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Movement of Sacramento sucker, *Catostomus occidentalis*, and hitch, *Lavinia exilicauda*, during a spring release of water from Camanche Dam in the Mokelumne River, California

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Synopsis

We recorded the movement of Sacramento suckers, *Catostomus occidentalis*, and hitch, *Lavinia exilicauda*, before and during a controlled flood release on a regulated California Central Valley River, using radio telemetry. Both species made small, local movements (<550 m) during pre-flood flows. During flood releases, some individual suckers made significantly larger movements (>8100 m) both up and downstream of pre-flood flow locations within the main channel while others did not. In contrast, increased flows did not significantly influence hitch movement from a side-channel pool. Sacramento suckers tended to move upstream during flow increases and downstream during flow reductions while no strong relationship for hitch was apparent. These data show that native Central Valley fishes may exhibit a variety of responses to flow change, including schooling and spawning activity, movements to refugia from higher velocities and no marked change. Managers must take into account life history, age and timing associated with specific species when implementing controlled flow strategies.

Introduction

Spring flooding is a natural process when a river's flow is enhanced by snowmelt. The frequency of spring floods in the California Central Valley has decreased dramatically because dams have been built on the main stems of virtually all of its rivers (Mount 1995). Historically, spring floods produced natural geomorphic change within rivers and acted as a cue for fish migrations (Kondolf 2000, Moyle 2002). High spring flows are now absent during all but extreme water years since construction of large dams. This change has had a dramatic effect on natural channel morphology processes and stream biota. For instance, with a lack of high water events, gravel substrates can become silted. With this siltation, aquatic vegetation can start to grow making gravels less suitable for spawning of native fish such as Chinook salmon, *Oncorhynchus tshawytscha*, and Sacramento suckers, *Catostomus occidentalis*. Lack of spring floods can disconnect habitats such as side channels and pools from the main channel further impacting species that utilize these habitats for spawning and rearing, such as the hitch, *Lavinia exilicauda*. Recently, spring floods have been used as a management tool to mobilize stream beds, enhance channel morphological processes, improve riparian vegetation and improve fish passage (Poff et al. 1997, Kondolf 2000, Marchetti & Moyle 2001, Valdez et al. 2001). However, in the Central Valley, most of these flood events have been aimed at charismatic and economically important fish species, such as Chinook salmon.

Water is periodically released from dams for the generation of hydroelectric power, recreation (i.e., rafting and kayaking), and to emulate floods that mobilize the channel substrate and enhance spawning habitat for various fishes. Studying a fish's behavior during these flow changes has been difficult with active sampling methods such as seining and electro-fishing. Radio tracking is an effective alternative to continually sampling and handling the fish (Jepson et al. 2002). On rivers where hydroelectric power is generated, river flows may fluctuate greatly on a diurnal basis. For instance, radio telemetry was used to determine that water releases for the production of hydroelectric power had little effect on the movements of brown trout, *Salmo trutta* (Bunt et al. 1999). In natural systems where large-scale spring flooding is still found, suckers (Catostomidae) have been found to move large distances, generally downstream, during the peak flows of natural spring flooding (Brown et al. 2001). They have been found also to move in to floodplain habitat where velocities are lower than the main channel (Ross & Baker 1983). In the Colorado River a pulsed dam release, meant to simulate a natural spring flood, had little effect on the movement and distribution of flannelmouth suckers, *Catostomus latipinnis*, during spawning (Valdez et al. 2001). Many rivers in California have altered flow regimes that have allowed non-native fish to forage more efficiently on local prey and occupy available habitat better than native fish (Marchetti & Moyle 2001). Artificially pulsed flows can be used as a tool to mimic spring floods that will help resource managers better manage native fish populations.

