that all species and size classes were highly selective in the microhabitats they occupied (Figs. 1, 3, 5). The pattern of electivities for total depth showed that as rainbow trout and Sacramento suckers increased in size they preferred deeper water (Fig. 1). Sacramento squawfish, hardheads, and speckled dace also used deeper water as adults, but there were no obvious ontogenetic trends within California roach, riffle sculpin (Baltz et al. 1982), or tule perch. Preferences for higher mean water column velocities also increased with size for rainbow trout and Sacramento sucker. Similar ontogenetic shifts to higher velocities occurred in all species except tule perch and riffle sculpin (Fig. 3). There were few clear patterns in electiv-

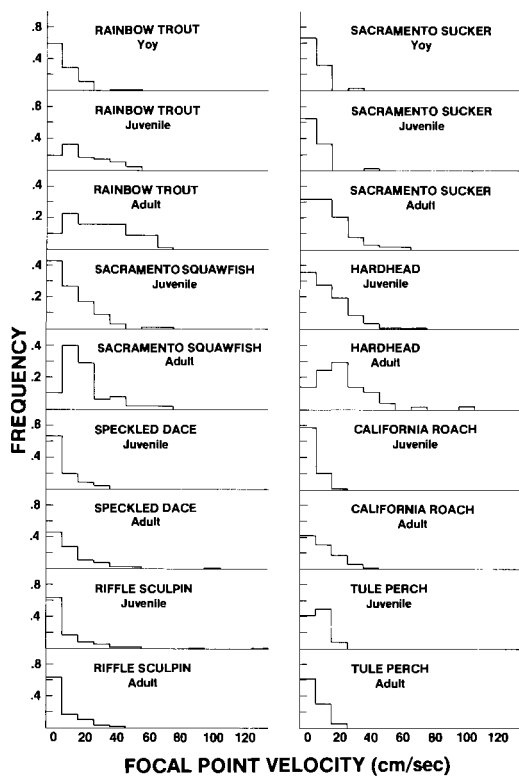


FIGURE 4.—Frequency distributions of focal point velocities used by native Deer Creek fishes. Yoy is young of year.

ity for substrate types. Substrates finer than cobble were not abundant in any of the reaches but were strongly selected by most life stages of all species except rainbow trout (Fig. 5). Boulder and bedrock substrates were generally avoided by most species except adult tule perch and Sacramento sucker.

Discussion

The native fishes of Deer Creek have distinct but widely overlapping distribution patterns along the creek's elevational gradient. Likewise, each species and size class selects a distinct set of microhabitat conditions that widely overlaps with those favored by co-occurring species. A formal overlap analysis (Baltz and Moyle, unpublished) indicates that the overlap in microhabitat use among species is high enough that competitive interactions might be expected, although the possibility of such interactions is reduced by the different feeding habits of each species (Moyle 1976; Moyle et al. 1982). However, high overlap

is often a poor predictor of competition (Thompson 1982). Baltz et al. (1982) found that speckled dace and riffle sculpin compete for riffle habitat in Deer Creek, but Baltz and Moyle (1984) showed that Sacramento sucker and rainbow trout do not compete for microhabitat space in another Sierra Nevada system.

The high overlap in microhabitat use among the fishes indicates that space is usually not a limiting resource among Deer Creek fishes, presumably because their populations are rarely large enough to use all the available space. Fish populations in streams naturally show considerable variation in numbers and biomass from year to year. Moyle and Vondracek (1985), for example, have shown that in sections of another California stream, fish numbers vary by factors of 7 to 21 and fish biomasses vary by factors of 5 to 12. Microhabitat use by each species and size class may be quite different in years of low abundance from the use in years of high abundance, due to the effects of interspecific and intraspecific competition. Moyle and Vondracek (1985) found that in years of high abundance, fishes were found in habitats from which they were normally absent and that seemed to be of marginal quality for the species. This may explain the differences between the results of this study and those of Alley and Reed (in press). They observed the fishes of Deer Creek using, on the average, water with higher velocities and greater depths than we did. Their study was conducted during drought years (1975, 1976) in which flows were considerably less and temperatures probably warmer than in the years (1979–1983) data were collected for this study. Their methods were also substantially different and concentrated on larger fishes.

Habitat and microhabitat use may also vary within a species from one stream to the next, reflecting not only availability, but also such factors as temperature regime, food supply, and presence of other species. Thus, Sacramento sucker and rainbow trout in three other Sierra Nevada streams show somewhat different patterns of microhabitat use than they do in Deer Creek (Baltz and Moyle 1984). Fausch (1984) showed that salmonids select microhabitats in the way that will maximize their ability to efficiently use local food supplies. This would result presumably in differences in microhabitat selection among streams. For riffle sculpin and speckled dace, the pattern of microhabitat use is de-

