3D. Temporal and spatial variation of condition of young-of-year fishes in the lower Cosumnes River, California.

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"This paper has not been submitted elsewhere in identical or similar form, nor will it be during the first three months after its submission to *Hydrobiologia*."

Abstract

The condition factors and growth rates of several fish species were compared in order to determine importance of floodplain habitats for early life stages. Emphasis was placed on Sacramento splittail because it is regarded as a threatened species. Sampling took place between April and June of 2001 and 2002 in the lower Cosumnes River in Central California. Five sites were sampled: two on the floodplain, two in the river and one in an irrigation channel. Floodplain fish had higher condition factors than those from riverine habitats. Sacramento splittail had higher condition in floodplain habitats and lower condition in altered habitats, while Sacramento sucker did not show a distinct difference in condition between floodplain and riverine habitats. Common carp and golden shiners, two alien species that spawned on the floodplain, had high growth rates and condition factors. Splittail growth varied considerably over a 10-day period (2.2 mm to 6.9 mm). Sacramento suckers from the floodplain had lower weights than those from the river. This study shows the usefulness of condition factor and growth rate in evaluating importance of different habitats for early life history stages of Central Valley fishes.

Introduction

Floodplains are important habitats for spawning and rearing of fishes (Welcomme, 1985; Bayley, 1995; Sparks, 1995). A major reason for their importance is that they can be highly productive of invertebrates used as food for larval and juvenile fishes and can have physical conditions (e.g., temperature, cover) that favour survival. When conditions are favourable such young of year (YOY) fishes grow rapidly and presumably are better able to avoid predators once they leave the floodplain as it drains. Thus growth rates and condition of YOY fish are likely to be good measures of the suitability of habitats for rearing, especially when environmental conditions, as indicated by temperature, are favourable as well (Bennett et al., 1995; Suthers, 1998; Grant & Brown, 1999, Suneetha et al., 1999). Floodplain habitat is not uniform, however, and it is likely that food resources in particular are patchily distributed, with some areas being more favourable for fish growth and survival than others, although this is not well documented. Physical conditions also change with location and time. Given the growing interest in floodplain restoration, understanding conditions that are most favourable for YOY should influence restoration strategies.

In this study, we examine growth and condition of YOY fish collected at various times and places on the floodplain of the Cosumnes River in order to obtain insights into conditions that are most favourable for YOY rearing. The Cosumnes floodplain was recently restored by breaching levees and is extensively used by both native and alien fishes (Crain et al., in press). The native fishes are part of an endemic fish fauna containing a number of species adapted for using floodplain habitats (Moyle, 2002). For example, the federally threatened Sacramento splittail (Cyprinidae: *Pogonichthys macrolepidotus*,(Ayres, 1854)) spawns on floodplains and use them as nursery habitat

(Sommer et al., 2001, 2002; Moyle, 2002; Crain et al., in press). Other species, such as Sacramento sucker (*Catostomus occidentalis*, Ayres, 1854), spawn in rivers but passively use the floodplain for rearing of YOY. Some alien fishes use the floodplain in similar ways. Common carp (*Cyprinus carpio*, Linnaeus, 1758) and golden shiner (*Notemigonus crysoleucas* (Mitchill, 1814)) both spawn and rear on the floodplain although the habitat does not appear to be crucial for their persistence (Moyle, 2002). 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., in press).

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

1. Are some parts of the floodplain as well as of the adjacent river and slough habitats, more suitable for YOY rearing than others?
2. Do rearing conditions for YOY fish change as the season progresses?
3. Are there differences in importance of floodplain habitat to the rearing of different species of native fishes, as well as of alien fishes?

Study area

The Cosumnes River Preserve is located in South Sacramento County bordering the Cosumnes River, 5 km above the confluence of the Cosumnes and Mokelumne Rivers (Fig. 1). The preserve has some of the best remaining examples of Central Valley freshwater wetlands, cottonwood-willow riparian corridors, and valley oak riparian forests.

It also contains managed farmlands and diked waterfowl ponds, together with annual grasslands interspersed with vernal pools. For more details of exact site location consult Crain et al. (in press.). Five sampling sites were studied representing 3 different habitats: riverine habitat (River 1, Middle Slough), River 2, Railroad Bridge), irrigation channel habitat (Wood Duck Slough) and the floodplain habitat (Floodplain Pond 1 and Floodplain Pond 2). The pond sites were relatively wide and shallow habitats, but different in their characteristics. Floodplain Pond 1 was hard bottomed and located close to the main levee breaches through which water entered the floodplain. It fluctuated greatly in size and depth in relation to flow. Pond 2 contained dense beds of terrestrial and aquatic vegetation and was more constant in size and volume because it was connected to a slough by a ditch, through which water backed up into the pond after flooding ceased.

Methods

Beach seining was used to sample YOY fish community on weekly basis (Mesh size)

YOY fish caught 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 length ± 1mm) and weighed (total dry weight ± 0.001 g).

