Patterns of Adult Fish Use on California's Yolo Bypass Floodplain

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ABSTRACT. In this paper we describe initial results from a study to examine adult fish diversity, abundance and timing of occurrence in the Yolo Bypass, the largest floodplain of the San Francisco Estuary. A fyke trap was used to capture adult fish between November 1999 and June 2000. We observed over 1,600 individuals representing 19 species including federally listed winter-run and spring-run chinook salmon (*Oncorhynchus tshawytscha*), splittail (*Pogonichthys macrolepidotus*) and sport fish such as white sturgeon (*Acipenser transmontanus*), striped bass (*Morone saxatilis*) and American shad (*Alosa sapidissima*) during the sampling period. Flow pulses immediately preceding floodplain inundation apparently triggered upstream movement of a suite of native fish including splittail, Sacramento sucker (*Catostomus occidentalis*), Sacramento pikeminnow (*Ptychocheilus grandis*) and Sacramento blackfish (*Orthodon microlepidontus*). However, we also observed immigration of chinook salmon, white sturgeon, American shad and striped bass during low flow periods, when there was no upstream connection to the Sacramento River. Concurrent screw trap sampling suggested that these migrations resulted in successful spawning of many species including splittail, American shad and striped bass. Our study demonstrates that the Yolo Bypass floodplain represents an important migration corridor and spawning habitat for Delta fish; however, restoration of the migration corridor will improve fish passage to upstream tributaries particularly during low flow periods.

INTRODUCTION

The San Francisco Estuary has been studied for the past several decades, yielding data on physical processes, biology and chemistry of channel, shoal and wetland regions (Monismith et al. 1996; Schemel et al. 1996; Kimmerer and Orsi 1996; Jassby et al. 1996; Bennet and Moyle 1996). However, very little research has been conducted on floodplain habitats of the Estuary. In this paper we report the results of a recent study on the Yolo Bypass floodplain, a little studied region of the Estuary (Figure 1).

Floodplain inundation is known to be a major process supporting ecosystems in other regions (Junk et al. 1989; Michener and Haeuber 1998). As noted by Sommer et al. (this volume), floodplain inundation during high flow years may favor several aquatic species in the Estuary. Sommer et al. (this volume) describe how the Yolo Bypass is an important nursery area for young fish and may help to support the food web of the San Francisco Estuary. However, little is known about how adult fish use floodplain habitat. The main objective of this study was to provide basic information on trends in adult fish abundance in the Yolo Bypass. Specific questions examined in our study included: 1) what adult fish species use the floodplain; 2) what is the timing and duration of adult fish use; 3) what environmental factors are responsible for the observed trends; and 4) what are some of the functions of floodplain habitat for adult fish?

