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Variation in condition factor and growth in young-of-year fishes in floodplain and riverine habitats of the Cosumnes River, California

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Abstract

Condition factors and growth rates of postlarval (young-of-year) fishes in a Central California river were compared in order to determine the relative importance of floodplain and riverine habitats for rearing. Sampling took place between April and June of 2001 and 2002 in the lower Cosumnes River and its floodplain. Sacramento splittail showed higher condition and length increment in floodplain habitats than in riverine habitats. Sacramento suckers showed differences in condition between sites, but suckers from the floodplain had lower weight increments than those from the river. The weight increment in Sacramento splittail was not significantly different between habitats. In addition, two alien species, common carp and golden shiner, had similar condition factors and growth rates. This study shows the usefulness of condition factor and growth rate in evaluating the importance of different habitats for early life history stages of fishes.

Introduction

Floodplains are important habitats for spawning and rearing of fishes (Welcomme, 1985; Coop, 1989; Bayley, 1995; Sparks, 1995). Major reasons for their importance include (1) floodplains produce a large biomass of invertebrates which are food for larval and juvenile fishes and (2) floodplains possess physical conditions (e.g., temperature, cover) that favour fish survival. When conditions are favourable, young-of-year (YOY) fishes on floodplains grow rapidly and presumably are better able to avoid predators once they leave the floodplain (Sommer et al., 2001; Crain et al., 2004). Thus growth rates and condition of YOY fish are likely to be good measures of suitability of habitats for rearing (Bennett et al., 1995; Suthers, 1998; Grant & Brown, 1999; Suneetha et al., 1999). Floodplain habitat is not uniform and it is likely that food resources are patchily distributed, resulting in some areas being more favourable for fish growth than others, although this is not well documented. Physical conditions also change with location and time (Coop, 1989). Given the growing interest in floodplain restoration, understanding conditions that are most favourable for YOY fishes is important for development of restoration strategies.

In this study, we examine growth rates and condition factors of YOY fishes collected on the floodplain of the Cosumnes River in Central California in order to obtain insights into factors that favour YOY fish rearing. The Cosumnes floodplain was recently restored by breaching levees and is extensively used by both native and alien fishes (Crain et al., 2004). Some of the native fishes are adapted for using floodplain habitats (Moyle, 2002). For example, the endemic Sacramento splittail (Cyprinidae: *Pogonichthys macrolepidotus*, (Ayres, 1854)) spawns on floodplains and uses them as nursery habitat (Sommer et al., 2001, 2002; Moyle, 2002; Crain et al., 2004). Other species, such as Sacramento sucker (Catostomidae: *Catostomus occidentalis*, Ayres, 1854), spawn in rivers but passively use the floodplain for rearing of YOY fish. In contrast, a number of alien fishes live in ponds, ditches, and sloughs within the floodplains and opportunistically use the floodplain for spawning and rearing (Moyle, 2002). Thus, common carp (*Cyprinus carpio*, Linnaeus, 1758) and golden shiner (*Notemigonus crysoleucas*, (Mitchill, 1814)) both spawn and rear on the floodplain. Rearing by native fishes in floodplain habitats tends to take place early in the season (March–April) when flooding is peaking and temperatures are low, while rearing by alien fishes tends to take place mainly later in the season (May–July) when inflow is low or absent and temperatures are higher (Crain et al., 2004).

The purpose of this study was to answer the following questions, using growth rate and condition factor as measures of habitat quality for YOY fishes (Suthers, 1998; Grant & Brown, 1999).

1. Which habitats in the river-floodplain complex are most suitable for rearing of each species?
2. Do rearing conditions for YOY fish change as the season progresses?
3. Are there general differences in floodplain use between native and alien fishes?

Methods

Study area

The Cosumnes River Preserve is located in southern Sacramento County bordering the Cosumnes River, 5 km above the confluence of the Cosumnes and Mokelumne Rivers (Fig. 1). The preserve contains some of the best remaining examples of Central Valley freshwater wetlands, riparian corridors, and riparian forests, much of which is seasonally inundated with flood waters. Today flood waters enter mainly through breaches

