3B. USE OF THE COSUMNES RIVER FLOODPLAIN BY NATIVE AND ALIEN FISHES: A FIVE YEAR STUDY

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Abstract

Fishes were sampled on the Cosumnes River floodplain for five years (1998-2002) during the winter-spring flooding season, typically February –May, although additional months were sampled in some years. Sampling was done with light traps (larval fish), seines (YOY and adults), and boat electrofishing (adults and juveniles). Over the five years of sampling, 33 species of fish were captured in the floodplain and adjacent river and sloughs. 18 of the species were abundant enough to use in analyses of trends and habitat use Eight of the abundant species were natives, while the rest were aliens. There was a fairly consistent pattern of floodplain use by fish over the five year period, although the basic pattern was modified on an annual basis by the extent of flooding. The first fish to appear on the floodplain were a few adult fish from ponds (e.g. golden shiner), some transient species (e.g., Pacific lamprey) and juvenile chinook salmon. The next fish to appear were adult floodplain spawners, principally splittail and common carp, which spawn on flooded annual vegetation, although small numbers of species resident in ponds and neighboring sloughs were continuously present. The juveniles of the splittail and carp quickly became large enough to dominate floodplain fish samples, along with juveniles of suckers and pikeminnows coming in from the river. The adult spawners left the flood as inflow decreased. The juveniles persisted on the floodplain as long as occasional new pulses of flood water kept water levels up and

temperatures down, but most juveniles of native fishes left the floodplain either with the pulses or with declining inflows. Most were gone by mid-May but some persisted through June if conditions favored their presence. Usually, the floodplain disconnected from the river by mid-May. In the two large shallow ponds of residual water sampled in this study, mosquitofish, inland silverside, and juvenile centrarchids tended to dominate catches by June. The centrarchids were mainly bluegill, redear sunfish, black crappie, and largemouth bass, which are abundant in adjacent sloughs and presumably colonized floodplain ponds through a combination of individuals moving in through ditches or resulting from spawning by stranded fish. In many years, the ponds dried up by August. Essentially, native fishes plus carp dominated the floodplain fish fauna early in the season while alien fishes dominated (almost completely) late in the season. Native fishes that were abundant each year were those that could use the floodplain for rearing of juveniles. Most alien fishes had resident populations in permanent waters associated with the floodplain (sloughs, ditches, ponds) and were not dependent on the floodplain for persistence. The fish fauna of the Cosumnes River was the same as that of the neighboring Mokelumne River but species composition was markedly different as the result of permanent cool-water flows (releases from Camanche Dam) and the lack of floodplain habitat.

Introduction

There is growing recognition worldwide that floodplains provide many benefits that historically have not been appreciated, including direct economic benefits, ecosystem services, and habitat for a wide diversity of species. In California, where rivers have historically been denied use of their floodplains, restoration is increasingly perceived as providing many benefits that are compatible with other societal uses of the land (e.g., Sommer et al. 2000). One of the key benefits is enhancement of native fish populations, including Chinook salmon and Sacramento splittail. However, our understanding of how fishes use floodplains is limited, as is our understanding of how to manage floodplains to favor native fishes. The floodplain of the Cosumnes River on the Cosumnes River Preserve provides an excellent opportunity to learn about how fish use floodplains because of its relatively small size, accessibility, and habitat diversity. Most of the Cosumnes floodplain was also recreated as the result of breaches in levees along the river, so it also provides an opportunity to study the impacts of restoration. The purpose of this study is to document the use of the floodplain by fishes by frequent sampling through the flooding season for five years, using a variety of techniques. Key questions we attempted to answer were:

1. What fishes use the floodplain?
2. How do fish species differ in their use of the floodplain in terms of behavior, season of use, and habitat?
3. What characteristics of flooding and floodplains favor native fishes?
4. How should a monitoring program be established for floodplain fishes?

To answer these questions, we examined floodplain use by (1) larval fishes, (2) young-of-year juveniles, (3) adults and older juveniles.

Background: how fishes use floodplains

Fishes use floodplains in many different ways. A classification of uses in California is presented here, based on information from Moyle (2002). This information in turn is based on our experiences sampling the Cosumnes River floodplain while the book was in progress, as well as the simultaneous studies of T. Sommer of DWR on the Yolo Bypass (Sommer et al. 1999, 2000, 2001, 2002). Floodplain fishes can be classified as follows: (1) floodplain spawners, (2) river spawners that rear on floodplains, (3) floodplain foragers, (4) floodplain pond fishes, and (5) inadvertent floodplain users.

Floodplain spawners. These are fishes that use the floodplain for spawning and for rearing of early life history stages. Typically, they migrate onto the floodplain when the water is rising or at equilibrium and then spawn on flooded substrates. The embryos stick to the substrate, off the bottom, hatch in a few days and then rear for varying periods of time until they reach an actively swimming juvenile stage (usually at ca. 25 mm TL). Juveniles leave the floodplain as the water recedes, which usually coincides with the time when they reach 40-60 mm TL. Floodplain spawners can be either obligate spawners or opportunistic spawners. Sacramento splittail is an example of an obligate floodplain spawner in the study area (as revealed by this study); year class strength is highly correlated with the number of days of flooding (Sommer et al. 1999). Common carp and goldfish are examples opportunistic floodplain spawners. They enter floodplains and spawn but will also spawn on submerged aquatic vegetation or on plants or debris along the edges of rivers when water levels are high. The degree to which year class strength depends on flooding is not known.

River spawners that rear on floodplains are species that spawn upstream of the floodplains, usually on gravel riffles, and then use the floodplain for rearing. These fishes are common but the importance of floodplains to their populations is poorly known, because they also rear on stream edges and other habitats. Sommer et al (1999) demonstrated that juvenile Chinook salmon rearing in the Yolo By pass grew faster and achieved larger sizes than fish rearing in the main river. Other native fishes with potential to benefit from floodplain rearing are Sacramento pikeminnow and Sacramento sucker. A key to the success of species that use the floodplain for rearing is that they 'know' how to get off the floodplain as it drains and do not get stranded as a consequence. These fishes may also enter the floodplain as adults to forage on the way back from spawning (or on the way up).

Floodplain foragers are fishes that are move on to the floodplain to feed, taking advantage of abundant food. Typically, they are most abundant in local sloughs and ponds and spawn after the flood has receded. They enter the floodplain as either juveniles or adults and seem to have a relatively low incidence of stranding, although some may spawn on the floodplain if the water stays long enough. Examples include golden shiners and bluegill/redear sunfish.

Floodplain pond fishes are species that are present in local sloughs and ponds but become abundant, through rapid growth and reproduction, mainly in shallow floodplain ponds as the water recedes. They are the fishes that most commonly become stranded in large numbers as ponds dry up. Examples are inland silversides and western mosquitofish.

Inadvertent floodplain users are probably a majority of species collected on floodplains but are a small number of individuals. They enter floodplains from ponds and sloughs on the floodplains or wash in from upstream. The have a variety of fates. If they are larvae or small juveniles washed in from upstream, they either just pass though on the currents (lampreys) or settle out to die or become stranded (prickly sculpin). Large adults of species such as largemouth bass or channel catfish that move too far from their home ponds are likely to become stranded in the falling water. Many of these fishes (e.g.,black crappie) enter the flood waters but do not move far from their permanent habitats, so are often capable of returning to their ponds or sloughs as the water recedes.

Study area

The Cosumnes River Preserve (CRP) is located in South Sacramento County boarding Franklin Rd. and the Cosumnes River. It is a large mosaic (5,261 hectares) of floodplain and surrounding uplands. The preserve has some of the best remaining examples of Central Valley freshwater wetlands, cottonwood-willow riparian corridors, and valley oak riparian forests. The preserve also contains managed farmlands and diked waterfowl ponds, together with annual grasslands interspersed with vernal pools. The CRP edge sits just above (.5 km) the confluence of the Cosumnes River and the Mokelumne River (Figure 1). The preserve encompasses three major tidally-influenced freshwater sloughs, Middle Slough, Tiechumne Slough, and Wood Duck Slough. During non-flood periods, the tidal range in these sloughs is about 15-30 cm/day. During high flows Middle Slough acts as an overflow channel with a large portion of the overland flow exiting through it into Lost Slough and into the North Delta (upper San Francisco

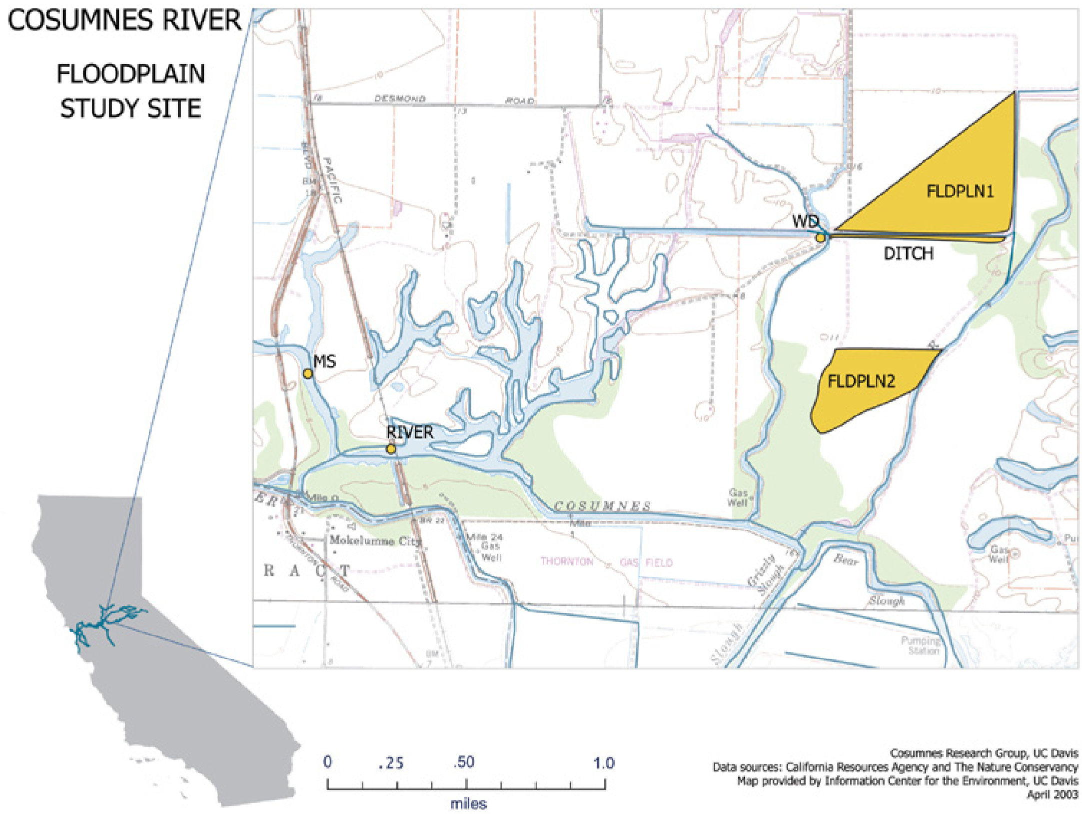


Figure 1. Map of the Consumnes River floodplain, showing major sampling areas.

Estuary). Wood Duck Slough bisects the middle of the floodplain area and also acts as a conveyor of overland flow during high inundation.

When flooding occurs, water flows through breaches in the levees that separate the river from the CRP. The first and largest breach delivers water into a shallow (1-2 m) depression (Pond 1 in our studies) that is 1-2 ha in extent, depending on the amount of flooding. The water from this pond either flows back into the river through another breach about 100 m downstream from the first breach or flows parallel to the river into a second pond (Pond 2), also 1-2 ha in extent, from which it can flow back into the river through another breach or through a ditch connecting the pond to Middle Slough. During high flow events, water inundates the fields and forests surrounding the ponds and there are overland flows in many directions, connecting ponds, ditches, and sloughs throughout the CRP.

Flooding occurred every year on the CRP but the extent varied among years (Figures 2, 3). 1998 was a very wet year and flooding was nearly continuous from early January through late June. Most of the CRP flooded during peak events. Water remained in ponds on the floodplain throughout the summer. 1999 was similar to 1998 only connection between the river and floodplain began in late January and was lost in early June. 2000 was fairly average in precipitation and spring flows; flooding began in late January and was continued through mid- May, with occasional breaks in connectivity. Only the lowest sections of the CRP flooded, mainly below a low cross levee. 2001 and 2002 were fairly dry years with flooding beginning in late January; connections between the river and floodplain were intermittent and ceased by early May. Flooding was largely confined to filling the two ponds and nearby surrounding areas of annual vegetation.

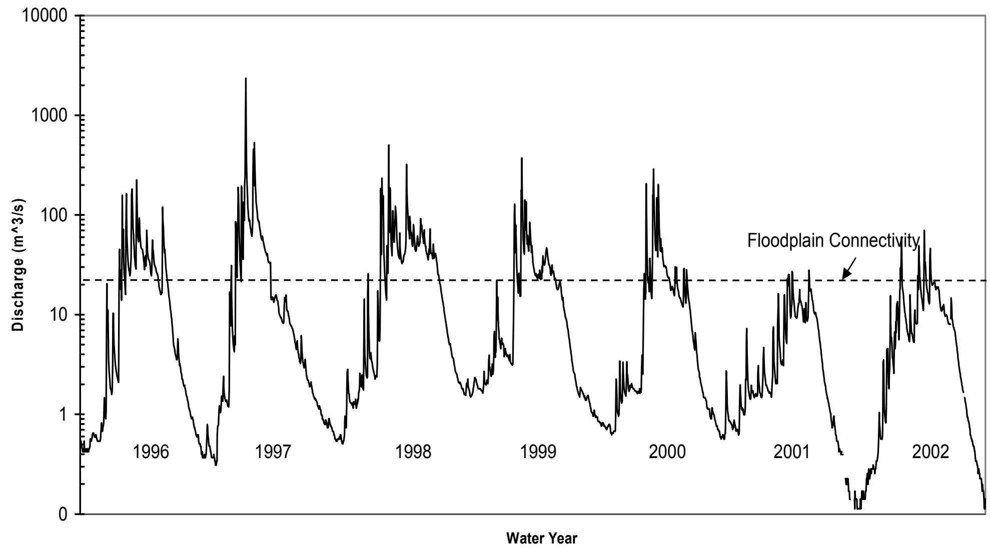


Figure 2. Flow regime, lower Consumnes River, as measured at the gauging station at Michigan Bar upstream of the study area, 1996-2002. Note the line indicating times when flows were sufficient to put water on the floodplain.