Over 35 native and non-native fish species have been observed in the lower Mokelumne River (LMR) (Merz & Workman 1997, Merz & Setka 2004). These fishes include five anadromous species: fall-run Chinook salmon, winter steelhead trout, *O. mykiss*, American shad, *Alosa sapidissima*, striped bass, *Morone saxatilis*, and Pacific lamprey, *Lampetra tridentata*. Native Chinook salmon and steelhead trout populations are supplemented by fish production at the Mokelumne River Fish Hatchery located at the base of Camanche Dam. Sacramento suckers (family Catostomidae) and hitch (family Cyprinidae), native to the Sacramento San Joaquin River system, are common throughout the LMR. Sacramento suckers typically begin spawning by their fourth year, reach over 600 mm FL and 30 years of age (Moyle 2002). They often make spawning migrations to smaller tributary streams from early December to mid-spring, which may be triggered by temperature or flow increase (Moyle 2002). Hitch can withstand moderate salinities (0 – 7 ppt) but are most commonly associated with slower freshwater habitats of Central Valley rivers and streams. Females typically begin spawning by their second or third year while males may start as early as their first (Moyle 2002). Hitch may make spawning migrations, which can be triggered by increased spring flows. Spawning typically occurs from mid-February through June. Hitch may live over 6 years and reach over 360 mm FL (Merz & Saldate 2004). Sacramento suckers and hitch have both been observed using the WID fish ladder to access the Mokelumne River above tidal influence and to move downstream (Workman 2005). While not economically charismatic in present-day California, both species were extremely important to pre-historic aboriginal peoples (Schulz & Simons 1973, Gobalet et al. 2004) and are an important food source for sensitive species such as bald eagles, *Haliaeetus leucocephalus* (Jackman & Jenkins 2004), osprey, *Pandion haliaetus* (J. Merz, personal observation), Chinook salmon (Merz 2001), and steelhead (Merz 2002).

To date no study has used radio telemetry to monitor the daily movement of native fishes during a flow pulsed during the spring, although some studies have monitored the behavior of native fishes during increases in water discharge (Ross & Baker 1983, Brown et al. 2001, Valdez et al. 2001). The objective of our study was to observe and quantify the movement and habitat preference of two native fish, Sacramento sucker and hitch, in response to a spring flood release of water into the Mokelumne River.

Methods

This study was conducted on the lower Mokelumne River between Camanche and Woodbridge