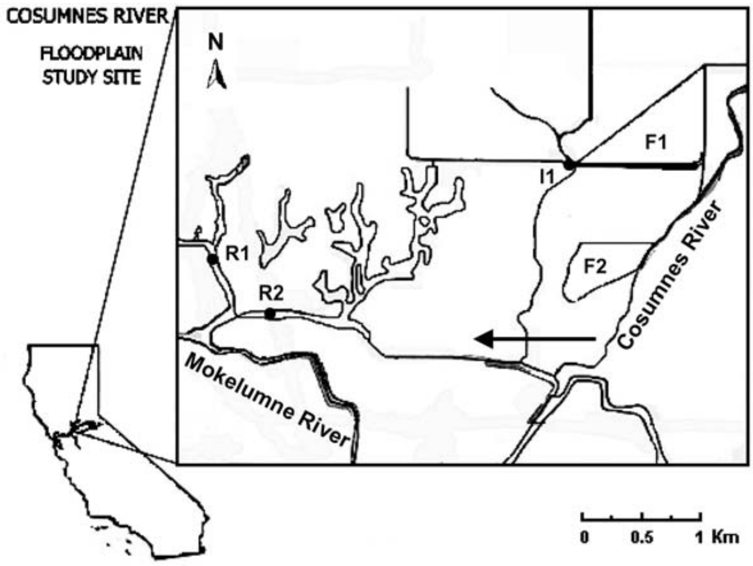

Figure 1. Map with Cosumnes Preserve in the Lower Cosumnes watershed; floodplain habitat: F1 – floodplain 1, F2 – floodplain 2; riverine habitat: R1 – middle slough, R2 – main Cosumnes River; irrigation channel habitat: I1 – Wood Duck Slough; arrow represents river flow direction.

in levees created as part of a floodplain restoration project. Also flooded at times are managed farmlands and diked waterfowl ponds, together with annual grasslands interspersed with vernal pools. Five sampling sites were studied representing three different habitats: riverine habitat (R1, Middle Slough, R2, main Cosumnes River), irrigation channel habitat (I1, Wood Duck Slough) and the floodplain habitat (F1, F2). The two floodplain sites were ponds that held water even after inflow ceased. Both were wide and shallow, but had some differences in their characteristics. Floodplain pond 1 (F1) was clay-silt bottomed and located close to the main levee breaches. Its edges were covered with a mix of annual vegetation, willows, and reeds. When river flows were high it was inundated with overland flow, but quickly (within 24 h) receded to pond status after connection to the river was lost. It remained an isolated pond into late spring, presumably through ground water seepage from the river. After the river dropped below its level it quickly receded to a small stagnant patch of water that was maintained into the summer months. Floodplain pond 2 (F2) contained dense beds of terrestrial (e.g., dead annual forbs and grasses) and aquatic vegetation and was more constant in size and volume; it was connected to a slough by a ditch, through which water backed up into the pond after flooding from the river ceased. River site 1 (R1) a tidal slough was relatively wide and its depth varied with tidal influence. Its margins were dense with terrestrial vegetation. River site 2 (R2) was on the main Cosumnes river channel and was also under tidal influence. Aquatic vegetation was less abundant than in R1 but the bank vegetation was equally well developed. The irrigation ditch (I1) was a channel 6–8 m wide with little flow accept during major flood events when it conveyed overland flow down and across it. The channel had dense beds of aquatic vegetation and large amounts of woody debris along its edges.

A beach seine (1.2×13 m with 3.2 mm mesh) was used to sample YOY fish on a weekly basis. The fish collected were euthanized and preserved in buffered formalin. Identification was made later in the laboratory using Wang (1985). The individuals of the four most abundant species (Sacramento splittail, Sacramento sucker, common carp, and golden shiner) were measured (standard and total lengths ± 1 mm) and weighed (total dry weight ± 0.001 g). Dry weight was obtained after drying the YOY fish in a Lingberg/Blue gravity oven at 60 °C for 24 h. Environmental temperature was recorded in each site using Onset Hobo, StowAway temperature recorders set at 1 h intervals.

Condition was calculated using Fulton condition factor (Nielsen & Johnson, 1983):

$$K = \left(\frac{D_{\mathrm{w}}}{\mathrm{SL}^{b}}\right) \times 10^{5},$$

where D_{w} is the total dry weight (g), SL is the standard length (mm) and b is the slope of the species length–weight relationship. For each species the condition factor was determined using the corresponding slope of the overall species length–weight relationship on the log transformed data to make the relationship linear. In order to determine if the calculated condition factor was independent from standard length, a regression analysis was performed using condition factor and standard length (Zar, 1999). This type of analysis permitted us to evaluate the influence of YOY fish length on condition factor.