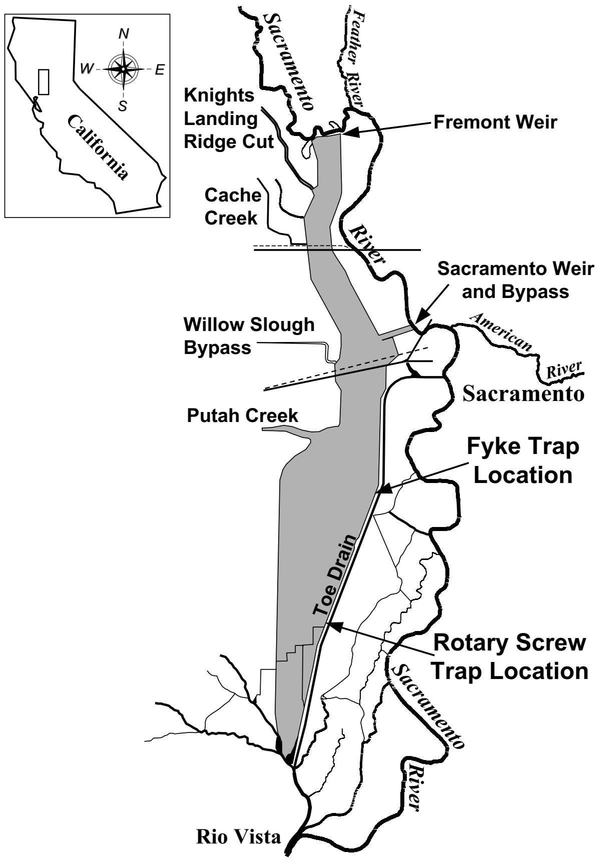
Study Area

The San Francisco Estuary has two component regions, a tidally-influenced Delta and downstream bays. The Yolo Bypass is a leveed 24,000 ha floodplain engineered to convey flood flows from the Sacramento River, Feather River, American River, Sutter Bypass and westside streams and drains (Figure 1). The Yolo Bypass floods seasonally in some 60% of years and when fully inundated roughly doubles the wetted area of the Delta. The lower Bypass is designed to convey flood water flows up to 14,000 m3/s. During peak flood events, up to 80% of inflow from the Sacramento basin passes through the Bypass. Most flow enters the Bypass via Fremont and Sacramento weirs. The Toe Drain is a perennial tidal channel that runs along the east side of the Bypass and drains adjacent fieldsduring low flow and the irrigation season (June through August). The Toe Drain also connects west side Bypass tributaries with tributaries of the north Delta.

METHODS

A large cylindrical fyke trap was our primary method for capturing adult fish. (Photograph 1).

FIGURE 1. The location of the Yolo Bypass in relation to the adjacent portion of the Sacramento River. Trap and weir locations are indicated with arrows.



The fyke trap is about seven meters long, three meters in diameter, and is constructed of chainlink fence material stretched around a steel frame. The terminal chamber of the trap is lined with 20-mm square plastic mesh and includes two hinged access doors for removing fish. The trap is anchored and accessed using a series of cables and a truck-mounted winch. The trap was installed at the lower end of the Yolo Bypass Toe Drain in November 1999 and was operated through June 2000. Fish were removed from the trap through the access door using a longhandled dip net, measured to the nearest millimeter fork length (FL) and released upstream of the trap. The trap was checked three to five days per week depending on species being captured, numbers of fish and debris load. Due to high flows through the Yolo Bypass (>1,400$m^3 \cdot s^{-1}$) primarily from the Cache Creek drainage, fyke trap sampling was suspended temporarily between February 15 and March 20, 2000. Such high flows and associated debris create risk of losing or collapsing the fyke trap.

Adult catch data were examined using catch frequency plots to assess timing and duration of adult fish use. Canonical Correspondence Analysis (CCA) was used to identify environmental factors associated with abundance trends (ter Braak and Smilauer 1998). CCA is a non-linear, multivariate, weighted-average method to investigate the community response to environmental gradients. It extracts synthetic gradients (ordination axes) of species abundance and environmental variables to maximize niche separation among species. We first examined the environmental variables with Pearson product moment correlation tests to identify variables that were highly correlated. Environmental variables used in the analysis were month, water temperature, tide (spring or neap) and Yolo Bypass inflow; however, water temperature was omitted from the CCA for two reasons. First, temperature was highly correlated (r>0.70) with month. Therefore, in order to maintain the integrity of the CCA, one of the similar variables was removed. Second, we wanted to look at the seasonality of fish migrations into the floodplain area independent of fall and spring temperature similarities. That is, we wanted to know how predicted migration periods for some species would be observed in the Toe Drain. The only continuous variable, flow, was standardized to a mean of zero and a standard deviation of one.

To examine which species may have used in the Yolo Bypass for spawning, we conducted rotary screw trap sampling from January 5 through June 30, 2000 to collect data on juvenile fish abundance. A 2.5 meter diameter rotary screw trap (EG Solutions, Corvallis, Oregon) was installed in the Toe Drain near the bottom of the Bypass (Figure 1). The trap was secured to an overhead cable and fished near the center of the channel. The trap was checked three to five times per week and was generally fished continuously. At each check, fish fork length were measured to the nearest millimeter and counted then released downstream. For this analysis, we focused on fish that were less than 50 mm FL because these fish were most likely young-of-the-year fish and a result of spawning during the current water year.

PHOTOGRAPH 1. Fyke trap in operation at the sampling site in the Yolo Bypass Toe Drain.