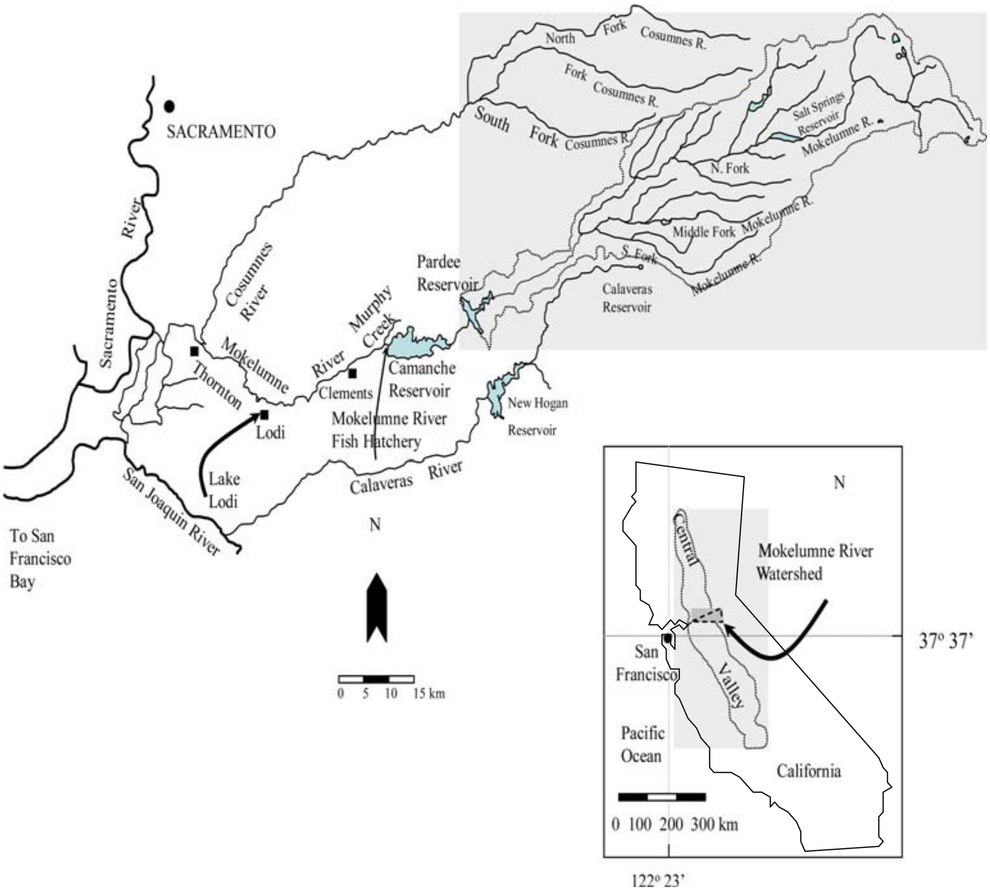

Figure 1. Map of the Mokelumne River basin. The study area consisted of the reach of river between Lake Lodi and Camanche Reservoir.

dams (Figure 1). The Mokelumne River originates at an elevation of 2652 m in the Sierra Nevada Mountains and flows into the Sacramento-San Joaquin Delta approximately 38 km southeast of Sacramento. It has a basin area of ~1700 km^2, receiving most of its precipitation in the November through March period and over 50% in the form of snow. River flow is regulated for flood control and municipal and agricultural water purposes. The river presently has 16 major water impoundments, including Salt Springs (175 032 089 m^3), Pardee (258 909 341 m^3) and Camanche reservoirs (531 387 061 m^3). High flows are only present in very wet years when the discharge is greater than the storage capacity of the upstream reservoirs.

The LMR ranges in elevation from approximately 28 m at Camanche Dam, the lowest non-passable barrier to migratory fish, to sea level at Thornton (Figure 1). The gradient of this section of river ranges from 0.10% near Camanche Dam to 0.02% near the Cosumnes River confluence. Extreme tidal influences are observed as high as RKM 53, downstream of Woodbridge Dam (Figure 1). Similar to many other tributaries of the Sacramento-San Joaquin River system, hydraulic mining, gravel extraction, dam construction, water diversions, altered flow regimes, deforestation, artificial bank protection, channelization and levee construction have had a significant influence on channel morphology.

Channel widths of the LMR range from 19 to 43 m with a mean of 30 m. The river tends to be wider in the first 9.5 km below Camanche Dam and, with the exception of Lake Lodi, generally narrower downstream to the tidal reach. Much of the narrowing of the channel downstream can be attributed to flood control levees built to protect homes and farmland on the historical floodplains of the river. There are approximately 64 km of levee constructed on the LMR between Camanche Dam and tidal influence. Tailings from continuing and abandoned gravel mining operations are apparent along the upper third of the LMR. These tailings are isolated from the river by berms and levees although several mining pits are now incorporated into the present river channel or attached as off-channel pools that may be connected or disconnected due to flow and time of year.

The study site consisted of the 14 km reach of the river below Camanche Dam, but sampling was concentrated within the 3 km below the dam. A weir is located approximately 150 m below Camanche Dam and used to prevent salmon and steelhead from entering the powerhouse during spawning migrations up the river. The weir is erected during fall and winter months to divert salmon and steelhead to the Mokelume River hatchery. During the study, the boards of the weir had been removed, permitting movement of fish in the river, but not allowing boats upstream. The habitat for salmon spawning had been enhanced in the 12 km below the dam. The habitat enhancement decreased the mean depth and increased the speed of water movement, thus increasing the amount of riffle and run habitat in the reach.