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

$$K = \left(\frac{D_w}{SL^b} \right) \times 10^5$$

where D_w is total dry weight (g), SL standard length (mm) and b 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.

We compared temporal variability in condition for Sacramento splittail in the two floodplain ponds between 3rd April and 8th May of 2001. The condition of Sacramento sucker and splittail was compared between different habitats in 2002 (between the 2nd April and July 10th) and for 2001. For carp and golden shiner, two alien fish species, the condition factor was calculated for the two floodplain ponds only with 2002 data. For each species the average condition per site and date was compared either with t-tests or with analysis of variance (ANOVA) for, respectively, 2 groups comparison and more than 2 groups comparisons (Zar, 1999). For these statistical analyses, only groups with N>20 were analysed. When the homogeneity of variances was not satisfied we performed a non-parametric test - Kruskal-Wallis test (Zar, 1999). For each species, the independence of the condition factor and standard length was calculated using a regression analysis (Zar, 1999).

We determined growth rates in two different ways: 1) studying the mean total length increment and 2) assessing the weight increment along the fish length. The mean total length of splittail, sucker, golden shiner and carp was calculated for different sites while for prickly sculpin (*Cottus asper*, Richardson, 1836) and Sacramento blackfish (*Orthodon microlepidotus*, (Ayres, 1854)) it was determined for one site. For first two species we used data from both years. A growth rate was defined as the total length increment (in mm) per a standard period (10 days).

$$Lgr = \frac{TL_0 - TL_{0+t}}{t} \times 10$$

where Lgr is growth rate (mm/10 days), TL_0 total length (mm) at the beginning of the period and TL_{0+t} total length (mm) after the period t (days). This analysis assumes that 1) growth rate reflects condition (is dependent on environmental conditions) and, 2) the YOY fish community was the same throughout the period of the study. We accounted for batch-spawning of some species that results in the persistence of the same or smaller total length for consecutive samples by generating low or negative growth rates (e.g., when the modal class of length decreased it suggested that the fish spawned again). YOY movement was assessed using length frequency histograms for the different sites over time.

The length-weight relationship was compared between two habitats, riverine vs floodplain, for Sacramento sucker and Sacramento splittail. In order to be more precise this comparison was only made using the same length range. The data from each site was pooled per habitat, the two floodplain pools for floodplain and the two river sites for riverine habitat. The length-weight relations were compared between habitats using an Analysis of Covariance (ANCOVA) (Zar, 1999). The statistical tests where performed using SPSS © for Windows.

Results

Table 1 shows the species length-weight relationship for the lower Cosumnes. The Sacramento sucker seems to have a higher weight increment due to the higher slope. Condition of the four species was found to be independent of standard length ($P<0.01$). There were significant changes in splittail YOY condition in both floodplain ponds (Pond 1, Kruskal-Wallis, $P<0.001$; Pond 2, ANOVA, $P<0.001$) through time (Figure 2). Splittail condition varied synchronously in both sites, tracking temperature (Figure 2).

Figure 3 we observed the mean condition for each species and per site. Splittail and sucker condition was compared between habitats using the Kruskal-Wallis test once the variances where found not to be homogeneous (Levene’s Test, $P<0.001$). There were significant differences in condition for splittail and sucker (Kruskal-Wallis, $P<0.001$). Splittail YOY condition in Floodplain Pond 1 was significantly higher then all the other sites, while splittail condition factors from the two river sites and the channel site were not significantly different. Condition of suckers in Floodplain Pond 2 sucker was not significantly different from those in River site 1. . Sucker condition in Floodplain Pond 2 and River Site 1, however, were significantly different from all the other sites with the River Site 2 and Floodplain Pond 1 fish having significantly lower condition factors. The two alien fishes (carp and golden shiner) showed similar trends in condition within the floodplain sites. Condition in Floodplain Pond 1 condition was generally higher than in Pond 2, although it was only significantly higher for the golden shiner (t-test; $P<0.05$),

Splittail growth rates seemed to be different at each site. Fish in River Site 2 had the largest growth rate followed by the fish in Floodplain Pond 2, while the fish in Pond 1 had generally lower growth rates (Figure 4). Conversely, carp and golden shiner, had higher growth rates in Floodplain Pond 1 when compared to Pond 2; this was also the case for their condition (Figure 4). When species are compared, common carp and suckers exhibited the highest growth rates in a 10-day period, while golden shiner and prickly sculpin had very low growth rates (3.2 and 3.5 mm/10 days, respectively) (Table 2). The Sacramento splittail had a mean growth rate of 4.5 mm/10 days and the Sacramento blackfish of 6.3 mm/10 days.