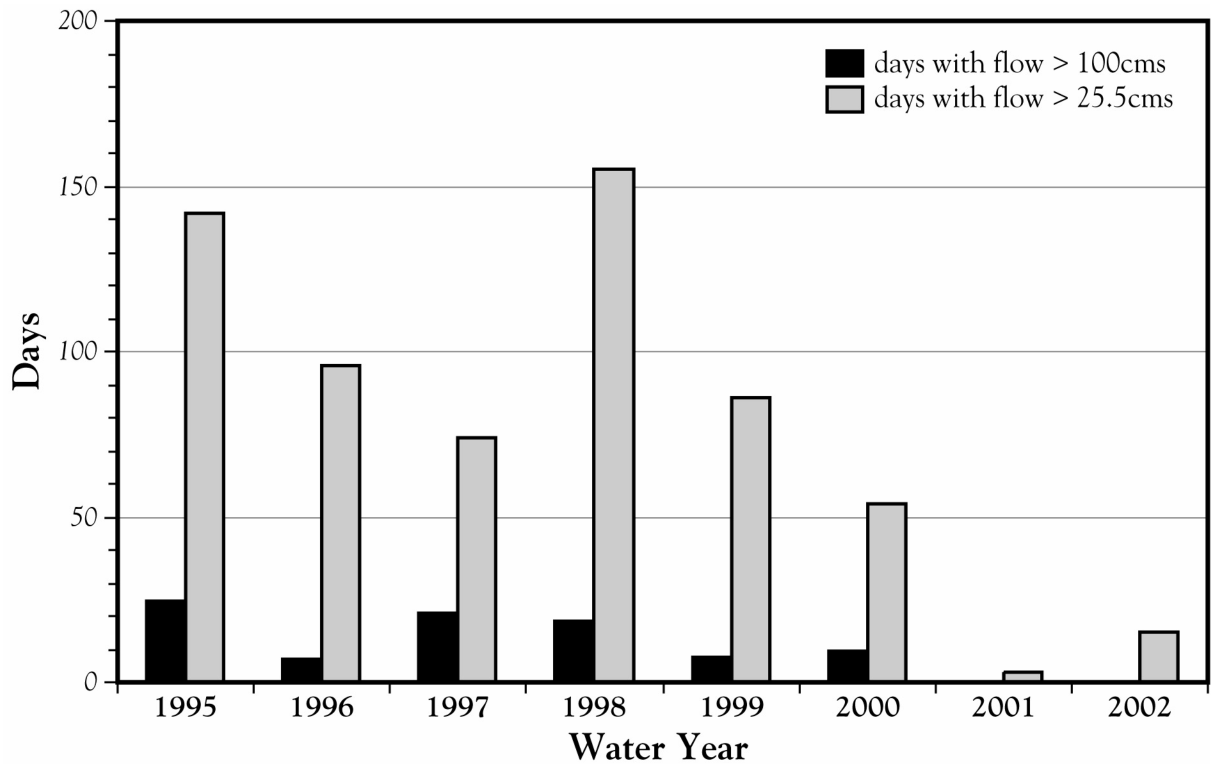


Figure 3. Number of days in which the Consumnes River had high enough flows to move sediment (100 m^3/sec) and to flood the Consumnes River Preserve (25.5m^3/sec).

Floodplain sampling focused on two ponds. Pond 1 was originally constructed as a source of earth for a levee but also to hold water for waterfowl. It is adjacent to the two uppermost levee breaches and became partially filled with sand carried in by the river during the course of the study (Mount study). In most years it held water though July and then dried up. When disconnected, maximum depth was about 1.5 m and it became progressively shallower as it dried. Pond 2 was also constructed for waterfowl and had a narrow channel connecting it to Middle Slough. An earthen dam constructed annually on the slough (to provide water for irrigation of fields of neighboring farms) usually backed water up into the pond in late summer, so it rarely dried up completely, although it was usually small and shallow (<1m) by late summer. Maximum depth was around 2 m. When flood waters entered the study area, these ponds became the centers of two flooded areas separated by another levee, but connected by a breach in the middle through and a another breach at the end which the water flowed from the Pond 1 area to the Pond 2 area during periods of active flooding. As the flooded areas expanded in size and depth, the areas sampled also expanded, especially as areas suitable for seining progressively shifted back and forth across the flood plain.

For comparison with the floodplain samples, we also sampled sites on Middle Slough and on the Cosumnes River in 2000, 2001, and 2002. Both sites were downstream from the flooded areas, so represented principal routes of movement of fish off the floodplain as well as sites with permanent populations of fish. The same general sites could be fairly consistently sampled although actual locations for seining moved up and down the banks as waters rose and fell.

The patterns of flooding varied from year to year (Table 1). In 1998 and 1999 virtually the entire Cosumnes Preserve was under water during peak flows and flooding lasted late in the season. However in all five years, the regions around Ponds 1 and 2, bounded in part by low levees, were consistently flooded and connections of the river to the floodplain were at least intermittent during the season of flooding (Figure 1).

Year	Week,/Month first flooding	Week/Month, last connection	No. days connected	% flooded	Pond #1 dry in late summer?	
1998	2/12	4/6	165	100	No	
1999	3/1	4/5	118	100	No	
2000	3/1	3/5	86	20	Yes	
2001	4/2	4/4	18	10	Yes	
2002	1/1	2/4	42	10	Yes	

Table 1. Extent of flooding, Cosumnes River Preserve, 1998-2002. % flooding refers to approximate percentage of floodplain on the Cosumnes River Preserve covered with water at its maximum extent, compared to 1998, the wettest of the five years.

Methods

During each year, sampling began as soon as water entered the flood plain and continued until after flooding stopped, although extent of post-flooding sampling varied by size class and year (Table 2). Larval fishes were sampled with light traps and at intervals described in Appendix A to this section (Crain et al. 2003, a manuscript of a paper accepted for publication).

Year	Larval fish	Seining	Electrofishing
1998	None	March-June	None
1999	Feb-August	Feb- August	None
2000	April-July	Feb-July	Feb-June
2001	Feb-July	Feb-July	Feb -May
2002	None	Feb-June	Feb -May

Table 2. Years and months in which different sampling programs were present on the Cosumnes River Preserve.

The two major methods for sampling juvenile and adult fishes were seining and electrofishing. **Seining** was with a 10.5m x 1.5m net with 7 mm stretch mesh and bag that was 1x1x1 m. At each site, the net was set a minimum distance of 10 m from shore and stretched to its full length. Seiners pulled the net to shore in a standard fashion that enabled the area sampled to be estimated. Once the net was on shore, fish were removed and placed live in buckets. All fish were identified to species and measured (SL), until 50 fish of each species were measured. Remaining fish were counted. Most fish were released back into the water although small samples of fish were killed with a blow on the head (the preferred method for euthanasia; Robb and Kestin 2002) and preserved in formalin for use in dietary studies. Location of sample sites varied from time to time and year to year, depending on the extent of flooding, which regulated our ability to sample most areas. However, we consistently sampled areas in general localities (Figure 1). Sampling was done weekly. At each site, temperature (°C), conductivity (μS), and turbidity (secchi depth, cm) were measured. In 2000 and 2002, continuous temperature recorders (Hobotemps) were located near most seining sites.

Electrofishing was done with a shallow draft 5 m boat upon which a 5.0 GPP Smith-Root electrofishing array, including two 2-m long booms with a SA-6 umbrella anode arrays and bar array type cathode. The boat, propelled by a15 HP 4-stroke outboard motor, sampled fish effectively at depths of 0.5-2.0 m. The current used for shocking was adjusted automatically for conductivity but was normally 600 volts and 4 amps. Shocking was most effective for fish over 10 cm TL but smaller fish were also captured. Fish (mainly common carp) over 45 cm often escaped by swimming out of the electrical field before they could be captured. Fish were captured by a person standing in the bow of the boat with a long-handled (1.5-2 m) dipnet. All fish were placed in a large container of water after being captured. Fish were then measured (SL) and returned to the water. Electrofishing time varied from 2 to 5 minutes at each station because the focus was on sampling a fairly uniform section of habitat (e.g., marsh edge, open water, patches of vegetation). Because of fluctuating water levels station locations were variable, but efforts were made to sample all types of habitat accessible by the boat in a haphazard manner. At each station, various habitat variables were measured or estimated: using a standard form (Figure 4).

All data was entered on an Excel spread sheet for analysis. Data in this report is primarily presented graphically for ease of interpretation, but the data sets are (or will be) available on-line through the Interagency Ecological Program web site.

Results

Over the five years of sampling, 33 species of fish were captured in the floodplain and adjacent river and sloughs (Tables 3, 4). 18 of the species were abundant enough to use in analyses of trends and habitat use (Table 5). Eight of the abundant species were natives, while the rest were aliens.

Cosumnes Seine #____________________ Date ___________________

Site description____

____

Sample Method: Seine Fyke Water depth: time _____ depth _____

Avg. depth_____ _____ _____ _____ _____ = _____ Max. _____ Length_____ Width _____

Current: 0. None 1. Weak 2. Medium 3. Strong _____ _____ _____ _____ _____

Habitat Characterization

1. Floodplain 2. Slough 3. Slough-margin 4. River 5. River-margin 6. Old forest

7. New forest 8. Ditch 9. Farm field 10. Levy break 11. Pond

Substrate: 1. organic mud <.06cm; 2. mineral mud(sand+mud), <.06cm;

3. sandy silt, sand or silty sand, .06-.2cm; 4. pebbles and sand, or pebbles and mud, .2-2.0cm;

5. gravel, gravel and sand or gravel and pebbles, 2.0-6.0cm; 6. rocks, rocks and mud, rocks and sand or riprap, >6.0cm 7.

Clay, clay-silt, clay-sand, clay-gravel Other: _______________

Terrestrial vegetation: 0. absent 1. some 2. dense Type __________________

Woody debris: 0. absent 1. some 2.dense

Roots: 0. absent 1. some 2. dense

Woody vegetation: 0. absent 1. some bushes or trees, 2. dense bushes or trees

Aquatic vegetation:

Floating: 0. absent 1. some 2. dense,

Submerged: 0. absent 1. some 2. Dense

Filamentous algae: 0. absent 1. some 0 dense

Emergent: 0. absent 1. some 2. dense

Shade: 0. none 1. mixed 2. full 3. overcast

Water Parameters

Temp. (C) time:________ temp________ cond. ________ secchi ________ pH ________

Figure 4. Form used to collect habitat data during electrofishing surveys.

Species	origin	Floodplain, years	River, Years	Slough, Years
Pacific lamprey, *Lampetra tridentata*	N	5	5	5
American shad, *Alosa sapidissima*	A	2	5	
Threadfin shad, *Dorosoma petenense*	A	4	5	5
Hitch, *Lavinia exilicauda*	N	4	4	3
Sacramento blackfish, *Orthodon microlepidotus*	N	5	5	5
Sac. splittail, *Pogonichthys macrolepidotus*	N	5	5	5
Sac. Pikeminnow, *Ptychocheilus grandis*	N	5	5	5
Golden shiner, *Notemigonus chrysoleucas*	A	5	5	5
Fathead minnow, *Pimephales promelas*	A	1	0	0
Goldfish, *Carassius auratus*	A	3	3	3
Common carp, *Cyprinus carpio*	A	5	5	5
Sacramento sucker, *Catostomus occidentalis*	N	5	5	5
Brown bullhead, *Ameieurus nebulosus*	A	0	0	1
Black bullhead, *A. melas*	A	3	5	5
White catfish, *A. catus*	A	1	5	5
Channel catfish, *Ictalurus punctatus*	A	0	5	5
Chinook salmon, *Oncorhynchus tshawytscha*	N	5	5	4
Rainbow trout, *O. mykiss*	N	1	3	0
Wakasagi , *Hypomesus nipponensis*	A	1	0	0
Inland silverside, *Menidia beryllina*	A	5	5	5
Western mosquitofish, *Gambusia affinis*	A	5	5	5
Prickly sculpin, *Cottus asper*	N	5	5	5
Tule perch, *Hysterocarpus traski*	N	0	2	0
Bluegill, *Lepomis macrochirus*	A	5	5	5
Redear sunfish, *L. microlophus*	A	4	5	5
Green sunfish, *L. cyanellus*	A	0	2	0
Warmouth, *L. gulosus*	A	0	0	2
Black crappie, *Pomoxis nigromaculatus*	A	5	5	5
White crappie, *P. annularis*	A	2	0	3
Largemouth bass, *Micropterus salmoides*	A	5	5	5
Redeye bass, *M. coosae*	A	0	5	0
Spotted bass, *M. punctulatus*	A	0	5	5
Bigscale logperch, *Percia macrolepidotus*	A	5	5	5

Table 3. Fishes collected in the Cosumnes River floodplain, river, and sloughs, 1998-2002. N= native, A= Alien. Numbers are the number of years in which each species was collected in each ha itat.

Species	origin	type	Months as larvae	Months as YOY	Months as adults or yearlings	Abundance	Summer habitat (adults)
Pacific lamprey *Lampetra tridentata*	N	Inadvertent	None	None	Feb-March	Uncommon	O/E
Hitch, *Lavinia exilicauda*	N*	Floodplain Spawner ?	April-May?	April-June	April-May	Uncommon	S/R
Sacramento blackfish *Orthodon microlepidotus*	N*	Floodplain spawner	April-June	June-July	April-May?	Common	S
Sacramento splittail, *Pogonichthys macrolepidotus*	N	Floodplain spawner	March-April	April-June	January-March	Abundant	E
Sacramento pikeminnow *Ptychocheilus grandis*	N	River spawner	None	April-June	February-June	Common	R
Golden shiner, *Notemigonus chrysoleucas*	A*	Forager	March-June	April-June	All	Common	S/P
Goldfish *Carassius auratus*	A*	Floodplain spawner	April-May?	None	April-June	Common	S/P
Common carp, *Cyprinus carpio*	A*	Floodplain spawner	March-May	May-July	All	Abundant	S/P/R/E
Sacramento sucker *Catostomus occidentalis*	N	River spawner	April- May	April-June	March-May	Common	R/S/E
Chinook salmon *Oncorhynchus tshawytscha*	N	River spawner	None	Feb-April	None	Common	O/E
Inland silverside *Menidia beryllina*	A*	Pond fish	April-July	May-July	All	Abundant	P/S/E
Western mosquitofish *Gambusia affinis*	A*	Pond fish	None	April-July	All	abundant	P/S
Prickly sculpin, *Cottus asper*	N	River spawner	Feb.-May	March-June	Feb-April	Uncommon	R/E
Bluegill, *Lepomis macrochirus*	A*	Forager	April-July	May-July	All	Common	S/P
Redear sunfish, *Lepomis microlophus*	A*	Forager	April-July	May-July	All	Common	S/P
Black crappie, *Pomoxis nigromaculatus*	A*	Inadvertent	April-July	?	All	Uncommon	S/P
Largemouth bass, *Micropterus salmoides*	A*	Inadvertent	May-July	None	All	Uncommon	S/P
Bigscale logperch, *Percina macrolepidus*	A*	River spawner?	March-May	April-May	All	Uncommon	S/R

Table 4. Fishes of the Cosumnes River floodplain used in the analysis for this paper. Sampling in ponds usually ceased after July because in most years they were dry by that time and if they persisted, species composition remained the same through the summer. The months for larvae, YOY, and adults/yearling are those months they consistently appeared in our samples 1998-2002. N = native, A = alien. * indicates year around residency in floodplain sloughs and ponds. Fishes collected only occasionally were not included in the table. Summer habitat includes: E=estuary; O= ocean; P= ponds; R = river; S= sloughs

Larval fish

The results of this sampling program are summarized in Appendix A.

Young-of-year

Young-of-year (YOY) fish were caught primarily in the seining samples. The data on YOY were treated separately from the entire seining data set in order to better understand the importance of the floodplains for rearing of juveniles. Over the five years of sampling, there was a fairly predictable succession of YOY fishes, although there was also variation in the timing of appearance and disappearance. This succession is obvious when data is lumped together for two-month intervals (Figure 5) but is also clear in the progression of fish in monthly (Figure 6) and weekly data summaries (Figure 7). In February and March, chinook salmon dominated the catches, although splittail appeared in some late March samples (Figures 5, 6, 7). Splittail YOY typically dominated the catches in April and early May, except in 1999 when they were largely absent from the floodplain. Other YOY that usually appeared at this time were common carp and Sacramento sucker. During May, splittail became less abundant (except in 1998, an exceptionally wet year) while suckers and carp increased in abundance, and YOY golden shiners and other alien species started to make their appearance. In June, small numbers of splittail persisted in wet years (1998, 1999) but most left the floodplain before it became disconnected from the river (Figure 7).