The spring flood release in the Mokelumne started with a flow of 12.5 $m^3 s^{-1}$ and rose to 56.7 $m^3 s^{-1}$ over 4 days. The flow was then decreased to 14.1 $m^3 s^{-1}$ over 10 days. The flow remained 14.1 $m^3 s^{-1}$ for 4 days, then water flow was increase to 36.8 $m^3 s^{-1}$ due to lack of water storage in Camanche Reservoir. The second release allowed fish tracking over two sudden alterations in flow.

We placed radio transmitters on individuals of both species and tracked them during a spring release pulse flow (Table 1). The Sacramento sucker spends most of its time as an adult close to the bottom in deep riffle or run habitat. Suckers we observed during this study were in groups of five to ten fish when they could be seen. Hitch are generally found in slow-moving reaches of rivers and backwater habitat usually associated with aquatic vegetation (Moyle 2002). During this study, we found them in backwater and side channel habitat, where little to no current was observed and aquatic vegetation provided cover.

We captured fish using a 5.8-m shallow-draft boat (Smith-Root, Electro-fishing model SR-16H). We held the fish in a live well on the boat until the surgery area was prepared for transmitter implantation. We placed each fish in a cooler containing tricaine methanesulfonate (MS-222). When the fish lost equilibrium, we placed it on a platform inside another cooler filled with water and a smaller amount of MS-222. we placed the fish ventral side up and made a 1 cm incision anterior of the pelvic girdle and to the side of the ventral midline. The radio transmitter (Lotek, NTC-4-2S) had a diameter of 8 mm, length of 17 mm, a negative buoyancy of 0.9 g in water, and a life expectancy of 30 days. We placed the transmitter inside the body

Table 1. Table with specimen number, length, weight, dates and duration of tagging, for the subjects of the study.

Fish number	Species	Length (mm)	Weight (g)	Date of tagging	Initial date located	Last date located	Duration of tracking
1	Sacramento sucker	495	1700	15 May 2003	23 May 2003	25 June 2003	33
2	Sacramento sucker	475	1450	15 May 2003	N/A		0
3	Sacramento sucker	278	300	15 May 2003	N/A		0
4	Sacramento sucker	371	750	15 May 2003	23 May 2003	25 June 2003	33
5	Sacramento sucker	410	800	15 May 2003	23 May 2003	11 July 2003	49
6	Sacramento sucker	455	1000	15 May 2003	23 May 2003	11 July 2003	49
7	Hitch*	210	140	15 May 2003	23 May 2003	18 June 2003	26
8	Hitch	205	145	15 May 2003	23 May 2003	25 June 2003	33
9	Hitch	223	160	15 May 2003	N/A		0
10	Hitch	168	80	15 May 2003	N/A		0
11	Hitch	179	85	15 May 2003	N/A		0
12	Hitch	168	75	15 May 2003	26 May 2003	29 May 2003	4

*Denotes the fish that was recovered after the study was completed.

cavity of the fish and pushed it towards the anterior end of the body cavity. We then closed the incision with three or four braided silk sutures. The antenna exited the body at the posterior end of the incision. Each antenna was shortened to minimize interference with the fish's swimming. We then placed the tagged fish in a recovery tank without MS-222. Once a fish regained regular opercular movement and began swimming normally in the recovery tank, we released it at the location of collection.

Fish tracking began 2 days prior to the pulsed flow. We searched each day from the fish weir downstream until all the fish were located. During every sampling period each fish was located once per day. During some sampling periods a particular fish could not be located, and it is likely that the fish was behind an underwater feature (i.e., submerged log or boulder) and the signal was blocked from reaching the receiver. We conducted tracking daily until 3 days after the first pulse flow. During the second water release, one week after the planned pulse flow was over; we tracked the tagged fish every other day or when time permitted. The signals were weak and inconsistent during the last day of tracking, 49 days after tag implantation.