Figure 5 compares the length-weight relationship between the floodplain and riverine habitats for the splittail and the sucker within the same length range. The splittail length-weight relationship was not significantly different (ANCOVA, $P>0.05$) between riverine and floodplain habitats (Log (Dw) = 3.4743*Log (SL) - 6.2659; R^2 = 0.9776; N= 39; Log (Dw) = 3.3965*Log (SL) - 6.1624; R^2 = 0.9587; N= 107). For Sacramento sucker there were significant differences between the length-weight relationships of the riverine and floodplain habitats (ANCOVA, $P>0.05$). Riverine suckers gained weight at a faster rate than floodplain suckers (Log (Dw) = 7.2474*Log (SL) - 11.186; R^2 = 0.9235; N=27; Log (Dw) = 4.9734*Log (SL) - 8.5513; R^2 = 0.8425; N=98). Length distributions of splittail suggest that theymove from floodplain to riverine habitats on their way down stream to the San Francisco Estuary (Figure 6). The lengths of suckers, in contrast, seem to reflect batch-spawning in the river with some larvae washing on to the floodplain following spawning

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). Condition factors of juvenile splittail increased throughout their development in floodplain sites. This improvement in condition seemed to be linked to warmer temperatures and to abundant zooplankton and other food resources (Moyle & Crain, unpublished data). This seems plausible because high zooplankton concentrations linked with temperature rise would result in improved feeding efficiency.

Generally splittail on the floodplain had higher condition factors than those in the river and much higher factors than those from the more uniform channel site. The fish at River site 1 also had the highest condition between the two riverine sites, probably because these fish just left the floodplain in their migration to the San Francisco Estuary.

Fish growth rates were also different between sites. Splittail juveniles had higher growth rates in Floodplain Pond 2 and River Site 2 when compared with other sites. These preliminary results may seem contradictory to our condition findings, but there are some factors affecting this: YOY movement between sites and batch spawning events. For instance, Sacramento suckers apparently spawned twice with YOY from the first batch moving out onto the floodplain and the second batch being confined to the river (Figure 6) because of lost connection to the floodplain. Because these YOY were under different environmental conditions, they grew at different rates. Crain et al. (in press.) suggested that other species (carp, prickly sculpin, golden shiner, and inland silverside), also batch-spawned in the floodplain and riverine habitats. Batch-spawning behaviour has distinct advantages in the highly fluctuating environments such as floodplain habitat because the year's progeny are not all subjected to the same time risk.

Suckers from riverine habitats gained more weight than floodplain suckers. Suckers are widely distributed in riverine habitats and their YOY are well adapted to the edge habitat of cool, flowing streams (Moyle 2002), Floodplain habitat may less suitable for YOY suckers which are deposited there as pelagic larvae during high overland flow events. The less variable riverine habitats in terms of temperature may favour higher growth and condition. Alternatively, fish body shape and growth curves may change in different environments (Strauss, 1980 in Bookstein et al., 1985; Noakes, 1995) which could explain the intraspecific variation of length-weight relationship among sucker samples.

Our study shows that condition factors and juvenile growth rates are useful indicators in determining the importance of floodplain habitats as nursery areas. They indicate 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 versus those that use floodplains on an *ad hoc* basis.

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Tables

Table 1 - Length-weight relationship parameters for four species. Length-weight relationship – Log (Dw)=b*Log (SL)+a, where Dw is dry weight, SL is standard length, b the slope and a intercept.

Species	N	Standard Length Range	Slope	Intercept	R^2
Sacramento splittail	590	13-43	3.341	-6.069	0.981
Sacramento sucker	243	11-27	4.967	-8.391	0.765
Golden shiner	100	11-28	3.6337	-6.4871	0.9554
Common carp	45	16-38	3.3297	-5.9103	0.9896

Table 2 – YOY fish growth rate (mm/10 days) for five species of YOY fish, N represents the number of groups for which growth rate was measured. Length range is given in Table 1.

Species	N	Mean Growth Rate (mm/10 days)	Growth Rate Range (mm/10 days)
Sacramento Splittail	12	4.5	2.2 - 6.9
Sacramento Blackfish	1	6.3	-
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
Prickly Sculpin	1	3.5	-

Figure captions

Figure 1 - Map with Cosumnes Preserve in the Lower Cosumnes watershed.

Figure 2 – Temporal variation of Sacramento splittail YOY condition factor in Floodplain Ponds 1and 2 in 2001, in relation to temperature.

Figure 3 – Average condition factor per site for Sacramento
splittail (SST), Sacramento sucker (SKR), Carp (CRP) and Golden Shiner (GSH) (bars represent 95% confidence intervals)

Figure 4 – Growth rates per site for Sacramento splittail (SST), Carp (CRP) and Golden Shiner (GSH)

Figure 5 – Length-weight relationships comparison between floodplain and riverine habitats for Sacramento splittail (SST) and Sacramento sucker (SKR)

Figure 6 – Standard length temporal variation per site for Sacramento splittail (SST) and Sacramento sucker (SKR) in riverine and floodplain sites.