Following disconnection, the water warmed up and alien species increasingly dominated the YOY catches (Figures 7, 8). By late June and July, inland silverside and

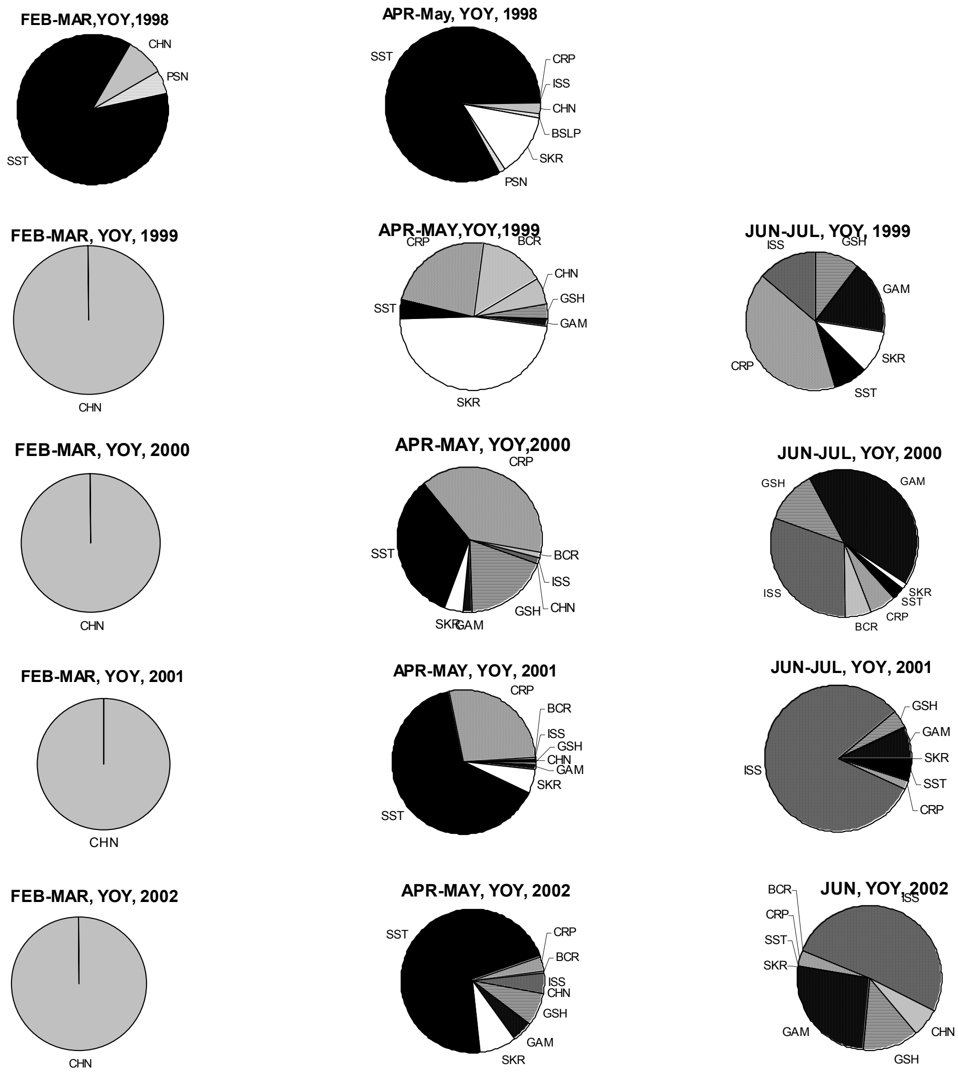


Figure 5. Shifts in the dominant young-of –year fishes on the Consumnes River floodplain in five years of flooding, with weekly seining data lumped into two month periods. 1998 was a wet year with early spawning of splittail in which sampling was terminated at the end of May. For abbreviations see Table 7.

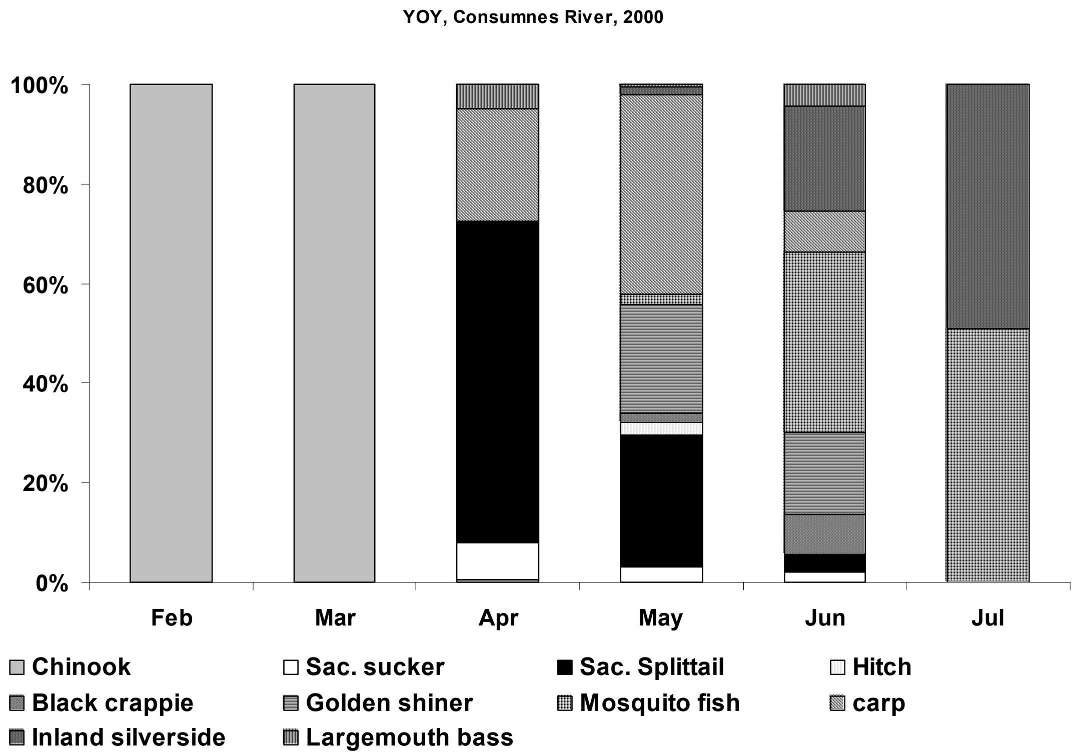


Figure 6. Shifts in the dominant young-of-year fishes on the Consumnes River floodplain in 2000, as shown by lumping weekly seining data by month. patterns were similar in the other four years. The year 2000 was chosen for the figure because it was intermediate in conditions between the wet and dry years.

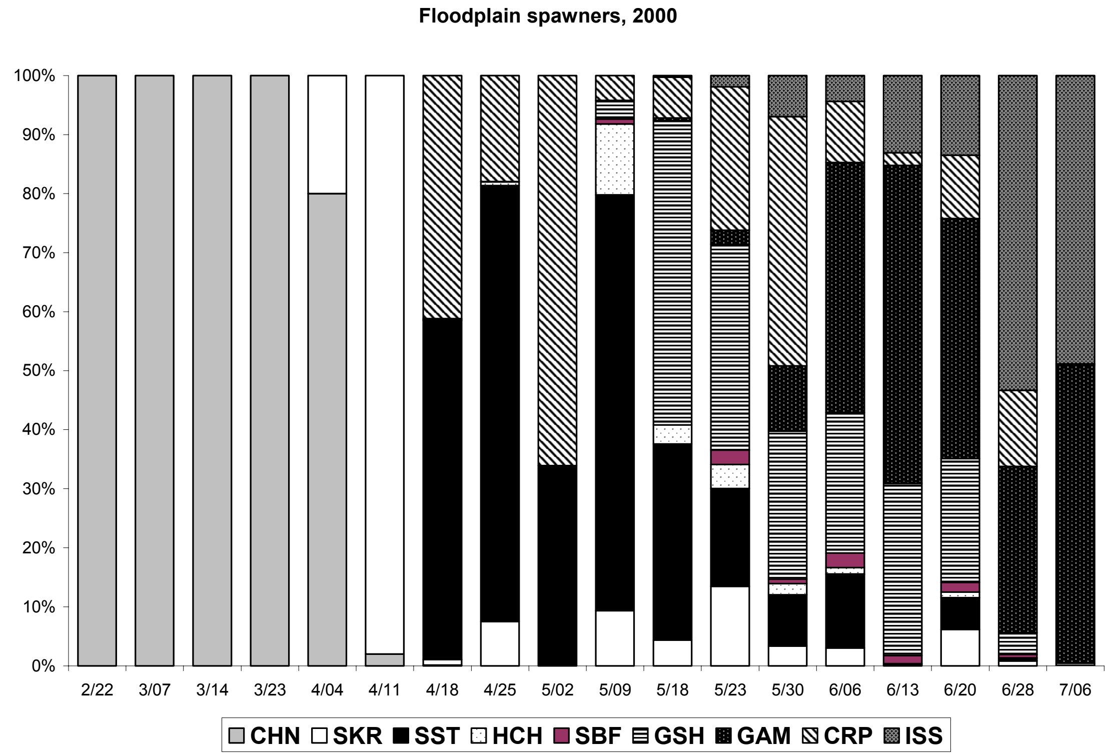


Figure 7. Shifts in the dominant young-of-year fishes on the Consumnes River floodplain in 2000, as shown by weekly seining data. Patterns were similar in the other four years. The year 2000 was chosen for the figure because it was intermediate in conditions between the wet and dry years.

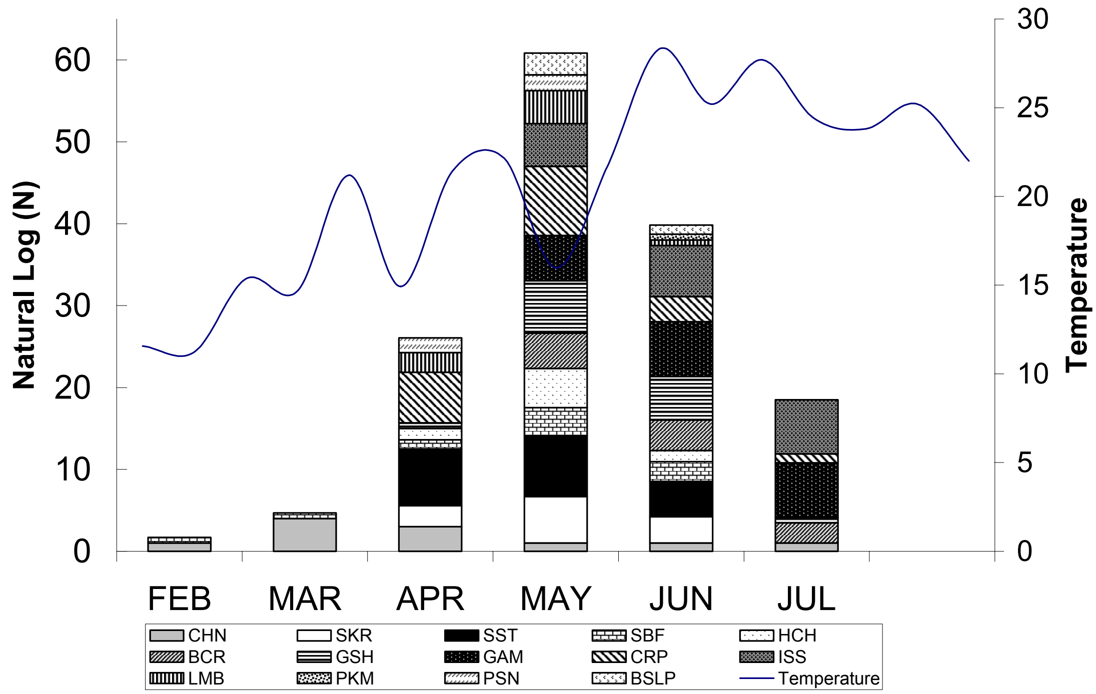


Figure 8. Relationship of mean water temperature and weakly seine catches of young-of-year fishes in Pond 1 for year 2000. The data for Pond 1 is shown because it is closest to the breach sites and is connected to the river only by flood waters. The year 2000 was chosen for the figure because it was intermediate in conditions between the wet and dry years. Temperature is mean hourly temperature.

Western mosquitofish were the most abundant fishes in the isolated floodplain ponds, which were often dry or only a few cm deep by August.

Despite this general pattern, there were differences in the timing and abundances of YOY fishes from year to year. Some species, such as Sacramento blackfish and golden shiner were abundant some years but uncommon in other years. Other species, such as Sacramento pikeminnow, were fairly consistently found from year to year but only in very low numbers. The pattern of occurrence for many fishes reflected the length of time the flood plain was connected to the river. In 1998 and 1999, which were wet years with long periods of connection, juvenile chinook salmon persisted on the floodplain through April but they were largely gone by late March in the other three years. In 1998, splittail juveniles appeared in March (indicating spawning on the floodplain a month earlier) and persisted in large numbers through June. In 1999, juvenile splittail first appeared in May and persisted through June but only in low numbers, despite apparently highly favorable conditions. This pattern of a strong spawning year followed by a weak one was noted in the Yolo Bypass as well (Sommer et al. 2000). During 2000-2002, splittail YOY were found mainly in April and May, although adults appeared on the floodplain as early as February (2002).

The ability of splittail to avoid stranding is illustrated by the events in Pond 1 in 2000. As the pond level dropped prior to disconnecting in early May, we captured large numbers of YOY splittail and common carp (Figure 8). Most these YOY were gone by the following week, apparently leaving through the draining water. For the next three weeks catches were variable, mainly a few YOY splittail plus a few adult or yearling fish of various species. As daytime temperatures rose (from roughly 20°C to 25°C), juveniles of golden shiners, mosquitofish, and inland silversides increasingly made up the catch. By July, almost all the catch consisted of silversides and mosquitofish.

However, stranding by splittail was not always avoided. The large numbers of YOY captured in 2001 reflected the intermittent conditions of flow which resulted in fish being concentrated in the periodically shrinking ponds and more vulnerable to capture and less able to escape to the river. Splittail present in early June in these years were stranded and were gone (presumably dead) by late June.

Another highly variable species was common carp. During 1998, YOY appeared late in the season in only small numbers. In 1999, they also appeared late (May) but were more abundant and persisted in the ponds through July. In the three drier years, YOY carp appeared in April in modest numbers but disappeared from the isolated ponds by mid June. Curiously, carp YOY (and larvae) seemed in disproportionately small numbers compared to the number of large adults observed spawning on the floodplain. Likewise, we did not collect *any* juvenile goldfish on the floodplain, despite capturing large ripe adult females during all years of electrofisher sampling.