FIGURE 2. Selected native species catch in the fyke trap for the study period in relation to mean daily flow ($m^3 \cdot s^{-1}$) through the Yolo bypass floodplain.

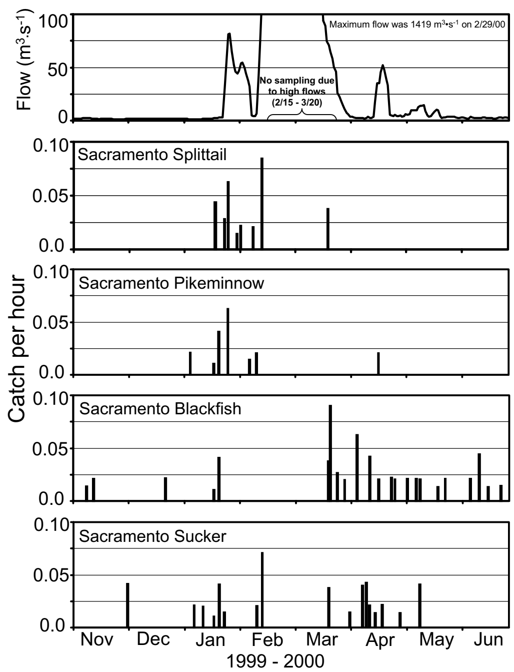
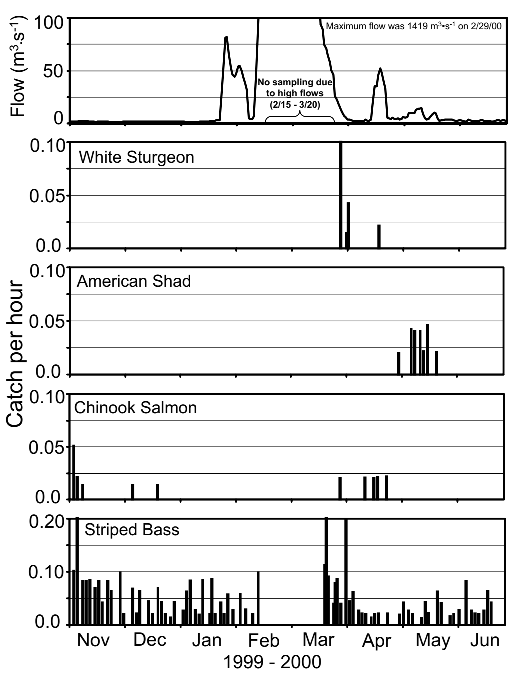


FIGURE 3. Selected anadromus species catch in the fyke trap for the study period in relation to mean daily flow ($m^3 \cdot s^{-1}$) through the Yolo Bypass floodplain.



RESULTS

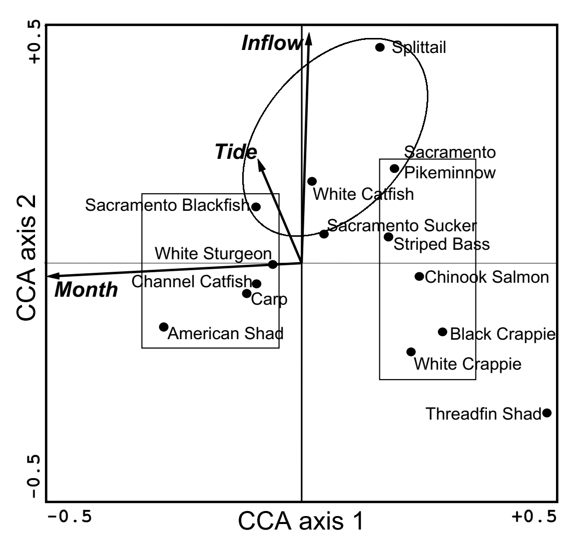
We captured 1,610 fish in the fyke trap representing 19 different species (Table 1). Fish captured included the federally listed winter-run and spring-run chinook salmon and splittail. To determine race of adult chinook salmon captured, we used criteria developed by F.Fisher (California Department of Fish and Game, unpublished data). Sport fish such as white sturgeon, striped bass and American shad were also collected during the sampling period.