Figure 1

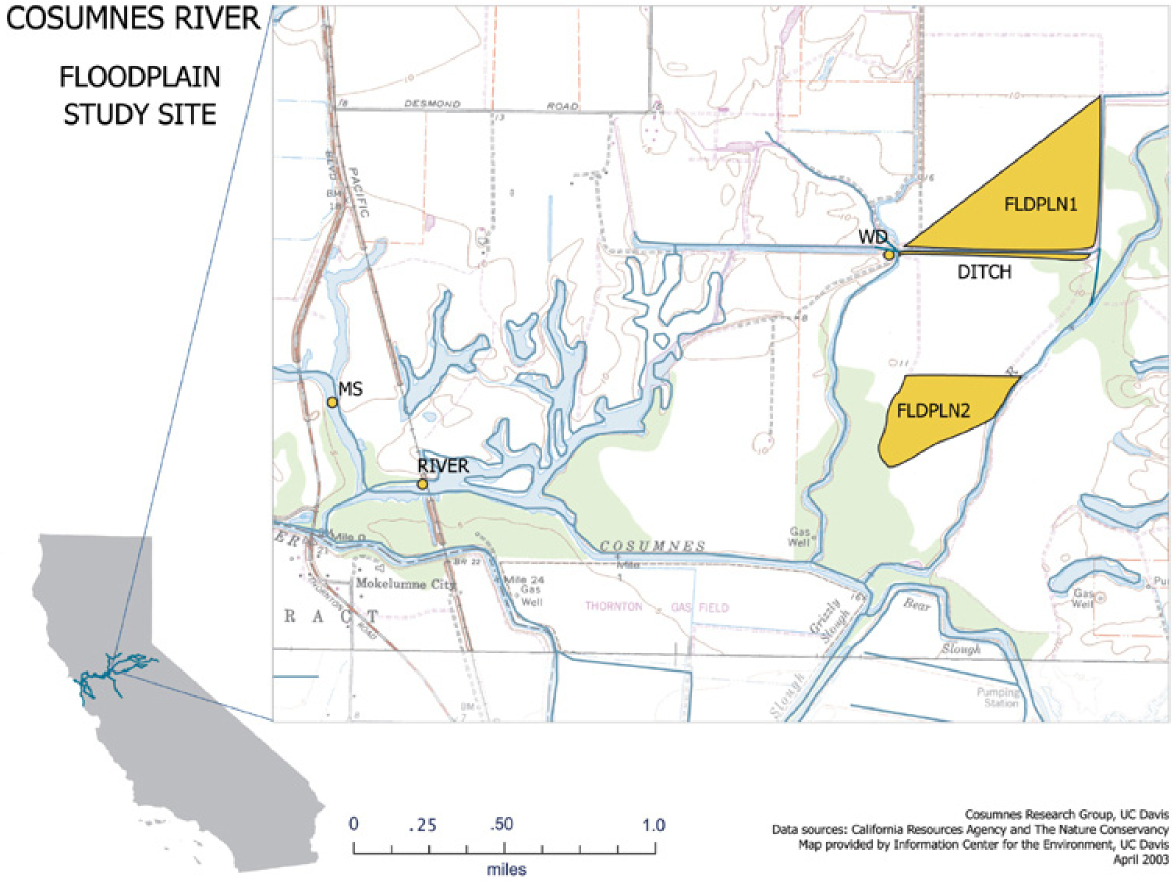

COSUMNES RIVER
FLOODPLAIN
STUDY SITE
FLDPLN1
WD
DITCH
MS
FLDPLN2
RIVER
COSUMNES
Mokelumne City
THORNTON GAS FIELD
0 .25 .50 1.0
miles
Cosumnes Research Group, UC Davis
Data sources: California Resources Agency and The Nature Conservancy
Map provided by Information Center for the Environment, UC Davis
April 2003