YOY captured in Middle Slough in March were primarily chinook salmon and in April and May splittail, suckers, and carp, usually with sharp peaks of abundance (Figure 9), suggesting these were fish leaving the floodplain when water either was flowing across the floodplain or draining pond 2. The lengths of the fish were also coincident with those of larger fish on the floodplain. Juveniles of resident species dominated the catches in later months. In the Cosumnes River, the patterns of YOY succession were similar although catches of YOY of native fishes was more consistent from week to week, reflecting both fish leaving the floodplain through the breaches and coming from

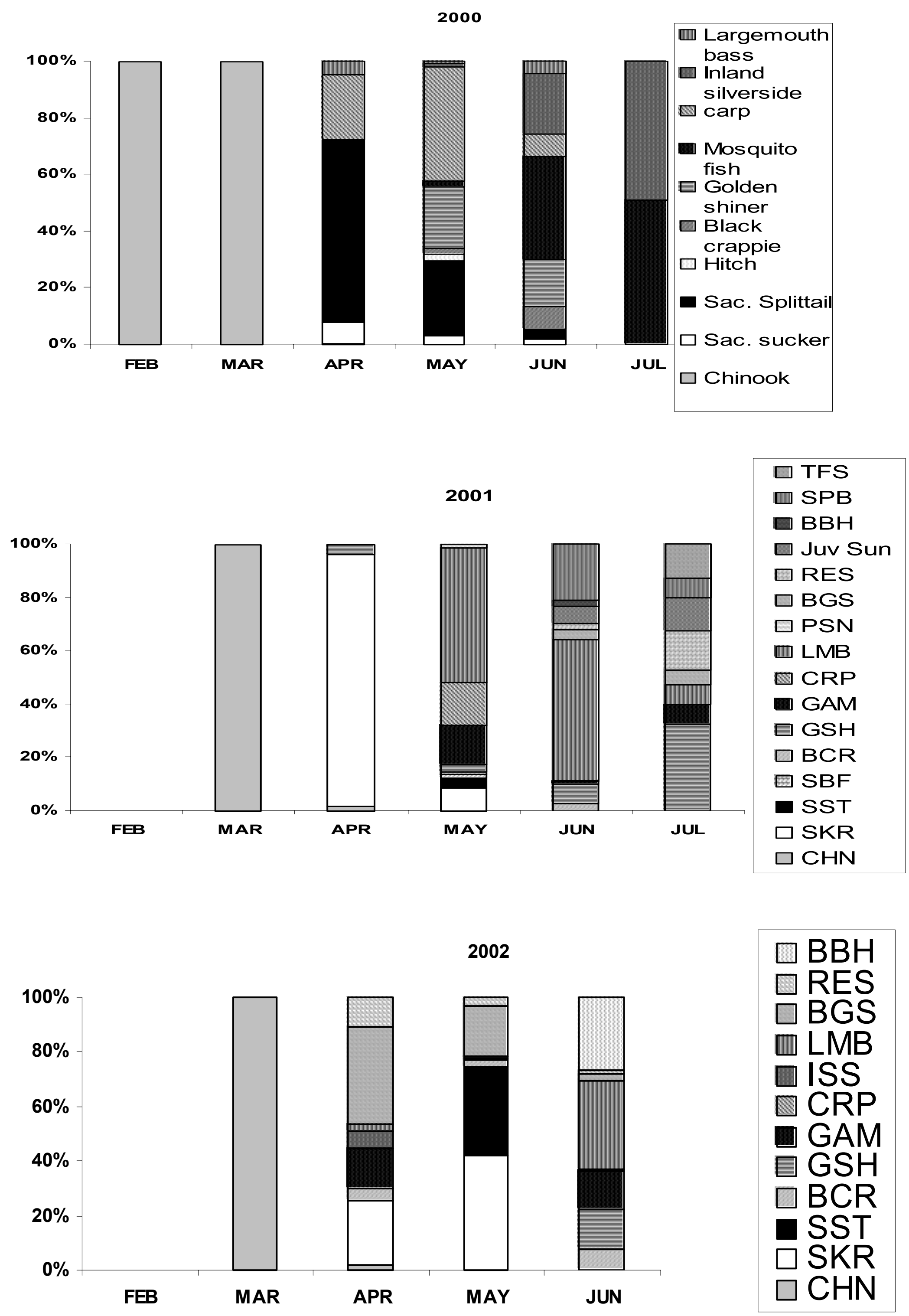


Figure 9. Monthly seine catches of young-of-year fish in Middle Slough in 2000, 2001, and 2002.

upstream areas (Figure 10). Alien fish most common in the river were often species not found on the floodplain or in sloughs (e.g., American shad, threadfin shad, spotted bass). The change in YOY species in the floodplain, river, and slough relative to one another showed how most native fishes left the floodplain, took up temporary residence in the river and slough and then left the region, or got eaten by predators (Figure 11).

Adults and yearlings

With seining and electrofishing combined we captured 29 species of adult and yearling fish on the floodplain although only 17 were abundant enough to be taken on a regular basis (Table 3). The seines mostly caught fish < 10 cm SL, so caught mainly the smaller species (golden shiners, mosquitofish) or yearling fish, especially centrarchids, usually in fairly small numbers. The electrofisher was set up to capture larger fish because we were looking for spawning adults, but by number catches tended to be dominated by fish 8-20 cm SL, mainly golden shiners and centrarchids (Figure 13). Despite these differences in catch, the basic pattern observed every year with both kinds of gear was as follows (Figures 12-14): Small numbers of fish appeared on the floodplain in January and February following the first flooding events. They were mostly species resident in ponds (e.g., golden shiners, bluegill, mosquitofish) or fish washed in from the river (prickly sculpin, yearling Sacramento pikeminnow). Recently transformed lampreys moving down stream were caught with the early high flows both in our regular samples and in fyke nets set in floodplain channels (unpublished data). In late February and March, ripe adult splittail, common carp, and goldfish moved into flooded areas and were usually present through April. Adult suckers also moved in at this time, apparently

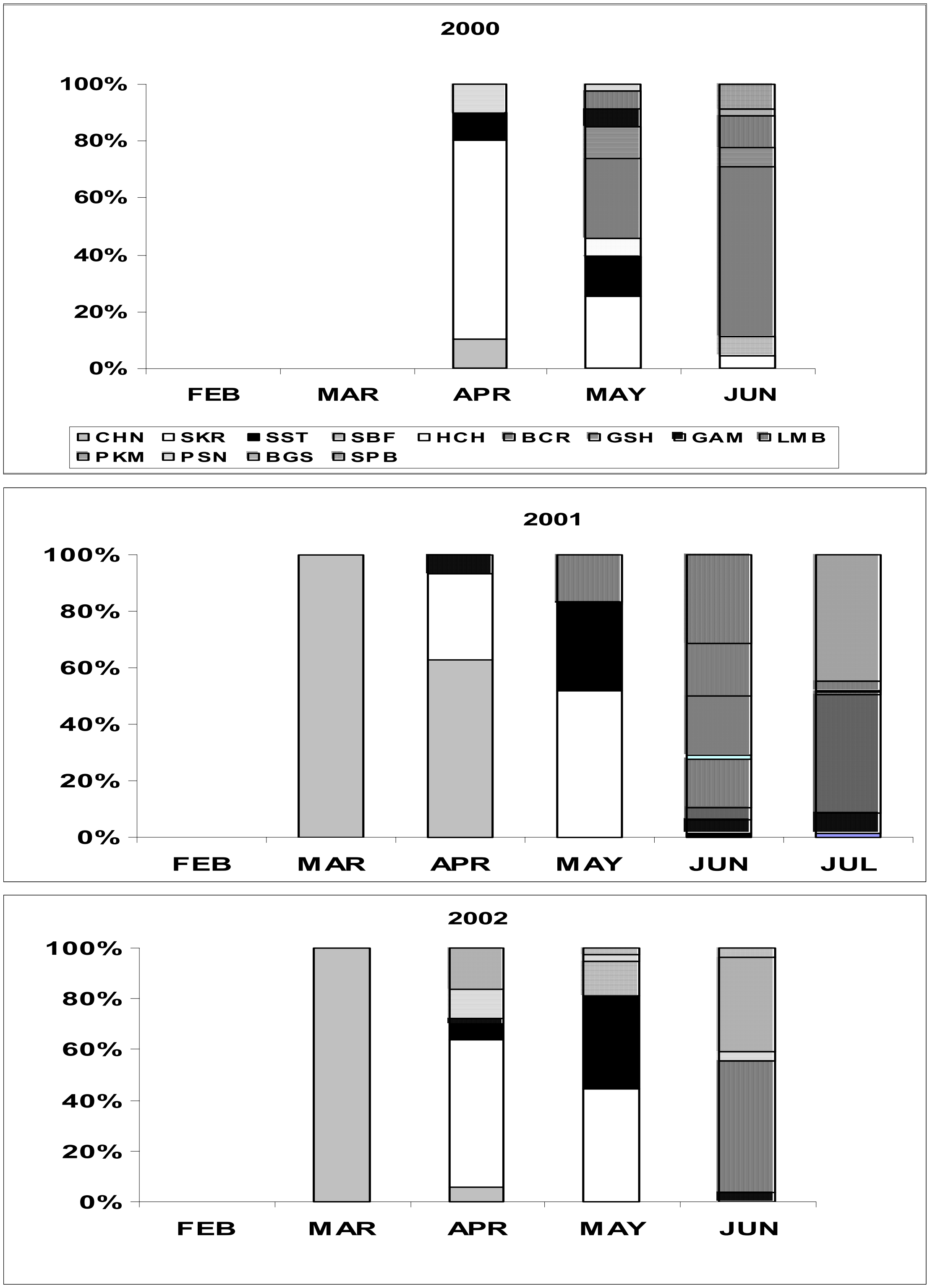
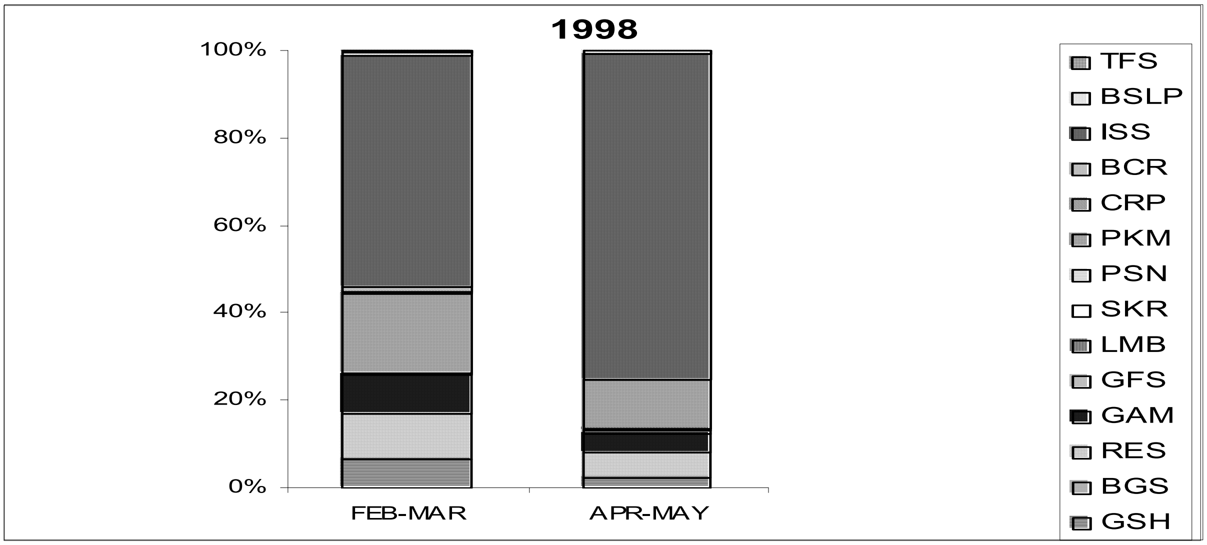