At least two major patterns of adult fish use of the floodplain were apparent. One group showed a clear positive response to flow pulses. A second group showed strong seasonal patterns without a similar obvious flow effect. Within the second group, some species where most abundant during late season (spring periods), where as others showed both fall and spring peaks.

A suite of native fish showed a positive response to an early season (January) flow pulse before floodplain inundation (Figure 2). Splittail and Sacramento pikeminnow showed the most prominent catch peaks during the January pulse. Sacramento sucker and Sacramento blackfish showed a similar trend, but the response was less pronounced.

White sturgeon and American shad had no detectable positive flow responses (Figure 3).

FIGURE 4. Environmental correlation vectors and species scores in the first two canonical correspondence analysis (CCA) dimensions for those species collected with the fyke trap. The vectors of environmental variables point in the direction of increasing values for each variable. The length of the vector signifies the strength of the correlation with each axis. The positive flow responsive group is highlighted with an oval whereas the fish that showed seasonality are highlighted with two rectangles. The rectangle on the right corresponds to species that had peak abundance during the earlier part of the season and the left rectangle reflects species that peaked during late season.



Instead, they showed a late season (spring) pattern of migration into the Yolo Bypass. However, for white sturgeon we think this may be an artifact of the absence of sampling during the highest flow period (February 15 through March 20, 2000) when they migrated onto the floodplain but were not detected. Threadfin shad, black crappie and white crappie were prevalent early in the season (fall) (Table 1), when Yolo Bypass flow was lowest.

Two anadromous species, chinook salmon and striped bass showed both late fall and spring peaks in abundance (Figure 3). Similar to white sturgeon, we cannot discount that the spring peak in striped bass catch may be an artifact of the absence of sampling during the highest flow period, although fall and spring striped bass migrations are common in this estuary. Carp, channel catfish, white catfish and striped bass were present in all sampling months (Table 1).

The CCA biplot (Figure 4) demonstrated that most of the variability in adult fish use of the floodplain was explained by month and inflow. The first two CCA axes explain 58.9% (eigenvalue = 0.23) and 34.2% (eigenvalue = 0.14) of the species-environment relation, respectively. Month was the most important variable on axis 1, while inflow was the most important variable on axis 2. The CCA results are reasonably consistent with the two general patterns of adult use, described previously. To help illustrate these trends, the positive flow responsive group is highlighted in Figure 4 with an oval whereas the fish that showed seasonality are highlighted with two rectangles. The rectangle on the right corresponds to species that had peak abundance during the earlier part of the season and the left rectangle reflects species that peaked during late season.

A total of 20 fish species with fork length <50 mm were captured in the rotary screw trap (Table 2). Of the 19 species observed in the fyke trap as adults (Table 1), 12 were also captured as young-of-the-year in the screw trap (Table 2).

DISCUSSION

Fish fauna in the Yolo Bypass is relatively diverse, providing habitat for native and nonnative fish. The present study shows that the Yolo Bypass floodplain functions as both a migration corridor and potentially as spawning habitat. Although we did not sample in all months of the year, based on other fish surveys of the Yolo Bypass (CDWR, unpublished data), we know that non-native fish such as carp, channel catfish, threadfin shad, black crappie and white crappie use perennial floodplain water sources as year round habitat. Our results support the findings of Sommer et al. (1997) and Sommer et al. (2001) that floodplain represents one of the most important fish habitats in the San Francisco Estuary.

The majority of fish species captured as adults in the fyke trap were subsequently collected as young-of-the-year in the screw trap, which suggests that the Yolo Bypass provides spawning habitat for many of these fish. Of the species captured as adults, there was indirect evidence of substantial spawning (i.e., more than a few juveniles captured in the screw trap) for splittail, American shad, striped bass, threadfin shad, largemouth bass and carp. Other species for which there may have been at least limited spawning included bluegill, channel catfish, black crappie and Sacramento sucker. Small adult fish (typically <100 mm FL) such as golden shiner, yellowfin goby, mosquitofish and inland silverside were not observed in the fyke trap because they can swim through the trap mesh. However, young-of-the-year of these small species were collected in the screw trap in substantial numbers, suggesting some spawning occurred in the Yolo Bypass.