We assessed condition factor variability for Sacramento splittail in both floodplain ponds from 3 April to 8 May, 2001. To determine if there were differences in the condition factors, an analysis of variance (ANOVA, $p < 0.05$) was performed (Zar, 1999).

Spatial variation of Sacramento sucker and Sacramento splittail condition factors was compared among habitats using all of data from samples obtained in both years (2001 and 2002). An average value of the condition factor for both species in each site was calculated regardless the date of capture and sites were compared using a non-parametric test (Kruskal–Wallis or Mann–Whitney test; $p < 0.05$), once the variances were shown not to be homogeneous (Levene's test, $p < 0.05$). For carp and golden shiner, condition factor was calculated for both floodplain sites using only 2002 data (6th May and 13th May, respectively). For carp and golden shiner the average condition factor between sites (F1 and F2) was compared using a t-test ($p < 0.05$). These species were largely absent from the other sites.

Table 1. Linear relationship of log transformed data of length and weight for the studied species

Species	n	Slope	Intercept	R^2	SL Range
Sacramento splittail	590	3.34	−6.07	0.98	13–43
Sacramento sucker	243	4.97	−8.39	0.77	11–27
Golden shiner	100	3.63	−6.49	0.96	11–28
Common carp	45	3.33	−5.91	0.99	16–38

$\log(D_w) = b * \log(SL) + a$, where D_w is the dry weight, SL is standard length, b is the slope and a is the intercept. n is the number of individuals used, R^2 is the explained variation and standard length range.

Growth rates were determined by two different ways: (1) studying the mean total length increment and (2) assessing the weight increment with YOY fish length. The mean total length of Sacramento splittail, Sacramento sucker, golden shiner and common carp was calculated separately for different sites. A growth rate was defined as the total length increment (in mm) per a standard period (10 days).

$$L_{gr} = \frac{TL_0 - TL_{0+t}}{t} \times 10,$$

where L_{gr} is the growth rate (mm/10 days), TL_0 is the mean total length (mm) at the beginning of the period and TL_{0+t} is the mean total length (mm) after the period t (days). For most of the periods that we followed, the mean total length changed significantly over the course of a week although in some periods measurable change required over 15 days. We therefore standardized growth rates for a period of 10 days in order to make results comparable among periods. This analysis assumes that (1) growth rate was dependent on environmental conditions and (2) there was no emigration of YOY fish throughout the period of the study. For this last assumption, YOY fish movement was assessed using length frequency histograms for the different sites over time to make sure that we were following the same cohort of YOY fish. The length frequency histograms also permitted us to identify different spawning events which might influence results (e.g., when the modal class of length decreased, it indicated that the fish had spawned again, therefore this period was not considered for the calculation of a growth rate).

A length–weight relationship, on log transformed data, was compared between riverine and floodplain habitats for Sacramento sucker and Sacramento splittail. Both species had the same length range in both habitats, making comparisons more precise. The data was pooled for each habitat (F1 and F2 were combined and R1 and R2 were combined). The length–weight relationships were compared between habitats using an Analysis of Covariance (ANCOVA, $p < 0.05$) (Zar, 1999). All statistical tests were performed using SPSS© for Windows 1995.

Results

All four species showed a strong length–weight relationship (Table 1) allowing condition factors to be calculated. Sacramento sucker showed the greatest variability in length-weight relationship, due to higher error in dry weight measurements. This resulted from the postlarval fish being very elongate, so they had low weights for each length. Condition factors of the four species were found to be independent of standard length ($p > 0.05$). There were significant increases through time in Sacramento splittail YOY condition factors in both floodplain sites (F1, Kruskal–Wallis, $p < 0.001$; F2, ANOVA, $p < 0.001$) (Fig. 2). Sacramento splittail condition varied synchronously in both sites throughout most of the study period, tracking temperature within the sites (Fig. 2).