Figure 2

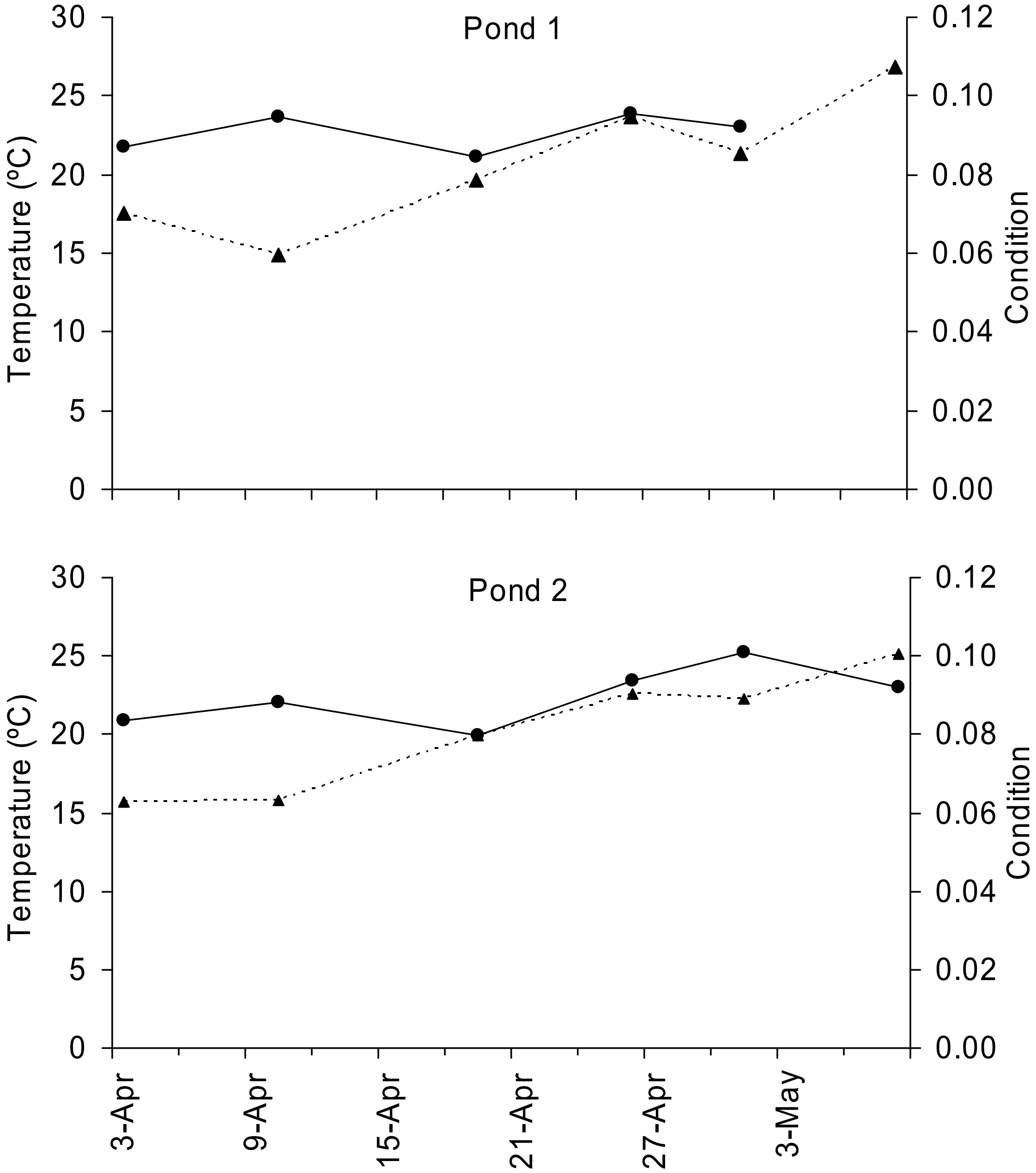

Pond 1
Pond 2
Temperature (ºC)
Condition
30
25
20
15
10
5
0
0.12
0.10
0.08
0.06
0.04
0.02
0.00
3-Apr
9-Apr
15-Apr
21-Apr
27-Apr
3-May