Figure 10. Monthly seine catches of young-of-year fish in the Consumnes River below the floodplain area, 2000, 2001, and 2002.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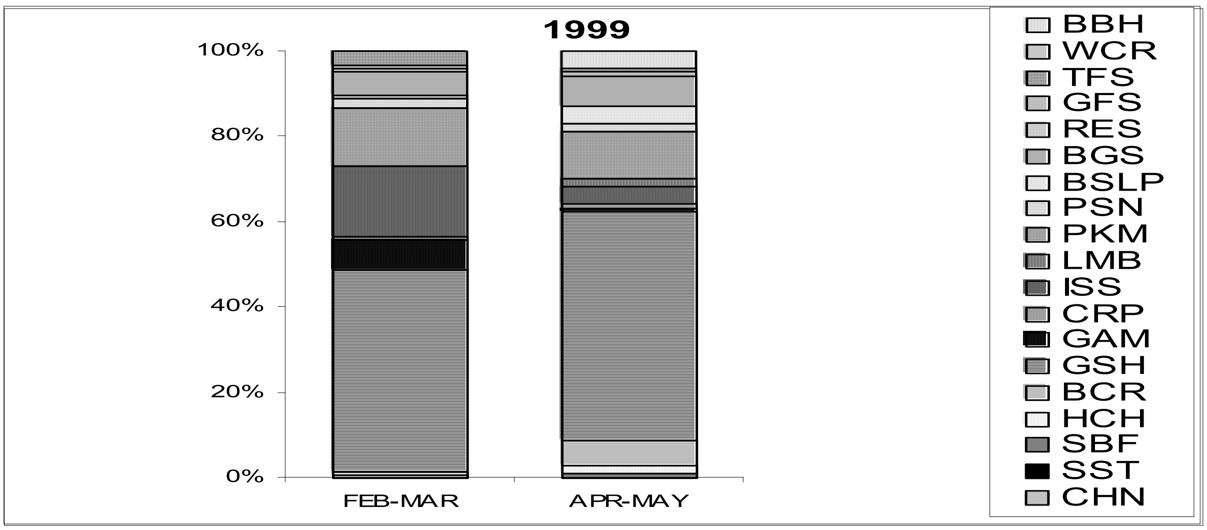
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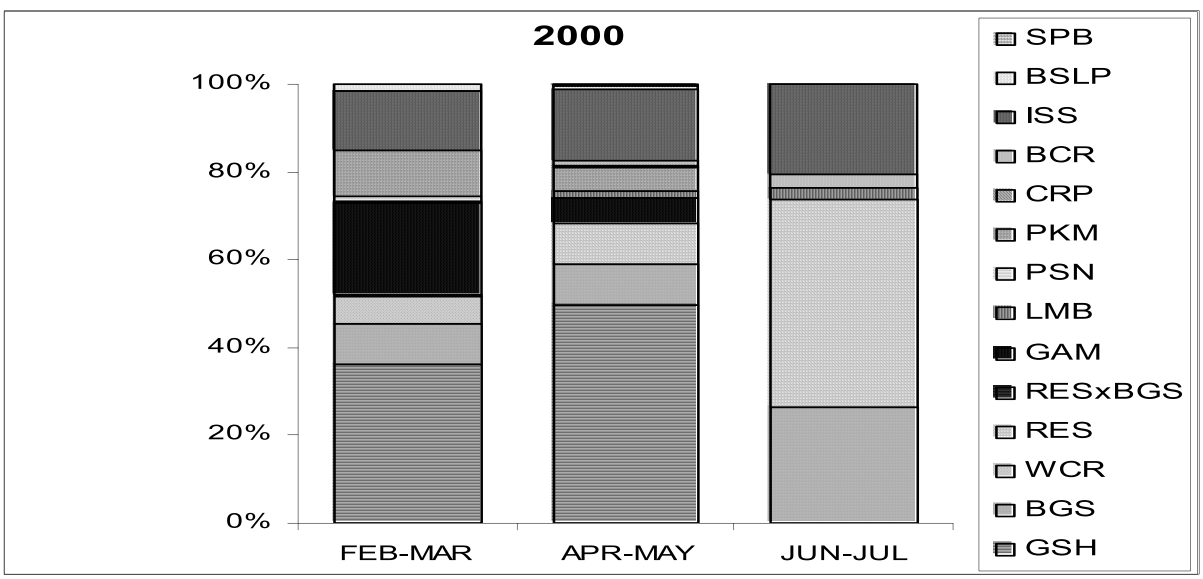
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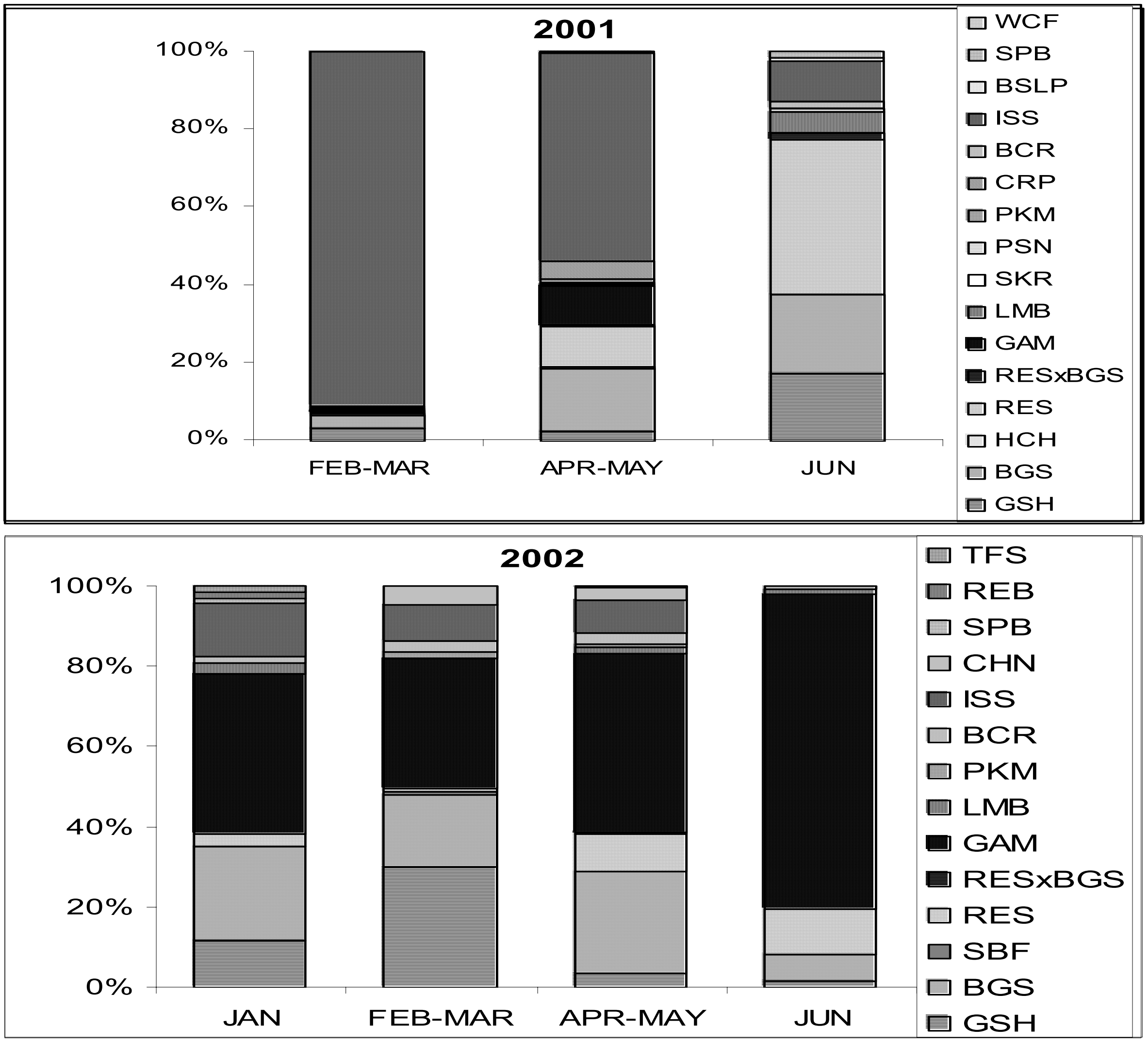
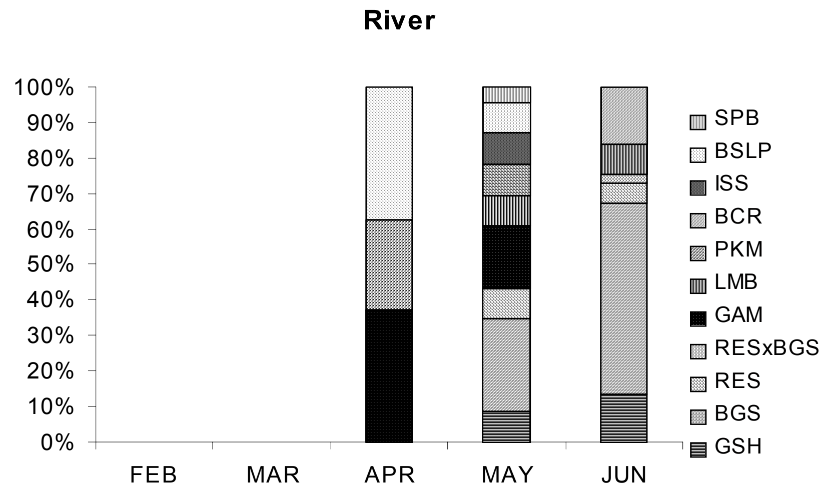
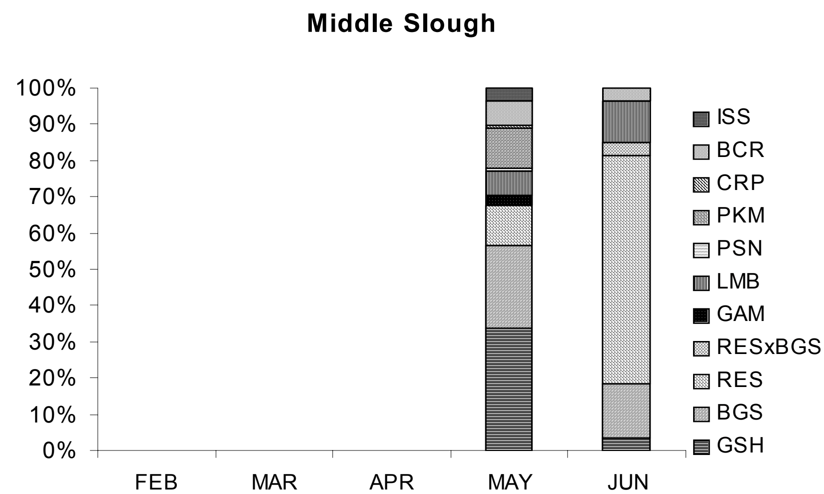


Figure 11. Bimonthly seine catches of adult and yearling fish on the Consumnes River floodplain, 1998-2002.





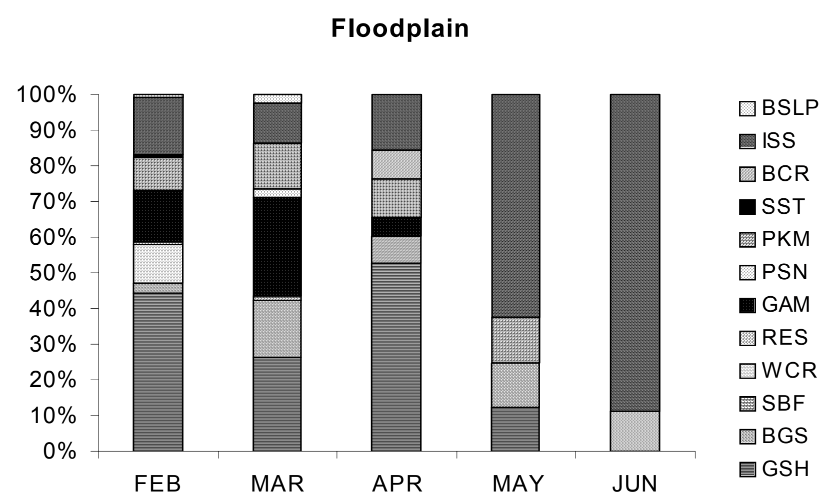


Figure 12. Monthly seine catches of adult and yearling fish on the Cosumnes River, Middle Slough and floodplain, 2000.

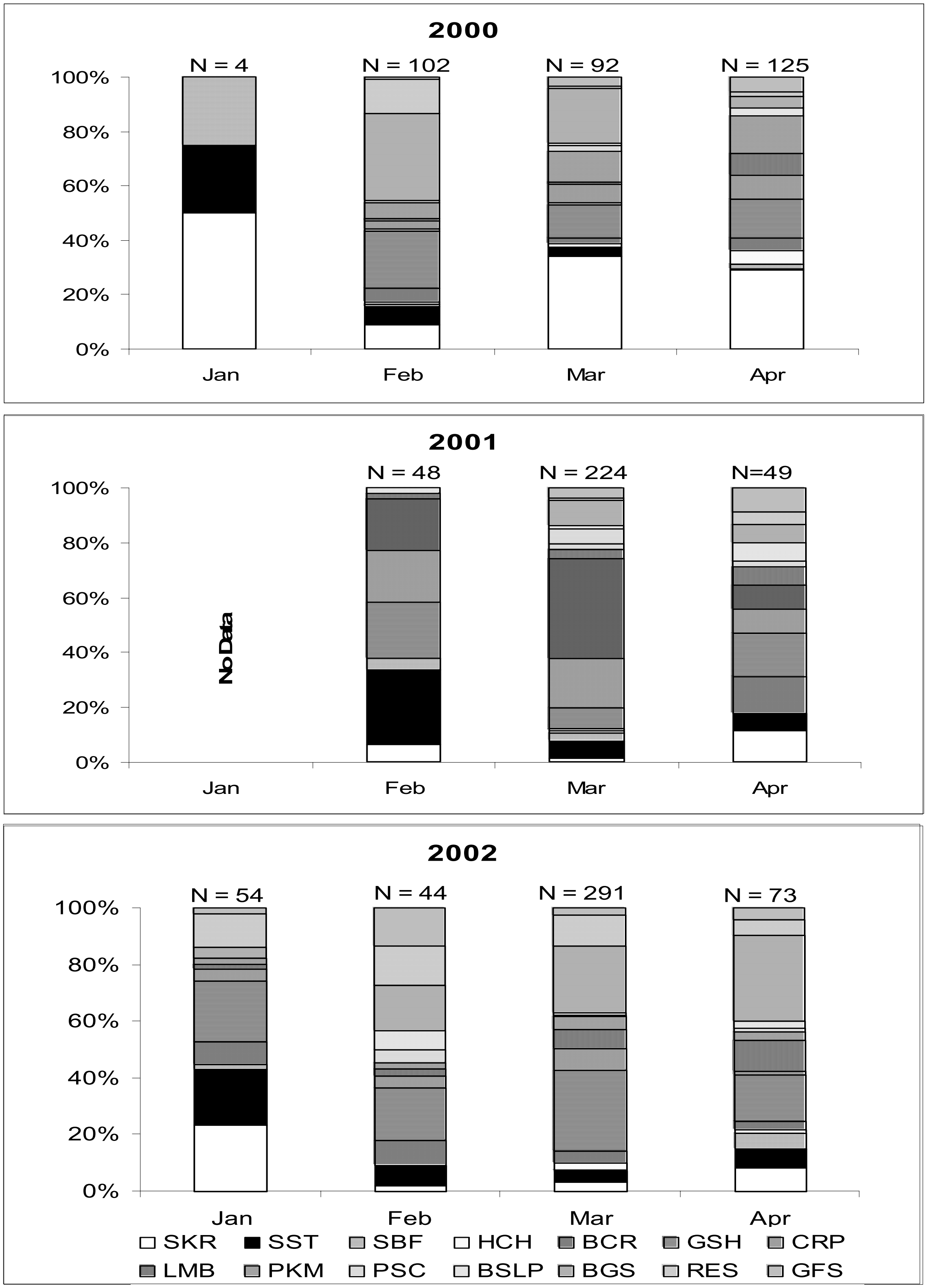
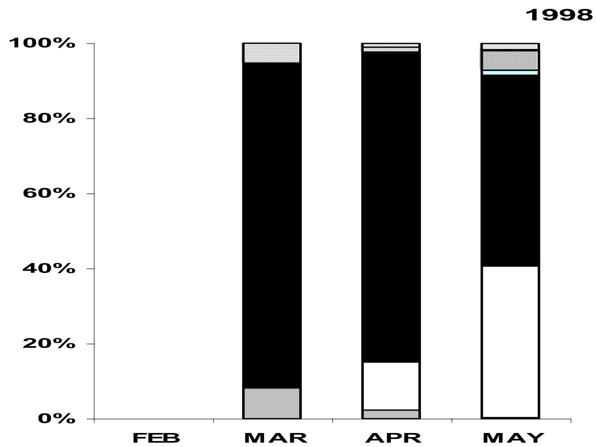


Figure 13. Monthly catches of adult and yearling fish by electrofishing, 2000, 2001, 2002.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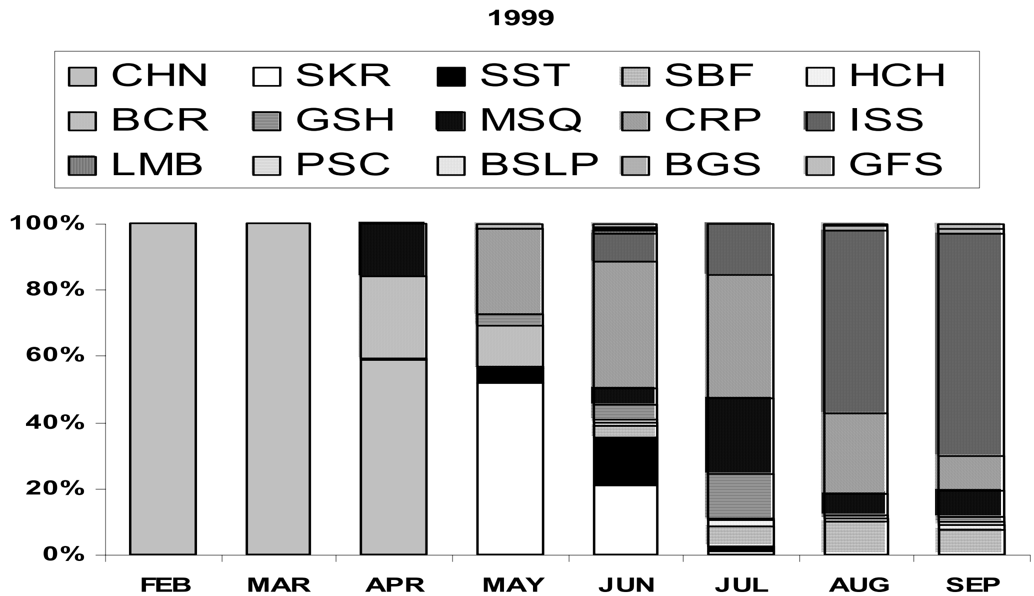
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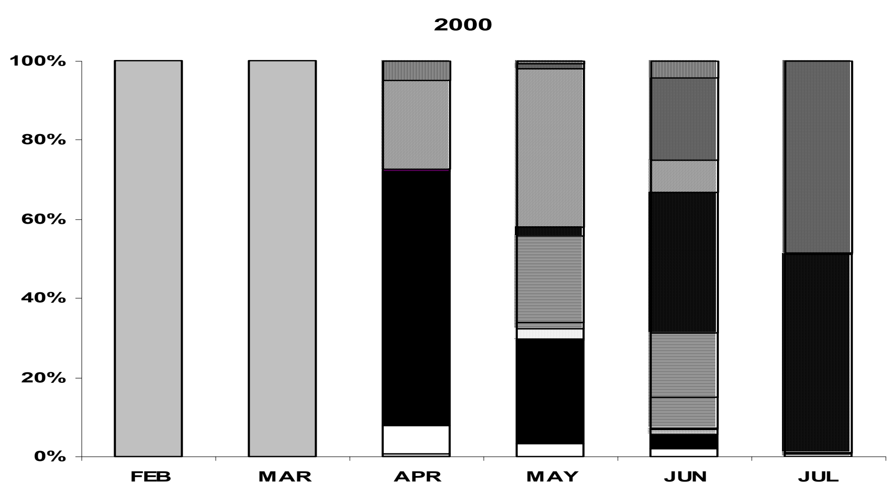
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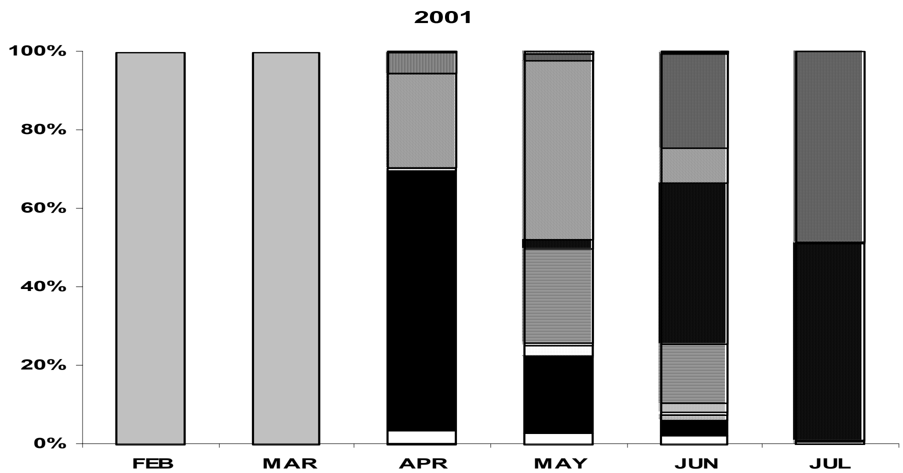