Sacramento splittail YOY condition factor in one floodplain site (F1, $K = 0.0889$) was significantly higher than at all other sites (Mann–Whitney, $p < 0.001$), while mean condition factors from both riverine sites (R1, $K = 0.0819$; R2, $K = 0.0840$) were not significantly different from each other (Mann–Whitney, $p > 0.05$). Mean

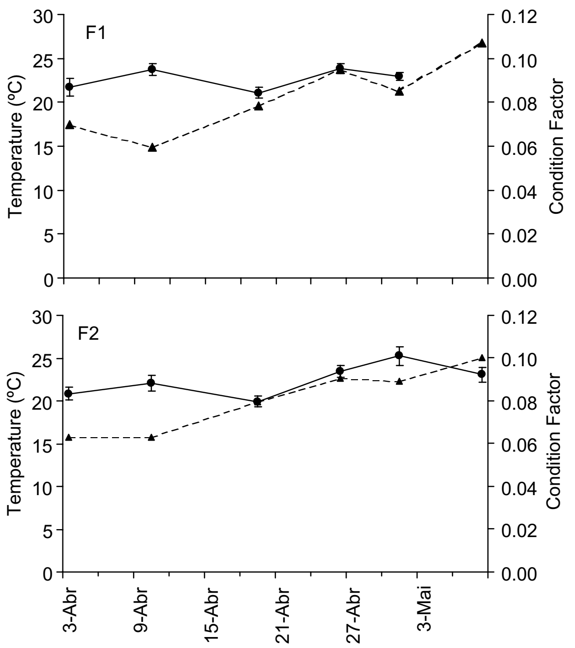

Figure 2. Temporal variation of Sacramento splittail YOY average condition factor (solid line) and temperature (dashed line) in floodplain sites F1 and F2 in 2001; bars represent 2 standard error.

condition factors of Sacramento sucker in F2 and R2 exhibit the highest condition factors ($K = 0.0005$ and $K = 0.0004$, respectively) and were significantly higher than in R1 and F1 ($K = 0.0003$ for both sites) (Kruskal–Wallis, $p < 0.05$). The two alien fishes (common carp and golden shiner) showed similar condition factors in both floodplain sites. Mean condition factors in the floodplain site closest to the river (F1) were generally higher than in F2, although they were significantly higher only for golden shiner (*t*-test; $p < 0.05$).

Sacramento splittail had a mean growth rate of 4.5 mm/10 days but the rate varied from 2 to 7 mm/10 days between sites (Table 2). Fish in river site R1 had the highest growth rates ($L_{gr} = 7$ mm/10 days), followed by the fish in floodplain site F2 ($L_{gr} = 6$ mm/10 days), while the fish in floodplain site F1 had the lowest growth rates ($L_{gr} = 2$ mm/10 days). Conversely, common carp and golden shiner had higher growth rates in F1 than in F2 (Table 2). Among species, common carp and Sacramento suckers exhibited the highest growth rates (11.6 and 8 mm/10 days, respectively) while golden shiner had the lowest growth rates (3.2 mm/10 days) (Table 2).

Table 2. YOY fish growth rate (mm/10 days) for five species of YOY fish, *n* represents the number of periods from which growth rate was determined

Species	*n*	Mean growth rate (mm/10 days)	Growth rate range (mm/10 days)
Sacramento splittail	12	4.5	2.2–6.9
Common carp	2	11.6	9.4–13.8
Golden shiner	2	3.2	3.1–3.3
Sacramento sucker	2	8.0	5.8–10.3

The length–weight relationships obtained for floodplain and riverine Sacramento splittail were not significantly different (ANCOVA, $p > 0.05$) ($\log(D_w) = 3.4743*\log(SL) - 6.2659$; $R^2 = 0.9776$, $n = 39$, for riverine habitat; $\text{Log}(D_w) = 3.3965*\log(SL) - 6.1624$; $R^2 = 0.9587$, $n = 107$, for floodplain habitat). In contrast, Sacramento suckers showed significantly different length–weight relationships in riverine and floodplain habitats (ANCOVA, $p > 0.05$) ($\log(D_w) = 7.2474*\log(SL) - 11.186$; $R^2 = 0.9235$, $n = 27$, for riverine habitat; $\log(D_w) = 4.9734*\log(SL) - 8.5513$; $R^2 = 0.8425$, $n = 98$, for floodplain habitat). Riverine Sacramento suckers gained weight at a faster rate than floodplain suckers (Fig. 3).

Length distributions of Sacramento splittail suggest movement of YOY fish from floodplain to riverine habitats (Fig. 4). The lengths of Sacramento suckers, in contrast, seem to reflect multiple spawning events in the river with some larvae washing passively on to the floodplain.