Our data are not definitive proof of floodplain spawning of any of these species. We cannot rule out the possibility that the young we captured may have originated in tributaries. Juveniles could have entered the floodplain from the Sacramento River during February and March when the Fremont Weir was overtopped or from Putah or Cache creeks during all months. For example, although chinook salmon were collected as adults and young-of-the-year, the juveniles likely entered the floodplain from upstream tributaries during the high flow period. The Yolo Bypass lacks suitable gravel substrate that would support salmon spawning. By contrast, we think the Yolo Bypass would have provided good spawning conditions for other species collected as juveniles given their life history requirements. For example, many of the fish collected are native to the Mississippi River, where floodplain spawning has been documented (Sabo and Kelso 1991). The results for splittail are consistent with Sommer et al. (1997), who reported that the Yolo Bypass was one of the most important locations in the Estuary for spawning. Striped bass and American shad also probably spawned in the Yolo Bypass; however, we believe these fish probably spawned in the perennial Toe Drain channel rather than on the seasonal floodplain because juveniles did not appear in our screw trap until two months after the flood pulse had subsided. The apparent spawning success of American shad was surprising because the Toe Drain is functionally

TABLE 1. Monthly catch of all species in the fyke trap during the sampling period, November 2, 1999 through February 14, 2000 and March 20 through June 30, 2000. Note that native species are in bold typeface and all species are listed in order of catch abundance. Mean fork length (FL) and standard deviation in parentheses are listed in millimeters.

Common Name	Scientific Name	FL	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Carp	*Cyprinus carpio*	392 (99)	19	25	69	36	33	92	174	172	609
Channel Catfish	*Ictalurus punctatus*	447 (98)	9	9	37	9	21	114	116	23	338
White Catfish	*Ameiurus catus*	301 (55)	23	17	30	28	48	29	49	20	244
Striped Bass	*Morone saxatilis*	551 (152)	61	24	30	13	19	24	17	18	206
Threadfin Shad	*Dorosoma petenense*	98 (10)	17	31	6						54
Sacramento Blackfish	*Orthodon microlepidontus*	394 (36)	2	1	3		6	6	5	5	28
Black Crappie	*Pomoxis nigromaculatus*	279 (33)	4	11	7				2	4	28
Sacramento Sucker	*Catostomus occidentalis*	443 (62)		2	6	6	1	9	3		27
Sacramento Splittail	*Pogonichths macrolepidotus*	343 (36)			7	8	1				16
American Shad	*Alosa sapidissima*	395 (33)							12		12
White Crappie	*Pomoxis annularis*	267 (34)	1	5	1					3	10
Sacramento Pikeminnow	*Ptychocheilus grandis*	458 (49)			7	2		1			10
Chinook Salmon	*Oncorhynchus tshawytscha*	694 (105)	3	2			1	4			10
White Sturgeon	*Acipenser transmontanus*	1204 (101)					5	3			8
Hitch	*Lavinia exilicauda*	329 (26)			1		4				5
Goldfish	*Carassius auratus*	292 (3)				1	1				2
Bluegill	*Lepomis macrochirus*	150		1							1
Black Bullhead	*Ameiurus melas*	219				1					1
Largemouth Bass	*Micropterus salmoides*	560		1							1

TABLE 2. Monthly catch of all species less than 50 mm in the rotary screw trap during the sampling period, January 5 through June 30, 2000. Note that native species are in bold typeface and all species are listed in order of catch abundance.