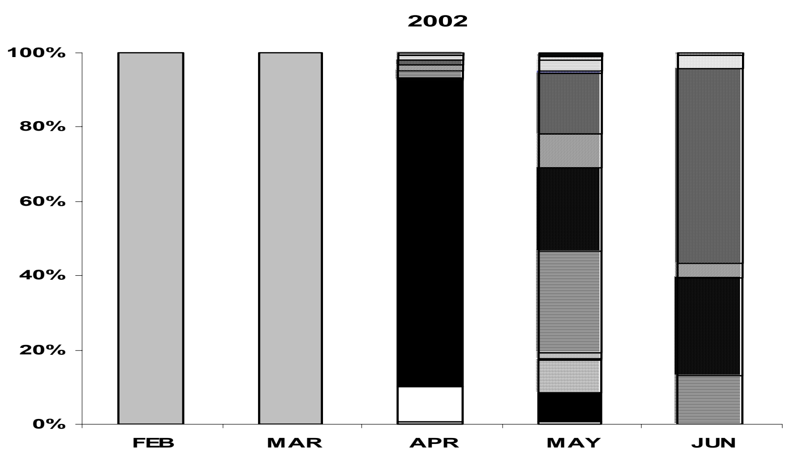

Figure 14. Monthly seine catches of young-of-year native and alien fishes, Consumnes River floodplain 1998-2002.

in process of moving upstream to spawn. Carp and goldfish frequently became stranded with falling water, but adult splittail usually moved off the floodplain before they became trapped.

In April and May, numbers and diversity of yearling and adult fishes steadily increased as more fish moved from the rivers or out from the ponds. Thus adult suckers, mostly fish spent from spawning, came in from the river, as did immature pikeminnows (8-12 cm SL), and, in some years, mature blackfish and hitch. Fairly large numbers of golden shiners and various sizes of centrarchids moved out from the ponds and sloughs to forage and perhaps spawn if water temperatures exceeded 20°C for an extended period of time.

In June and July, the floodplain dried up and shallow ponds became disconnected from the river. While a diversity of fishes were present in these ponds initially, most of the larger fish disappeared as the water became progressively warmer, shallower, and more turbid. Some of this was due to predation: large flocks of white pelicans were observed feeding in the ponds in some years, and carcasses of carp eaten by otters were common. Usually by July, the ponds were dominated by inland silversides, which can reproduce rapidly in such conditions (Moyle 2002).

In 1998 and 1999, flooding occurred far beyond our usual study area and an effort was made to sample widely, wherever seining was possible. Catches from these efforts were typically low but included various pond fishes (mainly golden shiners and centrarchids), juvenile salmon, and yearling pikeminnow (data not presented).

There were no clear patterns of habitat selection on the floodplain, although the data has not yet been fully analyzed. Yearly and adult fishes tended to be associated with emergent terrestrial vegetation in or near the deeper parts of the floodplain (Table 5).

Species (N)	Habitat	Substrate	Terrestrial vegetation	Aquatic vegetation	Temperature	Secchi (cm)	Depth (cm)
Sacramento blackfish (6)	SL, R	OM, MM	WD, RTS	SUB, FLT	20.5 (12.6 -24.6)	52 (16 - 73)	116 (60 - 160)
Hitch (5)	PD,FLP	OM*, MM	RIP, TRR	FLT*, EMR	19.0 (12.1 - 26)	57 (16 - 93)	96 (48 - 150)
Sacramento sucker (51)	FLP*, PD	OM*, MM	TRR*, RIP	EMR, FLT	16.9 (10.5 - 33)	49 (13 - 108)	96 (40 - 200)
Sacramento pikeminnow (18)	FLP*, SL	OM*, MM	TRR*, RIP	EMR, FLT	16.1 (10.1 - 33)	44 (17 - 95)	81 (43 - 150)
Sacramento splittail (8)	FLP*, PD	OM*	TRR*, RIP	EMR*	13.0 (10.1 - 20.9)	29 (13 - 75)	105 (50 - 178)
Common carp (10)	FLP, SL	OM, MM	TRR, RIP, WD	FLT, SUB	19.1 (10.1 - 33)	51 (16 - 95)	89 (45 - 150)
Golden shiner (31)	FLP, SL	OM*	TRR*, RIP	EMR, FLT	15.9 (9.9 - 33)	41 (13 - 95)	40 (43 - 190)
Bluegill sunfish (13)	SL, FLP	OM, MM	TRR*	EMR*, FLT	16.2 (10.1 - 33)	35 (16 - 85)	85 (45 - 180)
Redear sunfish (12)	SL*, R	OM, MM	RIP, WD	EMR, SUB	19.4 (10.5 - 27.2)	47 (16 - 85)	97 (45 - 150)
Black crappie (6)	SL*, PD	OM, MM	TRR, RIP, WD	EMR, FLT	18.8 (10.1 - 33)	53 (16 - 93)	103 (47 - 160)
Largemouth bass (3)	PD, R	OM, MM	RIP, WD, TRR	FLT, EMR	20.2 (10.6 - 33)	58 (19 - 108)	94 (49 - 150)

* Dominant variable based an average of a 0-2 rating with 0 = none, 1 = some, 2 = dense.

Habitat Types: FLP = flood plain, SL = slough, R = river, PD = permanent pond.

Substrate Types: OM = organic mud, MM = mineral mud/clay.

Terrestrial vegetation types: TRR = terrestrial (annual), RIP = riparian, WD = woody debris, RTS = Roots.

Aquatic vegetation types: EMR = emergent, SUB = submerged, FLT = floating

(XX - XXX) = minimum and maximum of values.

Table 5. Environmental variables associated with catches of fishes from by electrofishing on the Cosumnes River flood plain and associated habitats, January to July, 2000 (n = 125 sites).

Discussion

General patterns

There was a fairly consistent pattern of floodplain use by fish over the five-year period, although the basic pattern was modified on an annual basis by the extent of flooding. The first fish to appear on the floodplain were a few adult fish from ponds (e.g. golden shiner), some transient species (e.g., Pacific lamprey) and juvenile chinook salmon. The next fish to appear were adult floodplain spawners, principally splittail and carp, which spawned on flooded annual vegetation, although small numbers of species resident in ponds and neighboring sloughs were continuously present. The juveniles of the splittail and carp quickly became large enough to dominate floodplain fish samples, along with juveniles of suckers and pikeminnows coming in from the river. The adult spawners left the floodplain as inflow decreased and the water became clearer and warmer. The juveniles persisted on the floodplain as long as occasional new pulses of flood water kept water levels up and temperatures down, but most juveniles of native fishes left the floodplain either with the pulses or with declining inflows. Most were gone by mid-May but some persisted through June if conditions favored their presence. Usually, the floodplain became disconnected from the river by mid-May. In two large shallow ponds of residual water, mosquitofish, inland silverside, and juvenile centrarchids tended to dominate catches by June. The first two species can reproduce and reach maturity quickly, so can build up large populations in a short period of time. The centrarchids were mainly bluegill, redear sunfish, black crappie, and largemouth bass, which were abundant in adjacent sloughs and presumably colonized floodplain ponds through a combination of individuals moving in through ditches or resulting from spawning by stranded fish. In many years, the ponds dried up by August. If the ponds persisted, usually mainly mosquitofish and silversides persisted in them. Essentially, native fishes plus carp dominated the floodplain fish fauna early in the season while alien fishes dominated (almost completely) late in the season (Figure 14). Native fishes that are abundant each year are those that can use the floodplain for rearing of juveniles, which leave before the river disconnects from the floodplain. Most alien fishes have resident populations in permanent waters associated with the floodplain (sloughs, ditches, ponds) and are not dependent on the floodplain for persistence.

Floodplains vs. rivers and sloughs

In general, alien fishes found on the floodplains were the same species that were resident in the permanent tidal sloughs all year around, although inland silverside and mosquitofish reached much higher abundances in residual ponds than they were in the sloughs, presumably because of the absence of piscine predators and competitors. We assume that most other fishes, native or non-native, died as the result of unfavorable environmental conditions. Native fishes appeared in our slough samples mainly when juveniles were leaving the floodplain. This same pattern was true for fishes in the river below the floodplain, although there were some additional riverine species present that were rarely found on the floodplain. A few adult native blackfish, hitch, and Sacramento suckers were present in the sloughs and river but they were uncommon.

Stranding

Remarkably few native fishes became stranded on the floodplain when it became disconnected, although in most years we captured a few stranded individuals, especially splittail and chinook salmon. Both adults and juveniles of all native species seemed to have the capacity to find their way off the floodplain before it disconnected, although in 2001 the rapid and early disconnection did seem to strand large numbers of splittail. Also in 2001, we noted large numbers of splittail trapped behind a dirt diversion dam that was present in Middle Slough; this dam maintained the slough at high water levels through the use of a flapper valve to capture tidal inflow. The fish in the slough presumably came from Pond 2, which has an artificial drainage ditch connecting it to the slough. When the dam was constructed, water backed up into the pond, allowing access of fish to the slough. When the slough was allowed to drain on June 4, to release the splittail, we observed most individuals were small (30-40 mm SL) suggesting that growth conditions in the slough were relatively poor.

Alien fishes were more often stranded on the floodplain, especially after large flood events that spread water widely. Large carp frequently became trapped in floodplain ponds, albeit in small numbers compared to the numbers on the floodplain itself. Most were quickly captured by otters and other predators, as indicated by half-eaten carcasses along the shoreline. Likewise, the numbers of adults and yearlings of centrarchids and other fishes that were stranded were small compared to the numbers present in the sloughs. In our electrofishing, most large resident fish on the floodplain were captured fairly close to permanent water, suggesting that they rarely wander far onto the floodplain. However, during years in which flood waters spread widely (1998, 1999), we found small numbers of both slough and river fish scattered throughout the flooded area.

Comparison of sampling methods

The three sampling methods produced different but complementary patterns of floodplain use by fishes. The larval sampling program, not surprisingly, caught mainly pelagic larvae of species that spawned on or near the floodplain. Splittail larvae were caught only in small numbers, presumably because they tended to be deep in the vegetation and were not strongly attracted to light. Prickly sculpin larvae were the most abundant larvae in our samples even though adult sculpins were rare in other samples. We assume that most of the larvae came from the dense population of sculpins inhabiting a rip-rapped bank just upstream from the first breach (unpubl. data), although some spawning may have taken place in debris on the floodplain itself.

Seining was most effective at capturing juvenile fishes >25 mm TL but yearling fishes and a few adults were also captured in small numbers. Seining was the most consistent sampling among years and captured the most fish. The succession of fishes captured by this method was consistent from year to year suggesting it was doing a reasonably good job of sampling the most abundant fishes on the floodplain. The boat electrofishing was most effective at capturing fish over 10 cm TL but small fish were frequently captured as well, especially in shallow water. It proved to be the best way to capture fish in the open waters of the flood plain that were 1-2 m deep, although we frequently sampled water 0.5-1 m deep as well. Large (>30 cm) fish were frequently able to swim out of the electrical field so were under-represented in the sampling.

In 1999 and 2000 fyke nets designed to catch small fish were set experimentally near the breaches and other places with strong currents. They were very effective at catching fish moving in and out of the floodplain but were frequently damaged or washed away by flood waters, did not provide consistent data.

Species accounts

Pacific lamprey appeared as silvery, eyed subadults moving downstream into the estuary. The ammocoetes are common in upstream areas (unpubl. data). They were caught every year in small numbers in January and/or February and presumably were passing through the floodplain as rapidly as possible.

American shad were common in the river upstream and adjacent to the floodplain as spawning adults in March-May. Juveniles rarely appeared on the floodplain but were often abundant in June and July in the lower river.

Threadfin shad are common in the sloughs of the Delta but only occasionally appeared in our samples.

Hitch were collected at all life stages in all habitats but were very uncommon and were not found every year. The reasons for this are not clear, although they apparently prefer to spawn in gravelly riffles of streams (Moyle 2002). They are abundant, however, in the cool, permanent flows of the lower Mokelumne River (J. Merz, EBay MUD, unpublished data).

Sacramento blackfish were only slightly more abundant than hitch, although a number of large adults were found in the Lagunitas sites in (year), where they apparently spawned late in the season.

Sacramento splittail were consistently one of the most abundant fish on the floodplain because they are obligate floodplain spawners (Moyle 2002). Adults migrate into the floodplain area from the Suisun Bay and may be present in the Cosumnes River in January, entering the floodplain in February and March as flows rise. We only captured small numbers (10-30) of adults on the floodplain each year but the earliest fish were typically ripe males. The presence of larvae in March-early May suggests that spawning time varies from year to year and/or that females will spawn multiple times. The juveniles rear on the floodplain but leave either following a late flood pulse or in response to dropping water levels (Figure 15). Juveniles that have left their rearing areas are 25-50 mm SL. It would seem advantageous to these fish to move out on a late flood pulse because they have to migrate downstream to brackish water (Suisun Bay) for rearing and high flows should reduce transit time (Moyle 2002). However, during low-flow years, we observed they will gradually leave the floodplain and some become stranded in the residual pools. Growth rates and condition of juvenile splittail in the floodplain are high (Appendix B) although vary from place to place (e.g., rates are higher in Pond 1 than Pond 2 and in both ponds than in the sloughs). YOY splittail collected in the river had high condition and were large in size, indicating they had reared on the floodplain (Appendix B).

Sacramento pikeminnow are common but declining fish in the lower Cosumnes River, which mostly dries up in late summer (stream report). Yearling pikeminnows (60-100 mm SL) fairly consistently appeared on the floodplain in low numbers, moving in from the river with the flood waters. They were rare late in the season so presumably most left the floodplain before it became disconnected.