Discussion

Our results show that YOY fish condition changed significantly in space and in time even though the Fulton Condition Factor is not very sensitive to small changes in condition (Suthers, 1998), especially in small fish. Condition factors of juvenile Sacramento splittail increased throughout their development in floodplain sites. This improvement

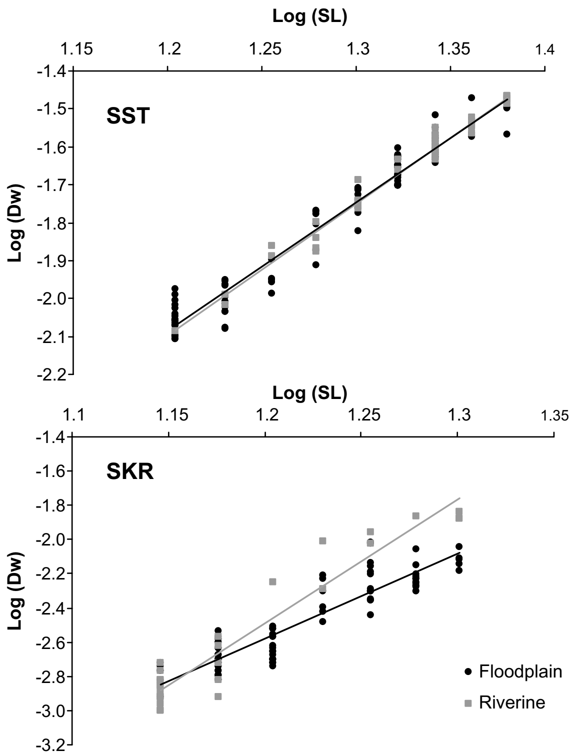

Figure 3. Linear regressions with log transformed data of standard length (SL) and dry weight (D_w) between floodplain (black line) and riverine (grey line) habitats for Sacramento splittail (SST) and Sacramento sucker (SKR).

in condition might be linked to warmer temperatures in the floodplain (F1 – 19.75 ± 0.30 °C; R1 – 16.81 ± 0.23 °C; R2 – 16.06 ± 0.12 °C; April-2002 mean ± 95% confidence interval) once it was higher than in the river sites, and to abundant zooplankton and other food resources (Crain, unpublished data). Coop (1989) and Grenoulliet et al. (2000) found that spatial patterns in YOY fish distribution were related to floodplain environmental variability. The observed YOY fish condition factor and growth rates may, therefore, reflect this environmental variability.

Generally Sacramento splittail in the floodplain ponds had higher condition factors than those in the river and much higher factors than those from the ditch site. The fish at R2 also had the highest condition factor between the two riverine sites, presumably because these fish had just left the floodplain to start their migration downstream to the San Francisco Estuary (Figs. 1 and 4).

Fish growth rates were also different between sites. Sacramento splittail juveniles had apparent higher growth rates in floodplain site F2 and river site R1 than in other sites. These results may seem contradictory to our condition findings, but presumably reflect fish movement between sites and fish spawning at different times. For example, Sacramento suckers spawned at least twice, with YOY from the first spawn being flushed onto the floodplain but YOY from the second spawning event only having access to the river (Fig. 4) because connection to the floodplain had been lost. Because these YOY suckers were living in different environmental conditions, they grew at different rates. Crain et al. (2004) suggest that other species (common carp, prickly sculpin – *Cottus asper*, Richardson, 1836, golden shiner, and inland silverside – *Menidia beryllina* (Code, 1867)), also had multiple spawnings in the floodplain and riverine habitats. Such behaviour has distinct advantages in highly fluctuating environments such as floodplains because the year's progeny are not all subjected to the same risk.

Sacramento suckers from riverine habitats gained more weight than those reared in floodplain habitats. Sacramento suckers are widely distributed in riverine habitats in California and their YOY are well adapted to edge habitat in cool streams (Moyle, 2002). The higher temperatures on floodplains might therefore be less suitable for them. Alternatively, fish body shape and growth curves may change in different environments (Strauss, 1980 in Bookstein et al., 1985; Noakes et al., 1995) which could explain the relatively high variation in the length–weight relationship among Sacramento sucker samples.