Figure 3

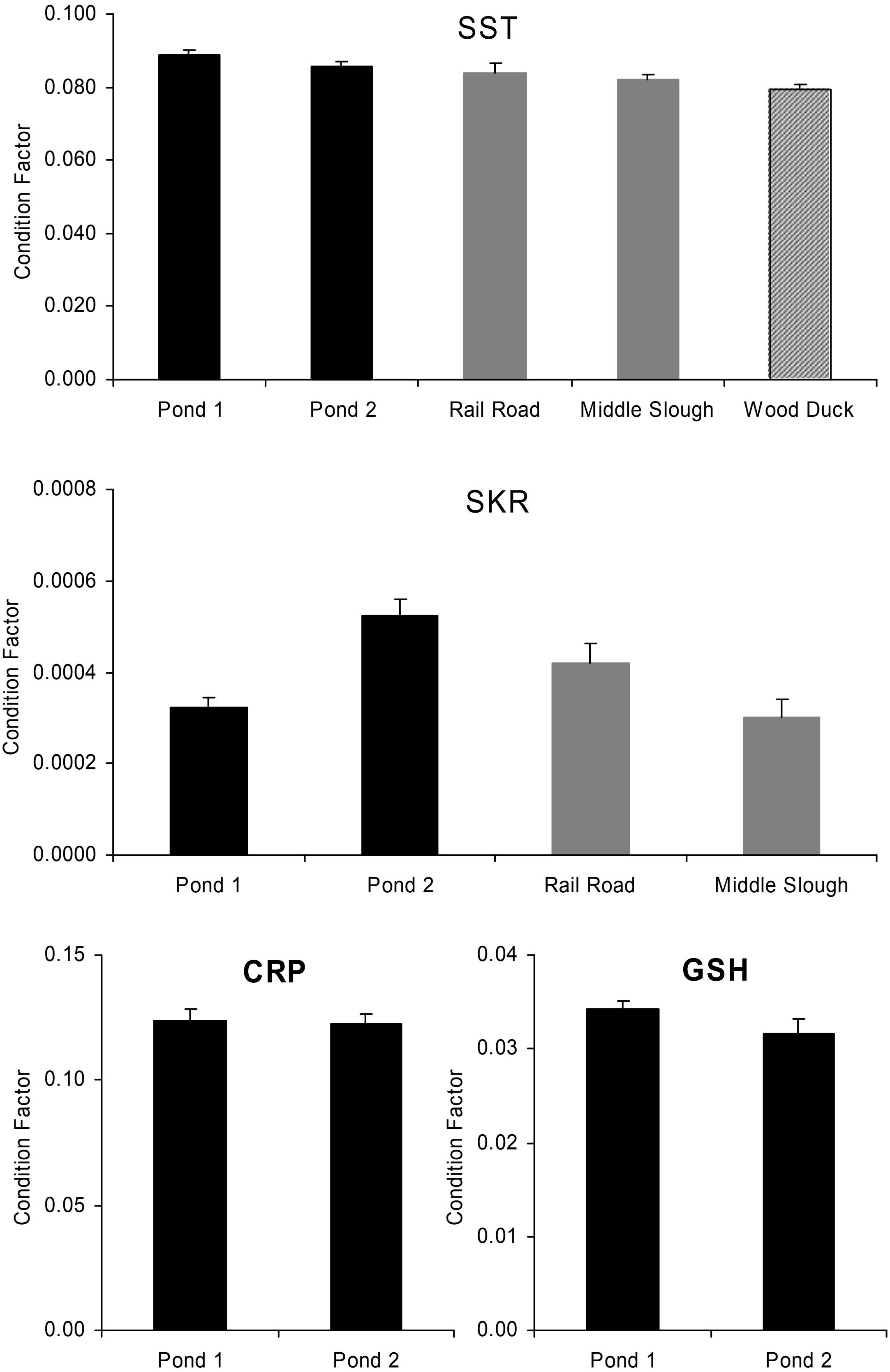

SST
Condition Factor
0.100
0.080
0.060
0.040
0.020
0.000
Pond 1
Pond 2
Rail Road
Middle Slough
Wood Duck
SKR
Condition Factor
0.0008
0.0006
0.0004
0.0002
0.0000
Pond 1
Pond 2
Rail Road
Middle Slough
CRP
Condition Factor
0.15
0.10
0.05
0.00
Pond 1
Pond 2
GSH
Condition Factor
0.04
0.03
0.02
0.01
0.00
Pond 1
Pond 2