We tracked the fish using radio two different receivers (ATS, R2000; Telonics, TR-4) and located either from a jet boat or from shore using an omidirectional loop antenna. Once a fish's general location was found, we used a hand-held antenna (Yagi, seven element) to find the direction of the fish relative to the receiver. Once this direction was determined we moved the receiver to a different location and again located the fish's direction. After two or more locations were used to locate the fish, we determined the fish's location by triangulation. We noted the location of the fish on aerial photographs of the river. When the water was shallow and clear, the fish could be positioned by sight to confirm the accuracy of the triangulation method. The accuracy of field location was ± 3 m.

We calculated daily displacement from the present location of the fish in relation to the location of the fish during the last sampling period. We assigned upstream values a positive value and downstream values a negative value. We determined distance moved relative to the location where the fish was released after the transmitter was implanted.

Results

We made a total of 57 observations on six tagged Sacramento suckers throughout the 38-day study. We made observations approximately every 2.27 days. We tracked four of the six Sacramento suckers with affixed transmitters throughout the study. The two Sacramento suckers that were not tracked throughout the study were never located after the initial day that the transmitters were implanted. The movements of tracked suckers varied during the study. There were movements upstream, downstream and within local pools. Sacramento suckers moved on average 365.9 m between each observation (STD: 1079.5). Mean displacement was −1825 m (downstream) and ranged from −8127 m to 1150 m (Figure 2). However, Sacramento suckers tended to move upstream

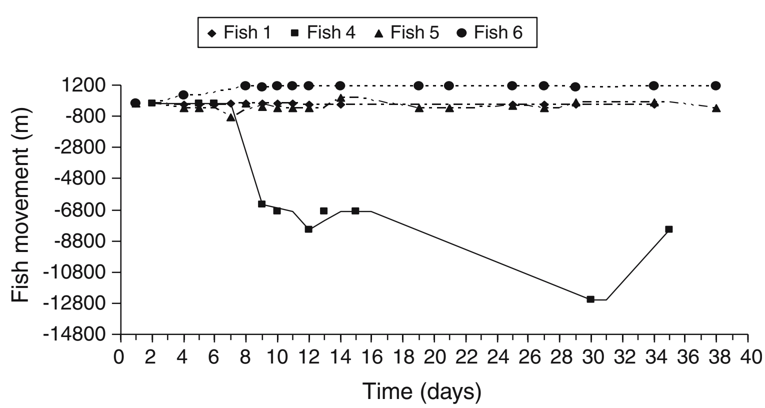

Figure 2. Movement of Sacramento suckers throughout the study displaying a leptokurtic distribution.

during flow increases and downstream with flow reductions (χ^2 = 8.095, df = 2, p = 0.0175). Regression of flow vs. distance Sacramento suckers moved showed no strong correlations (R^2 between 0.013 and 0.278). Only Sacramento sucker 2 showed a significant relationship between flow and distanced moved between observations (F = 4.9950; df = 13; p = 0.0436). While greatest Sacramento sucker movement occurred during the flood release, we observed no significant difference in distance suckers moved between observations before and after the flow change (t = 1.219; df = 51; p = 0.2283).

Sacramento sucker 1 remained within a single 150-m-long pool and moved only 80 m throughout the study. The fish was often behind a submerged tree on a shallow sandbar in the middle of the pool. When not behind the submerged tree, it was found in slow moving water near the side of the pool. On two occasions, the fish was in fast water near large woody debris.

Sacramento sucker 4 moved downstream when the flow began to increase (Figure 3). The fish moved downstream a maximum distance of 12.6 km. Before the pulsed flow, the fish remained in the thick vegetation on the edge of a very long pool. We located it in this pool three times prior to the increase in flow. Once flow increased, it moved downstream at approximately the same rate of movement as water flowed downstream in the river. During the period of decreased flow, the fish returned upstream 1.2 km where it remained until the second period of increased flow, when it again moved downstream. The last time that we located Sacramento sucker 4 it had moved upstream 4.4 km. In the last upstream movement recorded, there was no change in the flow.