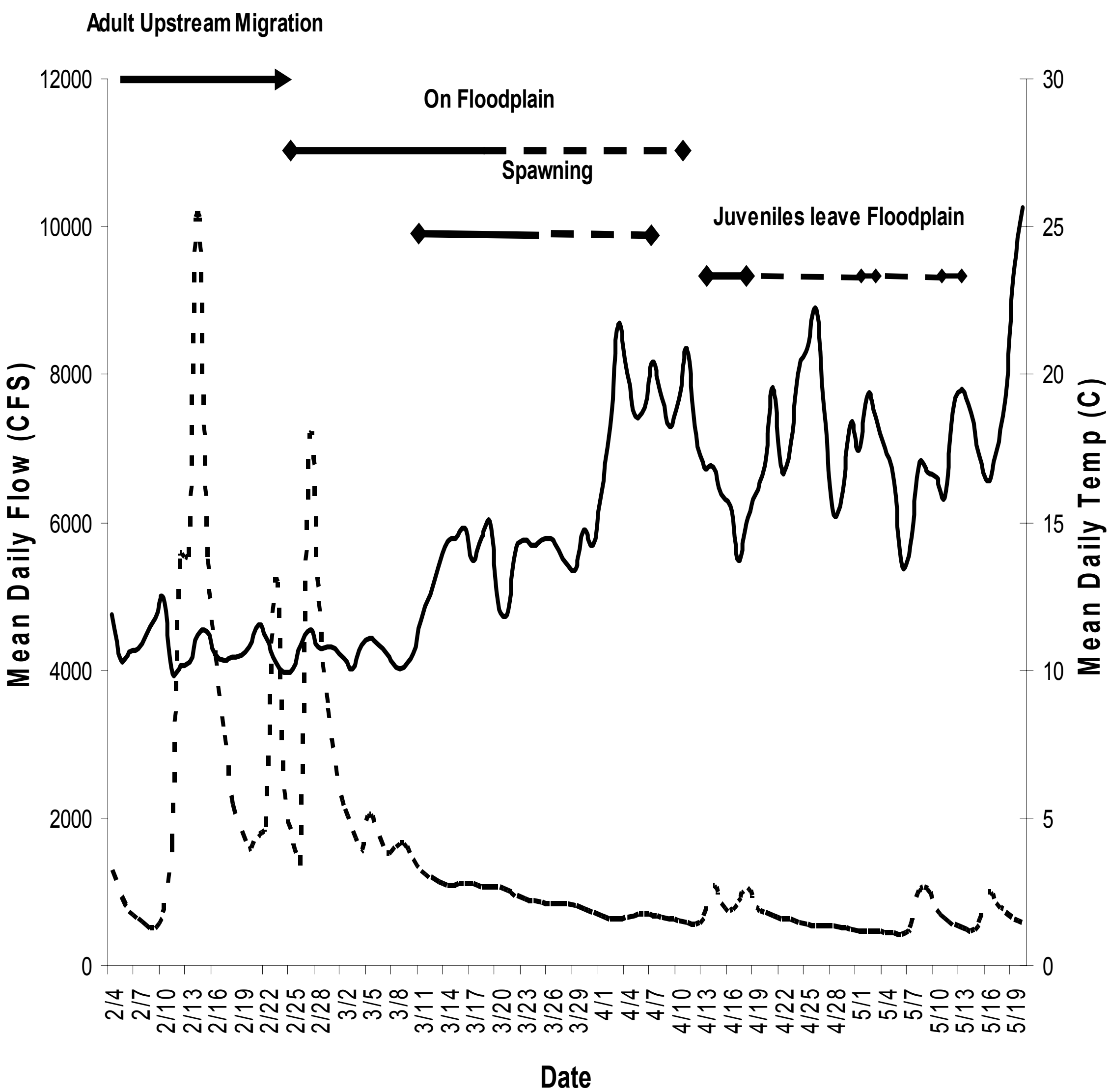

Figure 15. Use of the Consumnes River floodplain by Sacramento splittail in 2000, in relation to flow and temperature.

Golden shiners were one of the most consistent species to appear in our sampling, although they were never particularly abundant. They would often appear in our samples as early as February, as subadults (50-80 mm SL) and would typically be most abundant in late May and June, as YOY, presumably as the result of spawning on the flood plain. They would become stranded in ponds but die out once the water became warm and shallow and inland silverside became dominant. They are common as permanent residents in the sloughs draining the floodplain.

Goldfish appeared in small numbers every year on the floodplain as large (25-35 cm SL) adults, including ripe females and males, typically in April and May. However, we never collected a juvenile in any of the habitats sampled. It is possible that larval goldfish were present in our samples because they are extremely difficult to distinguish from the larvae of common carp, but, if so, they presumably were rare.

Common carp were one of the most conspicuous creatures of the floodplain when they were spawning in April and May. Pods of large individuals could be observed thrashing in the flooded vegetation, their backs often out of the water. Individuals over 50 cm SL were often captured although large fish also avoided capture by swimming rapidly out of the electrical field of our boat. Their larvae were present in the light traps although they were not especially abundant, presumably reflecting their tendency to be deep in the vegetation. The spawning time of carp coincided with that of splittail so the larvae and juveniles were often captured together, although carp were typically much less abundant than splittail. However, juvenile carp showed high growth rates and condition (Appendix B). Juvenile carp were uncommon in the samples from the sloughs and river and they often became stranded in large numbers in floodplain pools. This suggests that relatively few juvenile carp are able to leave the floodplain as water levels drop.

Sacramento suckers moved up the Cosumnes River in February and March in large numbers to spawn (unpublished observations), presumably on gravelly riffles (Moyle 2002). Adults are abundant in the sloughs of the Delta downstream from the study area (unpubl. data). Juvenile suckers entered the floodplain in April and May and were often common in the river and slough sites at the same time. Comparison of growth rates in the river with those on the floodplain suggest that YOY suckers actually fare less well on the floodplain than in the edge waters of the river (Appendix B). Spawned-out adult suckers and a few yearlings were also present on the floodplain during this period but these fish were usually gone before floodplain pools became isolated from the river.

Chinook salmon entered the flood plain as juveniles, sometimes as 'button-up' fry 30 mm SL, just beginning to feed. They appeared in February and March, the progeny of fall-run chinook salmon that spawned on riffles some distance upstream from the study area. Numbers were typically fairly low, reflecting the small size of the salmon run, but growth rates on the floodplain were fairly rapid, suggesting it is advantageous to be there (Figure 16), as has been found for the Yolo Bypass (Sommer et al. 2000). Most of the juveniles seem to leave the floodplain as the water dropped and we captured a number of them in 1999 by backpack electrofishing small channels draining the floodplain into the river. They were also common in the river and slough at this time. They can become stranded in floodplain pools, however, and we captured a number of large (80-90 mm) juveniles in one such pool in May 2001. The juveniles feed primarily on zooplankton on the floodplain and mainly on insects when in the river (unpublished data, (Figure 17).

Inland silversides were ubiquitous in habitats in the study area but mostly in small numbers, although at any time we could also capture a large (100+ fish) shoal of them. Along with mosquitofish, they seemed to be most tolerant of the warm shallow conditions of shrinking ponds of the floodplains and became extremely abundant in June and July, following spawning. If the ponds persisted through the summer, small numbers of silversides would be present the following winter when they refilled, to start the cycle again. Silversides are fractional spawners that are capable of having 2-3 generations in a summer (Moyle 2002).

Western mosquitofish were also ubiquitous on the floodplain, with self-sustaining populations, although they were planted in the region by the local vector control agency for mosquito control. Like silversides, they can build up large populations in a short period of time in shrinking floodplain ponds.

Prickly sculpin were abundant as larvae on the floodplain but rare as adults and juveniles. Adults were abundant, however, in boulder rip-rap along the river just upstream of the first breach. Prickly sculpin larvae are highly pelagic and normally drift downstream to rear in an estuary or backwater. While we saw few newly-settled juvenile sculpin, especially in relation to the number of larvae, it is possible that our sampling techniques were not effective for them, especially if they lived mainly in ditches or areas with lots of debris. Some floodplain spawning apparently also takes place. We have

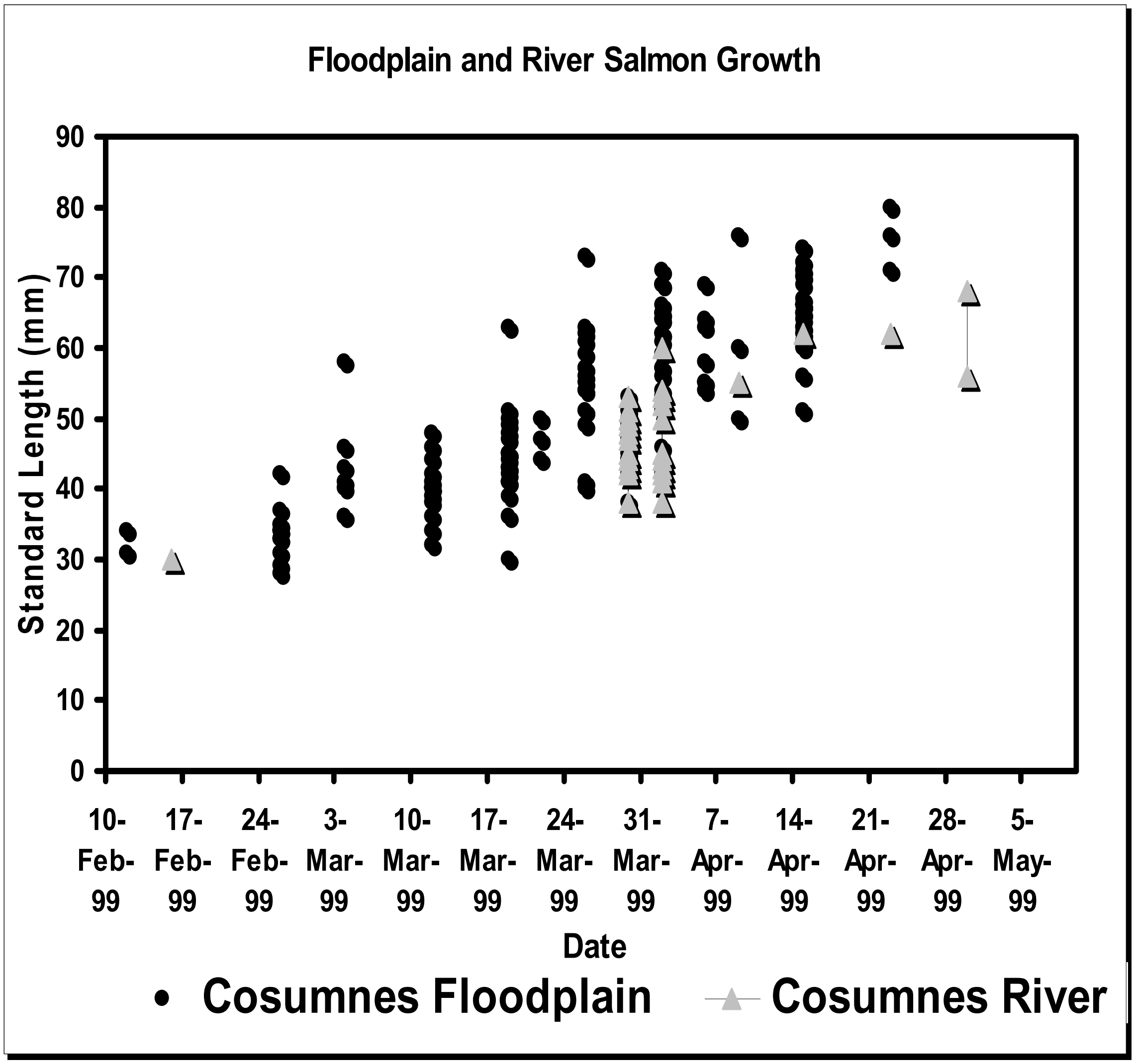

Figure 16. Growth rate of juvenile chinook salmon on the Consumnes River floodplain and in the river in 1999 as indicated by changes in standard length. We assumed that few salmon entered the floodplain after March 17 and the subsequent high variability in size is not the result of recruitment of small fish. The differences in lengths between floodplain and riverine fish are not significant, but sample sizes are small.

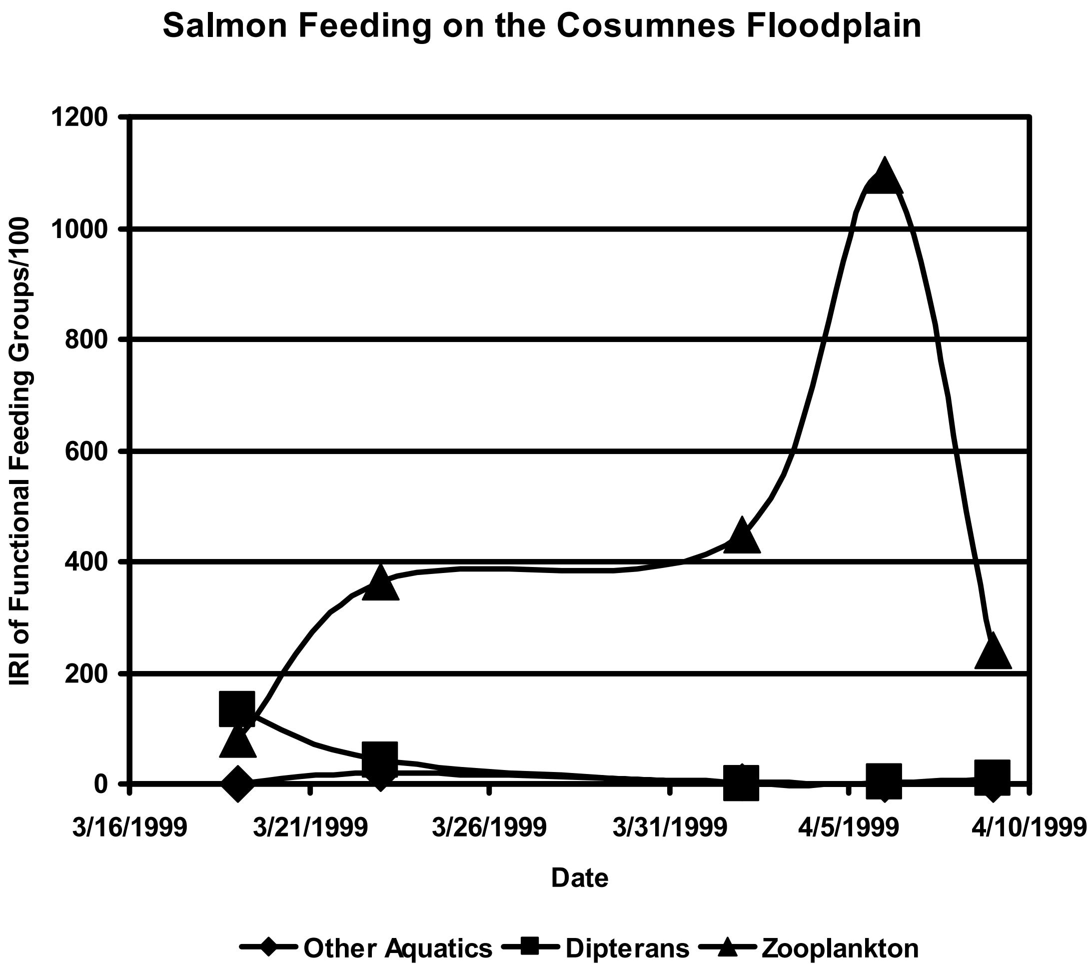

Figure 17. Changes in the diet of juvenile salmon on the Consumnes River floodplain in 1999. The Index of Relative Importance (IRI) is a measure of importance in the diet of key food items, in this case zooplankton and chironomid midge larvae (based on an unpublished study, UCD).

captured adults on the floodplain, including a few moving in with early flood flows (captured in fyke nets). In addition, C. Jeffres (pers. comm. 2003) has observed sculpin egg masses glued to stationary water quality sampling gear on the floodplain.

Largemouth bass were found in small numbers on the floodplain both as adults and juveniles, but were abundant in samples in sloughs and the river. Adults on the floodplain were typically found only a short distance from a source slough or pond, although occasionally one would wander far enough to become stranded. During wet years, capture of YOY bass in floodplain ponds indicated reproduction was taking place.

Bluegill and Redear sunfish are treated together here because their YOY are difficult to distinguish until they are 25-30 mm SL. Both species are abundant in the sloughs and were present on the floodplain in small numbers, although bluegill were generally more common than redear sunfish. Most sunfish identified in ponds after the flood receded were bluegill and in wet years some reproduction took place in these ponds.