Figure 4

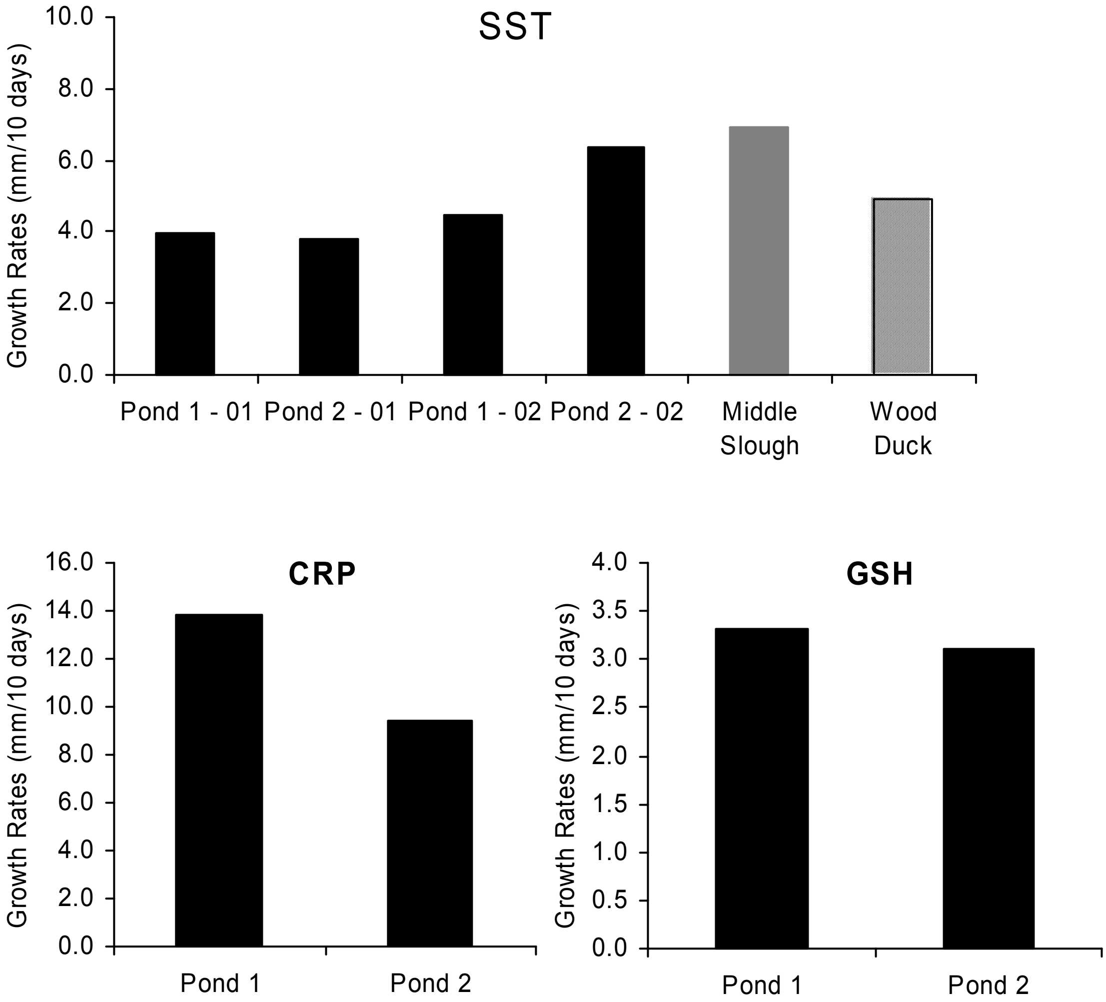
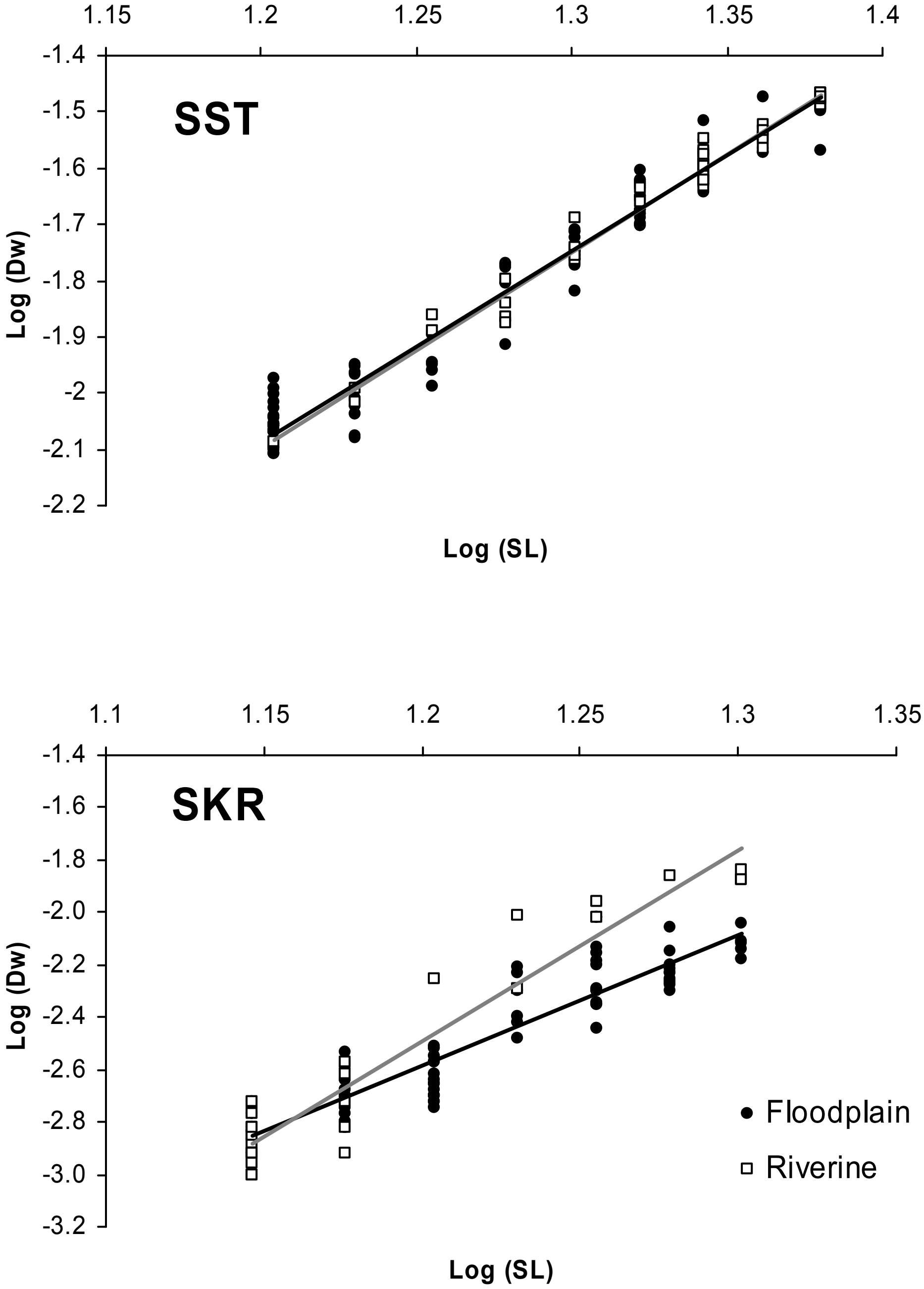
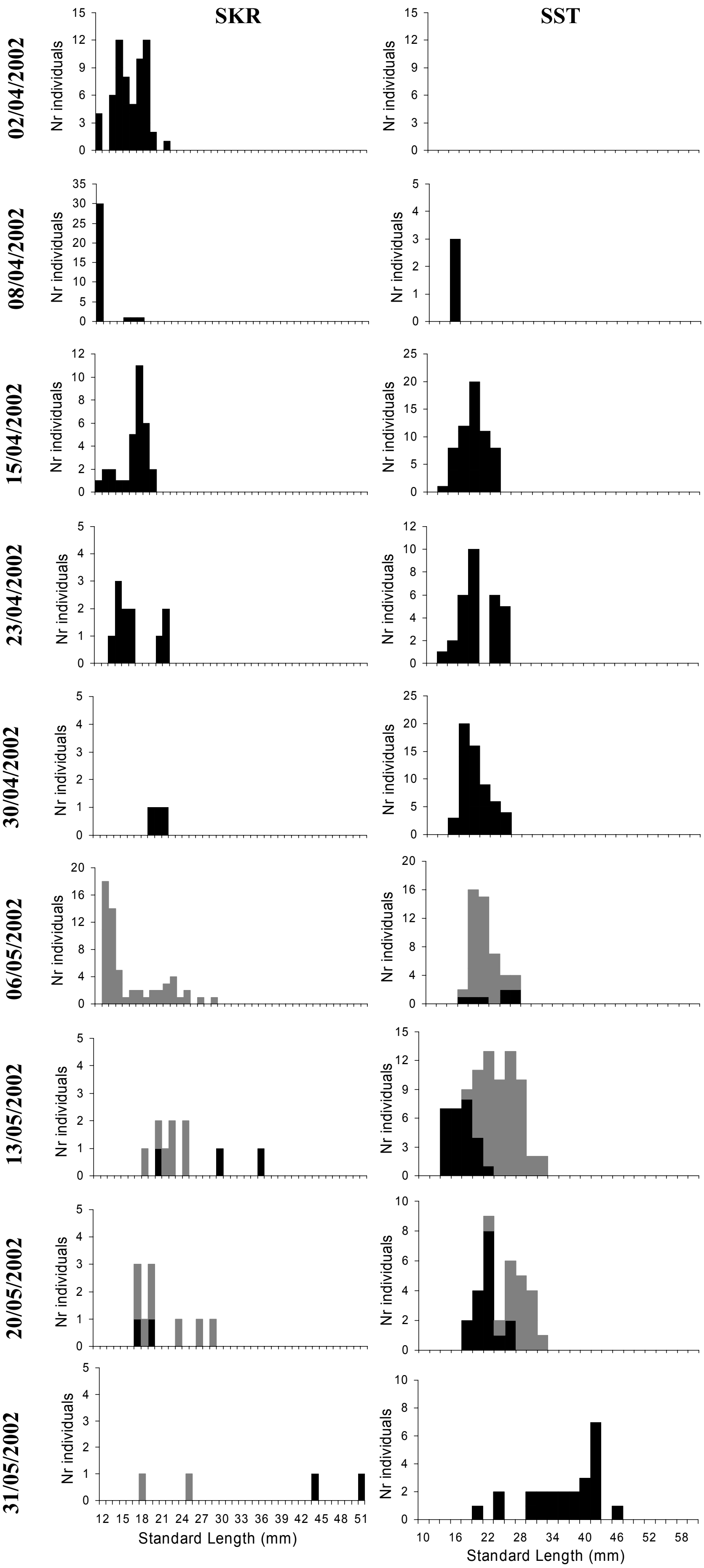

SST
Growth Rates (mm/10 days)
10.0
8.0
6.0
4.0
2.0
0.0
Pond 1 - 01
Pond 2 - 01
Pond 1 - 02
Pond 2 - 02
Middle Slough
Wood Duck
CRP
Growth Rates (mm/10 days)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Pond 1
Pond 2
GSH
Growth Rates (mm/10 days)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Pond 1
Pond 2

Figure 5


SST
1.15
1.2
1.25
1.3
1.35
1.4
-1.4
-1.5
-1.6
-1.7
-1.8
-1.9
-2
-2.1
-2.2
Log (Dw)
Log (SL)
SKR
1.1
1.15
1.2
1.25
1.3
1.35
-1.4
-1.6
-1.8
-2.0
-2.2
-2.4
-2.6
-2.8
-3.0
-3.2
Log (Dw)
Log (SL)
Floodplain
Riverine


SKR
SST
02/04/2002
08/04/2002
15/04/2002
23/04/2002
30/04/2002
06/05/2002
13/05/2002
20/05/2002
31/05/2002
Nr individuals
12 15 18 21 24 27 30 33 36 39 42 45 48 51
Standard Length (mm)
10 16 22 28 34 40 46 52 58
Standard Length (mm)