Sacramento sucker 5 moved downstream and upstream within a 1.2 km reach of the river. The fish initially moved downstream as flow increased, but then traveled upstream above its original position. During decreasing flow, the fish moved downstream to its original release location. The fish was most often located in the heads of riffles in the gravel enhancements sites in the river.

As the flow increased, Sacramento sucker 6 moved above the weir (Figure 4). We could not determine the exact location of the fish because of the noise on the receiver produced by the electrical interference from the power generation turbines on the dam. The sucker remained approximately 20 m below the weir during one sampling period, but then returned to the area above the weir where it remained until the end of the study.

Six hitch were initially tagged, but we could track only three throughout the study. We made a total of 33 observations throughout this portion of the study, approximately every 2.08 days. Tagged hitch remained in a pool away from the main channel of the river, which seemed to serve as a refuge as fast flows produced by dam discharges were absent in this pool. The hitch exhibited limited mobility within the pool, and the movements of these individuals were small and appeared to be independent of the changes in water release. Hitch moved on average 23 m between each observation (SD = 14.30). We found no significant relationship between hitch movement and flow change (p > 0.05) and no

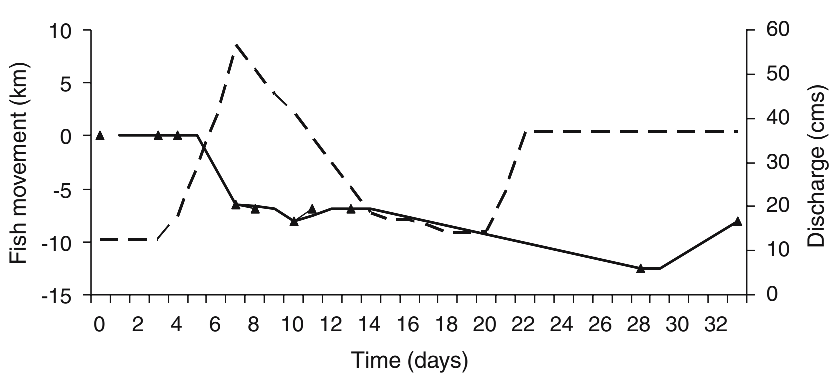

Figure 3. Example of downstream movement of Sacramento sucker when flows were increased. Location of fish relative to the initial location sampled (solid line) plotted with the hydrograph during the study (dashed line). Solid triangles indicate those days, when we searched for suckers on the river.

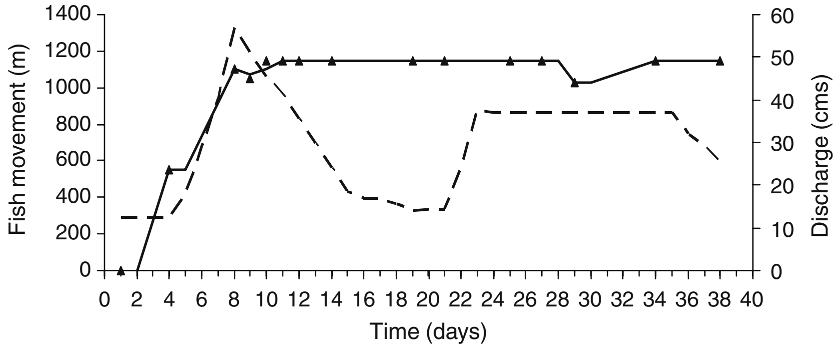

Figure 4. Example of upstream movement of Sacramento sucker when flows were increased. Location of fish relative to initial location sampled (solid line) plotted with the hydrograph during the study (dashed line).

significant difference in hitch movement before and after the flood release ($p > 0.05$). On one occasion, hitch 8 swam to a side channel 20 m upstream of the backwater, but returned to the pool by the next sampling period.