Comparison with Mokelumne River

The lower Mokelumne River is intensively sampled for fish by East Bay Municipal Utility District by a variety of methods (Merz 2001a, b, c, 2002, 2003; Setka 2001, 2002; Workman 2001, 2002). The river is highly regulated by Camanche Dam so maintains higher flows in the summer than the Cosumnes but lacks the peak flood flows in winter. The lower river is also contained within levees so lacks a floodplain. The relatively cold constant flows maintain a diverse population of fishes, including native fishes (Table 6). The fish fauna does show changes in the six designated reaches of the

Table 6. Common name, scientific name, origin, and presence in each river reach of the lower Mokelumne River, California
River sampled seasonally by electrofishing boat, seine, and rotary screwtrap (1996 - 2002). Data from J. Merz, EbayMUD
Status refers to reaches I and II, the area most comparable to the lower Cosumnes River. R = rare, <5 individuals taken of 6 yr period
U=uncommon, usually found every year but in low numbers; C = common, present every year, often locally or seasonally abundant; A = abundant, present in large numbers most of the year or seasonally.

				Presence/Absence by river reach						
Common Name	**Scientific Name**	**Abbrev-**	**Status**	**I**	**II**	**III**	**IV**	**V**	**VI**	**Camanche**
Petromyzontidae (lampreys)										
Pacific Lamprey	*Lampetra tridentata*	PLAM	C	X	X	X	X	X		
Acipenseridae (sturgeons)										
Unidentified juvenile sturgeon	*Acipenser sp.*	STR	R		X					
Clupeidae (shad and herring)										
American Shad	*Alosa sapidissma*	AMS	C	X	X					
Threadfin Shad	*Dorosoma petenense*	TFS	U	X	X					X
Salmonidae (salmon and trout)										
Chinook Salmon	*Oncorhynchus tshawytscha*	FCS	A	X	X	X	X	X	X	X
Kokanee Salmon	*Oncorhynchus nerka*	KS	R		X	X	X	X	X	X
Chum Salmon	*Oncorhynchus keta*	CHS	R		X				X	
Steelhead Trout	*Oncorhynchus mykiss*	STH	C		X	X	X	X	X	X
Osmeridae (smelts)										
Delta Smelt	*Hypomesus transpacificus*	DS	R	X						
Wakasagi	*Hypomesus nipponensis*	WS	R		X					
Cyprinidae (minnows)										
Common Carp	*Cyprinus carpio*	CARP	C	X	X	X	X	X	X	X
Goldfish	*Crassius auratus*	GF	U	X	X	X	X	X	X	X
Golden Shiner	*Notemigonus crysoleucas*	GS	C	X	X	X	X	X	X	X
Hardhead	*Mylopharodon conocephalus*	HH	R	X	X		X			
Sacramento Hitch	*Lavinia exilicauda*	HTC	C	X	X	X	X	X	X	X
Sacramento Pikeminnow	*Ptychocheilus grandis*	SSQ	A	X	X	X	X	X	X	X
Sacramento Blackfish	*Orthodon microlepidotus*	BF	U	X	X	X				X
Sacramento splittail	*Pogonichthys grandis*	SST	U	X	X	X	X	X		
Catostomidae (suckers)										
Sacramento Sucker	*Catostomus occidentalis*	SSKR	A	X	X	X	X	X	X	X
Embiotocidae (surfperch)										
Tule Perch	*Hysterocarpus traski*	TP	C	X	X	X	X	X		
Ictaluridae (catfish)										
Black Bullhead	*Ameiurus melas*	BLBH	U	X	X					X
Brown Bullhead	*Ameiurus nebulosus*	BBH	U	X	X	X			X	X
Channel Catfish	*Ictalurus punctatus*	CCAT	U	X	X				X	X
White Catfish	*Ameirus catus*	WCAT	U	X	X					X
Poeciliidae (livebearers)										
Western Mosquitofish	*Gambusia affinis*	GAM	A	X	X	X	X	X	X	X
Atherinidae (silversides)										
Inland Silverside	*Menidia beryllina*	ISS	C	X	X					
Gasterosteidae (Stickleback)										
Three-spined Stickelback	*Gasterosteus aculeatus*	STBK	R						X	
Moronidae (temperate basses)										
Striped Bass	*Morone saxatilis*	SSB	C	X	X					
Centrarchidae (sunfish)										
Largemouth Bass	*Micropterus salmoides*	LMB	C	X	X	X	X	X	X	X
Smallmouth Bass	*Micropterus dolomieu*	SMB	C	X	X				X	X
Spotted Bass	*Micropterus punctulatus*	SPB	C	X	X	X	X	X	X	X
Redeye Bass	*Micropterus coosae*	REB	C	X	X	X				
Bluegill	*Lepomis macrochirus*	BG	C	X	X	X	X	X	X	X
Redear Sunfish	*Lepomis microlophus*	RES	C	X	X	X	X	X	X	X
Green Sunfish	*Lepomis cyanellus*	GSF	C	X	X	X	X	X	X	X
Warmouth	*Lepomis gulosus*	WAR	U	X	X					
White Crappie	*Poxmis annularis*	WCP	R		X					
Black Crappie	*Poxmis nigromaculatus*	BCP	C	X	X	X		X	X	X
Hybrid Micropterus	*Micropterus x.*		U	X	X	X			X	X
Hybrid Lepomis	*Lepomis x.*	LAPX	U	X	X	X	X	X	X	X
Percidae (perch)										
Bigscale Logperch	*Percina macrolepida*	BSLP	C	X	X					
Gobiidae (Goby)										
Yellowfin Goby	*Acanthogobius flavimanus*	YFG	U	X	X					
Cottidae (sculpin)										
Prickly Sculpin	*Cottus asper*	PSCLP	A	X	X	X	X	X	X	X

*To date: 15 Native and 27 Non-native species.

river. Reaches I-II are below Woodbridge Dam, which has a fish ladder but blocks the upstream movement of many fishes of the lower river and Delta. There is also considerable spawning of chinook salmon below the Woodbridge Dam so juvenile salmon are present in the lower system in February-June, although numbers are augmented considerably by releases of fish from the Mokelumne River Hatchery. Large numbers of hatchery fish are attractive to predators, so large striped bass and Sacramento pikeminnow apparently move into the river to feed on them. Reaches II-VI are below Camanche Dam (and the Mokelumne Fish Hatchery) and get progressively colder (summer temperatures) in an upstream direction because of releases from the dam. They are largely managed for salmon production.

The species found in the lower Mokelumne are a mixture of (1) anadromous fishes, (2) alien warm-water fishes, and (3) native cool-water fishes. Anadromous fishes are mainly chinook salmon, steelhead, and Pacific lamprey. All three species probably spawn in the river but chinook salmon and steelhead are maintained by the Mokelumne Hatchery. The alien warmwater fishes are largely the same species found in the Cosumnes. They persist in most of the river by staying in warmer water along the edges, being washed down stream from Camanche Reservoir, or moving up from the Delta. The most abundant fish in the samples are mosquitofish, which are highly vulnerable to seines in shallow water. Most of the rest of the species are present only small numbers, although large striped bass frequently move up the river to prey on small salmon and other migratory fishes. Year around, excluding mosquitofish, the majority of the fish in the river are natives, especially Sacramento sucker, hitch, Sacramento pikeminnow, and prickly sculpin (Figures 18-21). Splittail are notable for their scarcity, although some may spawn upstream of Woodbridge Dam (J. Merz, pers. comm.). The presence of large hitch in some numbers is also in distinct contrast to the Cosumnes River.

It appears that there is enough diversity of habitat and sources of young fish to maintain a high diversity of native and alien fishes in the lower Mokelumne River. The cool, permanent flows, however, allows native fishes to be abundant throughout the year and keeps most alien species in low numbers. The absence of floodplain habitat seems to limit floodplain spawners such as splittail and common carp. The fish fauna seems to be relatively persistent all year around (Figures 18-21). In contrast, the lower Cosumnes is dominated by natives mainly when floodplains are inundated in spring. During the rest of the year, resident warmwater alien fishes dominate the fauna. Thus while the species lists of the two systems are nearly identical, the relative abundances of native and alien species are dramatically different, are as the seasonal patterns of occurrence.

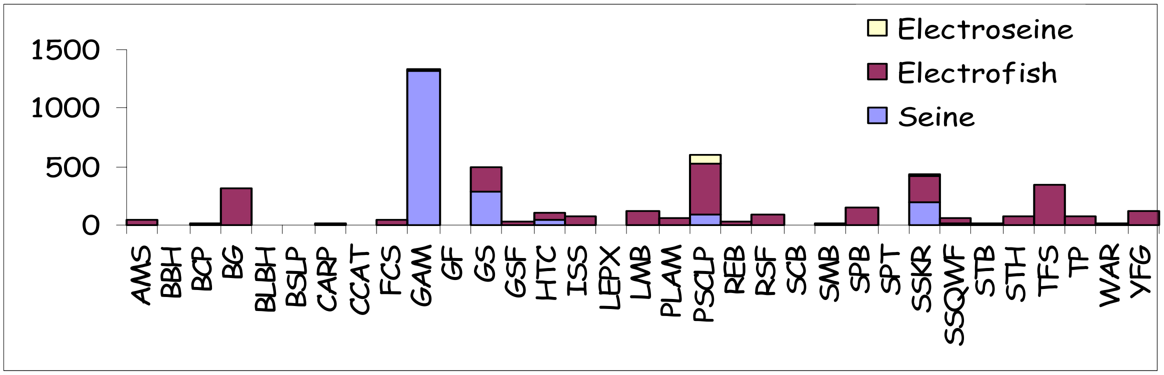

Figure 18. Fall 2002.

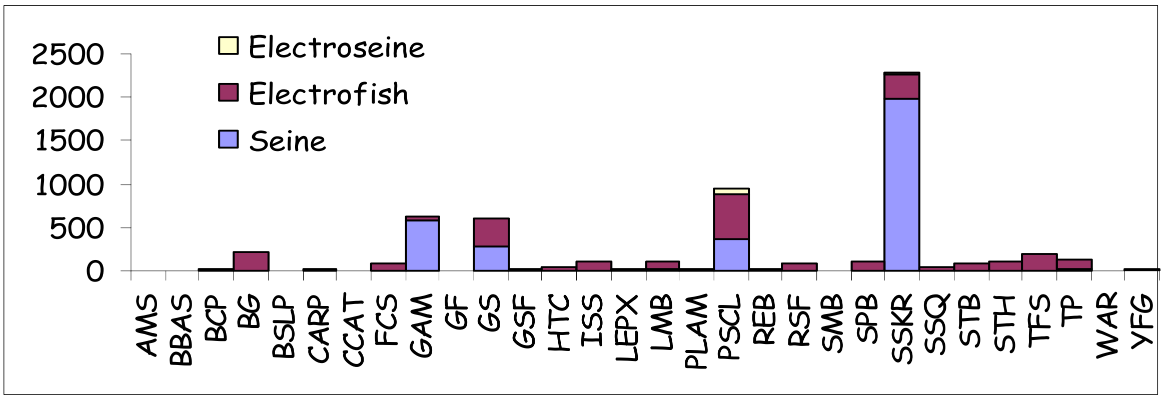

Figure 19. Summer 2002.

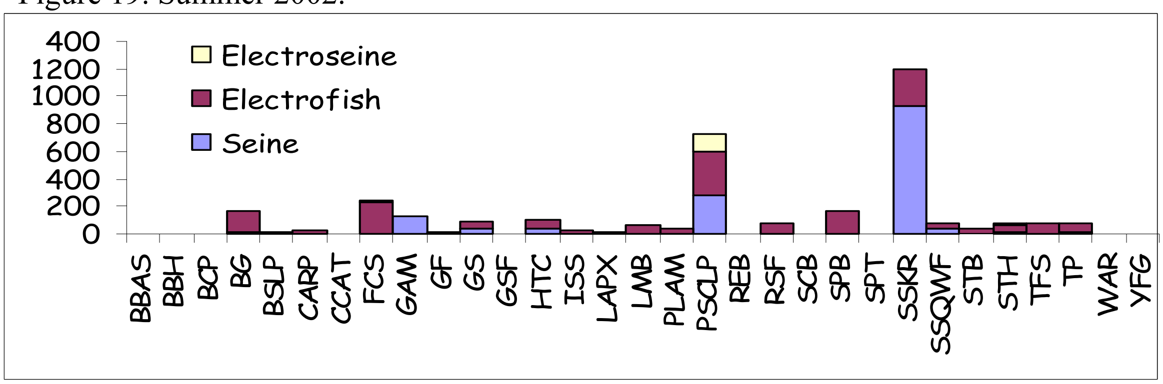

Figure 20. Spring 2002.

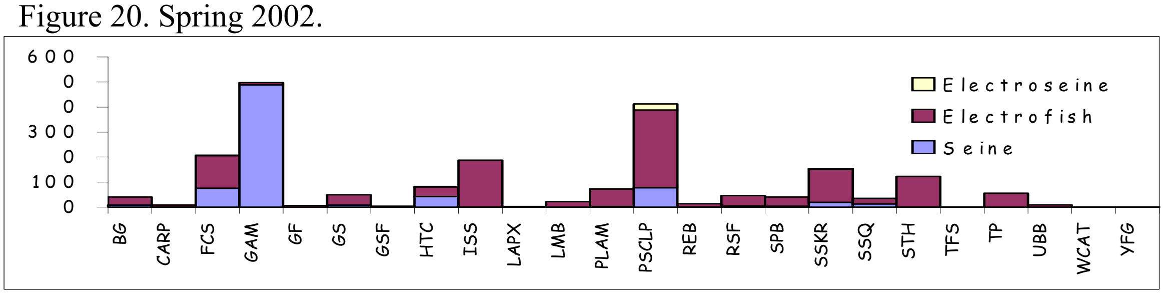

Figure 21. Winter 2002.

Figures 18-21. Catches of fish by three methods, lower Mokelumne River. Abbreviations are in table 7. Data from J. Merz, East Bay Municipal Utility District.

Conclusions

The Cosumnes River floodplain is important habitat for a number of fish species but is especially important for native fishes such as chinook salmon and splittail. The natives are clearly adapted for the seasonal pattern of flooding. They move onto the floodplain as soon as it floods and mostly leave before they become stranded. By and large, the alien fishes arrive on the flood plain later than the natives and often become stranded. This results in a definite succession of fishes in floodplain habitats. Juvenile chinook salmon are the first major users entering the floodplain from upstream spawning areas in February and usually leaving by mid-April. The next arrivals (in March) are prickly sculpin (mainly as larvae), juvenile pikeminnows, and Sacramento suckers (adults and juveniles), although splittail also arrive at this time. Splittail spawn on the floodplain in March and April and their YOY can quickly become among the most abundant fish on the floodplain, although the YOY leave as the water recedes in April and May. Common carp, an alien, have a pattern very similar to that of splittail although their YOY are more likely to be stranded as the water recedes. Through out the ‘native fish period’, small numbers of aliens are a constant presence, moving up from ponds and sloughs or washed in from the river. They typically do not become abundant, however, until the water recedes and temperatures start to rise above 20°C. Once the ponds are isolated, most native fish that are trapped die out fairly quickly (with the exception of Sacramento blackfish) and the dominant fishes become golden shiners, sunfish, inland silversides, and mosquitofish. The latter two species completely take over the fish fauna as the ponds become shallow, warm, and turbid, reaching high enough densities at times to attract feeding flocks of pelicans. During wet years, these fish will persist through the summer but during dry years they die when the ponds dry up. Alien species completely dominate the neighboring slough habitats but many species rarely appear on the floodplain and mosquitofish and silversides are only a small part of the community, confined to edge habitats.

In contrast, the regulated Mokolumne River does not provide very good habitat for fishes that depend on floodplains but the cool, permanent flows do allow resident populations of native fishes to persist, with alien species less dominant than in the Cosumnes River.

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