Our study shows that condition factors and juvenile growth rates are useful indicators for determining the importance of floodplain habitats as nursery areas. They indicate that for some fishes, floodplains are suboptimal rearing habitat despite the abundance of food. In order to confirm our findings, we suggest the use of a more sensitive condition index, such as RNA/DNA content or lipid content (e.g. Grant & Brown, 1999; Suneetha et al., 1999; Esteves et al., 2000; St John et al., 2001) over a wider range of species. Such a study would help to distinguish between species likely dependent on floodplains vs. those that use floodplains on an *ad hoc* basis.

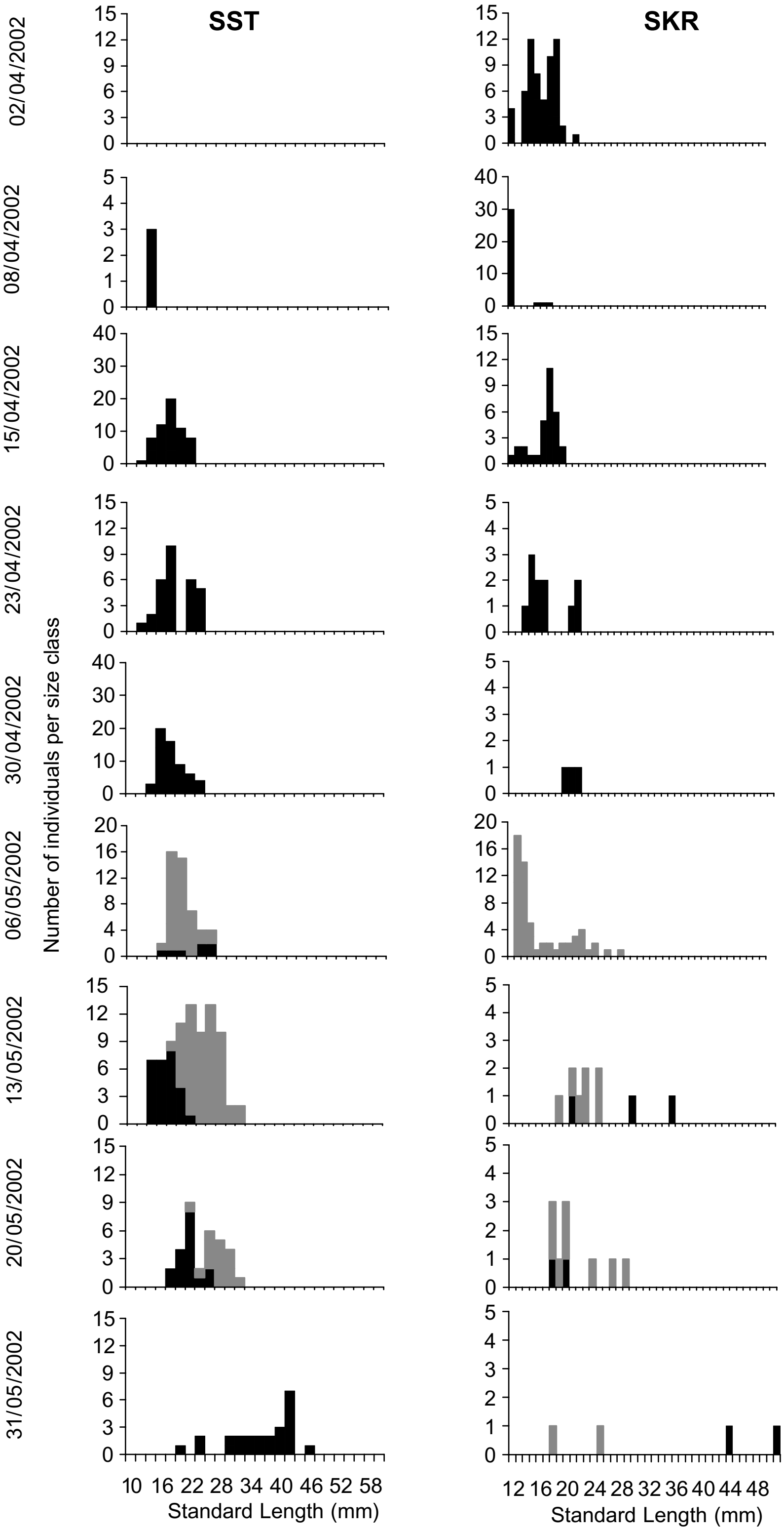

Figure 4. Temporal variation of standard length distribution for Sacramento splittail (SST) and Sacramento sucker (SKR) in each habitat: floodplain (black bars) and riverine (grey bars) sites.

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