Discussion

Habitat use by native fishes of the California Central Valley has been altered by anthropogenic changes such as dams and water diversions (Mount 1995, Marchetti & Moyle 2001). Despite these large-scale changes in watershed dynamics, efforts are being made to more closely mimic the natural hydrograph to help restore habitat and native fauna. Movement of native fishes such as the Sacramento sucker and hitch varied during a Mokelumne River spring controlled flood release in May and June 2003. Sacramento suckers exhibited a variety of responses to flow increases, while hitch remained in one location throughout the study. This difference in response may be attributed to the difference in habitat preference between the two species. Sacramento suckers utilize mid-channel riffle and run habitat, where flow speeds changed significantly during the increase in flows. Sacramento suckers are strong swimmers, often making large migrations (> 50 km) and negotiating fish ladders (Villa 1985, Moyle 2002, Workman 2005) Both Sacramento suckers and hitch utilized various refuges from velocity during the increase in flow. Sacramento suckers were often located in channel margins and behind or near large woody debris in the channel. In contrast, hitch utilized off-channel pool habitat with aquatic vegetation, where flow speeds changed little during the releases. The lack of movement outside of the backwater habitat by the hitch may be due to the fact that hitch are not aggressive swimmers (Moyle 2002) and very few are seen in the WID fish ladder compared to Sacramento suckers (Workman 2005).

Movements of stream fish using radio telemetry and mark-recapture have shown that fish movement over time generally results in a leptokurtic distribution of fish relative to the "home" range (Gown & Fausch 1996, Skalski & Gilliam 2000, Fraser et al. 2001, Fausch et al. 2002). Skalski & Gilliam (2000) found that three of the four species that they studied over a 1 month period moved with a leptokurtic distribution, while the fourth species moved with a normal distribution. The Sacramento suckers that we tracked moved with a leptokurtic distribution (Figure 2). Three of the four fish tracked stayed within a home range and the fourth fish moved a long distance downstream. The hitch remained in their home range throughout the entire study, showing a normal distribution. Further study is needed to determine if hitch make large-scale movements during longer temporal periods and different water conditions than those observed in our study.

Spring flood releases appear to stimulate various responses in Sacramento suckers. The direction and magnitude of movement varied between individual fish. Sacramento suckers are a spring-spawning species and have been shown to begin spawning activity in response to environmental cues, such as changes in water temperature and river discharge (Villa 1985, Moyle 2002). If a sucker had not yet started to spawn, the flood release may have stimulated members of the species to start their spawning migration. Two fish began to swim upstream when the pulse flow was released. It appeared that they migrated upstream until they reached the dam and upstream movement was no longer possible. When Sacramento sucker 5 changed direction and moved downstream, it was often seen with a group of 5–10 other fish in riffle-run habitat. This fish may have moved upstream until blocked by the dam, then migrated back downstream to find suitable spawning habitat, where it stayed throughout the remainder of the study. Due to the electrical interference from Camanche Dam power generators, Sacramento sucker 6 could only be located within a general area. Due to the lack of visual confirmation, it is difficult to know what habitat preference and behavior the fish exhibited during the pulse flow.

A natural flow regime, which includes high peaking flows in the winter and spring and maintaining base flows throughout the summer, has been show to enhance native fishes and displace non-native fish (Marchetti & Moyle 2001). In this study, we have shown that using spring floods as a multi-purpose management tool to maintain salmon spawning habitat has had varying displacement effects on the native Sacramento sucker and hitch in the Mokelumne River. Five of the fish that were tagged were never located and the effects on their habitat preference and migration are not known. Future study of the movement and habitat preferences is still needed to answer many questions about the effects of spring floods on native fishes.

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