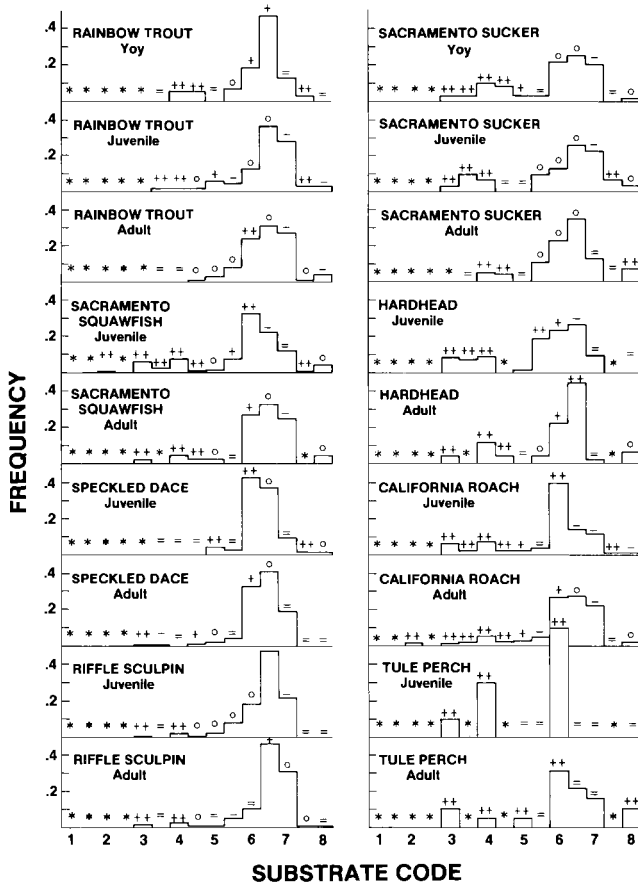


FIGURE 5.—Frequency distributions of substrate types used by native Deer Creek fishes. Substrate codes 1 through 8 are plant detritus, mud, silt, sand, gravel, cobble, boulder, and bedrock, respectively (Bovee and Cochnauer 1977). Intermediate codes indicate a mixture of adjacent substrate types. Electivities are indicated by ++ (≥ 0.50 , strong preference), + (> 0.25 but < 0.50 , moderate preference), O (± 0.25 , no preference), - (> -0.50 but < -0.025 , moderate avoidance), and = (≤ -0.50 , strong avoidance). Asterisks indicate lack of availability data. Yoy is young of year.

terminated in a large part by temperature, because sculpin competitively exclude dace from riffles at low temperatures but cannot maintain themselves in this favored habitat at higher temperatures, allowing dace to become dominant (Baltz et al. 1982). Smith and Li (1983) showed that juvenile rainbow trout sought faster water as temperatures increased above their optimum, probably because more food was available there to satisfy the increased metabolic demand that comes with higher temperatures. Studies presently being conducted in our laboratory show that each species in Deer Creek has its own preferred and lethal temperatures, a result consistent with other studies (Jobling 1981). Thus, it is likely that the differences in summer temperatures among the three reaches account for the differ-

ences in species composition, despite the apparent availability of otherwise suitable microhabitat for all species at all three sites.

In view of the many complex factors that influence the microhabitat choice of a fish, can meaningful curves of habitat suitability for a species (Bovee and Milhous 1978) be constructed from data such as we and others (e.g., Orth and Maughan 1982) have collected for instream flow studies? The answer is a cautious yes, but with a number of strong qualifications.

(1) Meaningful habitat suitability curves should not be constructed from use data alone. They should be modified (by eye if necessary) by comparing them with habitat availability curves, for a microhabitat may be used most frequently by a fish species only because the preferred mi-

crohabitat is in short supply. These selectivity curves, in turn, should eventually be replaced with true preference curves, derived from laboratory tests, much as are currently conducted to determine temperature preferences.

(2) Each instream flow study should use selectivity curves developed on site, or in comparable sites nearby, to reduce biases caused by temperature differences, competitive interactions, and other factors. Thus the data presented here should be used only for streams that are similar to Deer Creek in fish assemblages and temperature regimes.

(3) Suitability curves developed by standard methods (Bovee and Cochnauer 1977) should be used in conjunction with population data, for microhabitat use may vary with population densities. Because fish populations are regulated by many factors besides availability of appropriate microhabitat (e.g., extreme floods and summer droughts), the amount of usable area calculated for a fish species may have no relation to its actual population size.

(4) Where possible, macrohabitat variables, especially temperature, should be incorporated into instream flow analyses (Bovee 1982).

(5) Selectivity curves for an instream flow analysis should not be limited to just game fishes or other conspicuous species, because interspecific interactions can have a strong influence on habitat selection. Changes in the distribution of depths, velocities, substrates, and other physical characteristics, particularly temperature, may cause unexpected shifts in community composition. In the long run, we should be developing instream flow criteria for fish communities, not just species.

(6) Detailed habitat mapping studies should be conducted in conjunction with microhabitat and instream flow modeling studies especially in large streams. This would permit the field data to be weighted to reflect the proportional habitat composition of the stream reach. This study would have been improved had we done this. In small streams, the habitat mapping may not be necessary if the microhabitat use and availability data were collected over a large proportion of the stream.

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