Common Name	Scientific Name	Jan	Feb	Mar	Apr	May	Jun	Total
Sacramento Splittail	*Pogonichths macrolepidotus*				45	358	63	466
Inland Silverside	*Menidia beryllina*	18	13	36	29	14	24	134
American Shad	*Alosa sapidissima*					2	125	127
Striped Bass	*Morone saxatilis*						124	124
Yellowfin Goby	*Acanthogobius flavimanus*					1	54	55
Chinook Salmon	*Oncorhynchus tshawytscha*		3	39				42
Fathead Minnow	*Pimephales promelas*	4	18	5	4	4	2	37
Threadfin Shad	*Dorosoma petenense*	10	1				26	37
Largemouth Bass	*Micropterus salmoides*					22	8	30
Mosquitofish	*Gambusia affinis*		2	22	2	12	2	28
Carp	*Cyprinus carpio*				9	6	9	24
Threespine Stickleback	*Gasterosteus aculeatus*					16	6	22
Bluegill	*Lepomis macrochirus*	1	1	3				5
Channel Catfish	*Ictalurus punctatus*			3	1		1	5
Golden Shiner	*Notemigonus crysoleucas*			2		2	1	5
Red Shiner	*Notropis lutrensis*					2		2
Black Crappie	*Pomoxis nigromaculatus*					1		1
Bigscale Logperch	*Percina macrolepida*					1		1
Sacramento Sucker	*Catostomus occidentalis*					1		1
White Crappie	*Pomoxis annularis*						1	1

a tidal slough during May and June, quite unlike higher flow channels thought to be preferred spawning habitat for American shad (Moyle 2001).

The Yolo Bypass appears to provide a potential migration corridor for chinook salmon, white sturgeon, splittail and perhaps other species such as Sacramento pikeminnow. Moderate to low flow pulses through the Bypass seem to trigger immigration of some native fish such as splittail, and the fact that the January flow pulse came primarily from Cache Creek indicates that flow from the Sacramento River is not necessary to attract native fish into the floodplain.

From a management perspective, it is important to note that some winter-run, spring-run and fallrun chinook salmon and white sturgeon migrate into Yolo Bypass when there was no flow into the floodplain via Fremont Weir. These fish are therefore unable to reach upstream spawning habitat in the Sacramento River and its tributaries. Future restoration efforts are needed to address this fish passage issue for these ecologically and economically significant fish.

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LITERATURE CITED

Bennett, W.A. and P.B. Moyle. 1996. Where have all the fishes gone?: interactive factors producing fish declines in the Sacramento-San Joaquin estuary. Pages 479-518 in: J.T. Hollibaugh (Editor). San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. 542 pp.

Jassby, A.D., J.R. Koseff, and S.G. Monismith. 1996. Processes underlying phytoplankton variability in San Francisco Bay. Pages 325-350 in: J.T. Hollibaugh (Editor). San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. 542 pp.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Special Publication of the Canadian Journal of Fisheries and Aquatic Sciences 106:110-127.

Kimmerer, W.J. and J.J. Orsi. 1996. Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam Potamcorbula amurensis. Pages 403-424 in: J.T. Hollibaugh (Editor). San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. 542 pp.

Michener, W.K. and R.A. Haeuber. 1998. Flooding: natural and managed disturbances. Bioscience 48(9):677-680.

Monismith, J.S., J.R. Burau, and M. Stacey. 1996. Stratification dynamics and gravitational circulation in northern San Francisco Bay. Pages 123-153 in: J.T. Hollibaugh (Editor). San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. 542 pp.

Moyle, P.B. 2002. Inland Fishes of California. UC Press, Berkeley. In press.

Sabo, M.J. and W.E. Kelso. 1991. Relationship between morphometry of excavated floodplain ponds along the Mississippi River and their use as fish nurseries. Transactions of the American Fisheries Society 120:552-561.

Schemel, L.E., S.W. Hager, and D. Childerns, Jr. 1996. The supply and carbon content of suspended sediment from the Sacramento River to San Francisco Bay. Pages 237-260 in: J.T. Hollibaugh (Editor). San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. 542 pp.

Sommer, T.R., R. Baxter, and B. Herbold. 1997. The resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126:961-976.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58(2):325-333.

Sommer, T.R., W.C. Harrell, M. Nobriga, and R. Kurth. Floodplain as habitat for native fish: lessons from California's Yolo Bypass. This volume.

Ter Braak, C.J.F. and P. Similauer. 1998. CANOCO Reference Manual and User's Guide to Canoco for Windows: Software for Canonical Community Ordination (Version 4). ºMicrocomputer Power, Ithaca, NY.