Pilot study: the feasibility of using fyke traps in the lower San Joaquin River to capture adult striped bass

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<u>Abstract:</u>

The purpose of this pilot study was to assess the feasibility of using fyke traps to estimate the abundance of adult striped bass (*Morone saxatilis*) in the San Joaquin River. The study focused on 20 miles of the lower river between the Head of the Old River and the confluence with the Stanislaus River. FISHBIO fabrication experts constructed two fyke traps similar in design to traps that have been used by the Department of Fish and Wildlife in the Sacramento River for decades. The traps were deployed at two locations, Sturgeon Bend and Banta Carbona Irrigation District (BCID), between May 6 and 24, and fished for a total of 19 trap-days (437.5 trap-hours). Overall, 45 striped bass and 49 bycatch fishes were captured, with higher catch and species diversity observed at the Sturgeon Bend site. Striped bass catch per trap-hour was calculated for each day-long trap set, and ranged from 0 to 0.12 STB/hr. at BCID and 0 to 0.94 STB/hr. at Sturgeon Bend. Forty striped bass were tagged with disk tags and passive integrated transponder (PIT) tags, and were released in good condition. No striped bass were recaptured in the traps, but an angler recaptured one tagged striped bass near the city of Stockton. The results of this pilot study have demonstrated the successful use of fyke traps to sample striped bass in the mainstem of the San Joaquin River, but indicate that greater effort would be needed (i.e., more traps fishing for a longer sampling period) for a successful mark-recapture population study.




Project Purpose:

The California Department of Fish and Wildlife (DFW) has been conducting a mark-and-recapture population study of striped bass in the Sacramento River and the Delta since 1969. Sacramento River striped bass are targeted with fyke traps at Knights Landing, upstream of the Delta, while SJR striped bass are targeted by gill net as they pass near the Antioch Bridge or Winter Island (DuBois and Mayfield 2009, DuBois et al. 2010, 2011, 2012). This sampling effort is focused on the lower Sacramento and the Delta, and a comparable fyke trap data set that focuses on SJR striped bass upstream of the Delta is not available. Striped bass in their native habitat on the East Coast show distinct sub-populations with patterns of seasonal migration ranging from "resident" (i.e., fish stay in freshwater) to "migratory" (anadromous) (Ng et al. 2007, Wingate and Secor 2007). A recent study in the Central Valley demonstrated that resident subpopulations exist in the Delta (Walsh 2011): researchers found evidence that some striped bass had never left freshwater (e.g., 75% of the fish caught in Clifton Court Forebay and 50% of the fish caught in Knights Landing were resident). If striped bass in the Central Valley are not a single mixed population, but rather exist as distinct groups with different migration characteristics, as they do in their native habitat, then additional information on striped bass may be gained from sampling the SJR basin population.

Distribution of striped bass in the Central Valley not only changes seasonally, but may also show considerable inter-annual variability. For example, striped bass have been detected migrating upstream in the spring (March-June) at the Stanislaus River fish counting weir. However, the number of striped bass counted passing upstream during this period has varied considerably, from 220 in 2007 to 7 in 2010 (FISHBIO, unpublished), which may be an indication of varying annual abundance in the San Joaquin River system. Chadwick (1967) found changes in the distribution of striped bass when comparing 1950-1952 with 1958-1961: the later period reflected a shift toward more tag returns from the Sacramento River and less from the eastern Delta/lower San Joaquin River, indicating a northward shift in relative use of habitat in the Central Valley or a change in relative abundance of various subpopulations. Although Chadwick (1967) found that very few striped bass were caught in the "upper San Joaquin River" between 1958 and 1964 relative to the catch in the upper Sacramento River, there have been many alterations to the Delta ecosystem since the mid-1960s (e.g., water quality, prey abundance, water exports, etc.) that may have affected the distribution and abundance of striped bass. Thus, the population of striped bass in the San Joaquin River may now be larger than originally thought. Radtke (1966) hypothesized that the lack of striped bass in the San Joaquin River above the Delta was due to the high concentration of total dissolved solids upstream from Stockton; however, this condition has improved since the 1960s. Furthermore, Turner (1976) found evidence of striped bass spawning in the San Joaquin River between the confluences with the Tuolumne and Stanislaus rivers in 1968, the only year of sampling in this reach, indicating that there may be an additional spawning ground further upstream from the Delta. Consequently, an important question is: what is the current abundance of striped bass in the San Joaquin River during the spring (when young-of-the-year Chinook are migrating out of the system)?

In recent years, growing concern about introduced species preying on Endangered Species Act (ESA) listed Chinook and steelhead runs has increased the need for further information on widespread, non-native predators. Results of the Vernalis Adaptive Management Plan's (VAMP) juvenile salmon survival studies in the SJR have demonstrated that predation on tagged smolts can greatly complicate estimates of survival and analysis of environmental relationships with survival (San Joaquin River Group Authority 2008, 2010, Vogel 2010). Furthermore, the recent striped bass settlement agreement between the Coalition for a Sustainable Delta and the DFW emphasized the importance of better understanding the relationship between the striped bass population and predation on ESA listed species (U.S. District Court Eastem District 2011). Thus, information regarding the abundance and distribution of this non-native predator in the SJR would inform management decision regarding the restoration of Chinook and steelhead populations in the basin.

The objective of this pilot study is to determine whether wire fyke traps can be used in a mark-recapture study to estimate the abundance of adult striped bass in the SJR during spring. Goals of the study included evaluating catch rates and testing trap deployment locations. If a sampling program were to be established in the future, an additional two years of mark-recapture data would be necessary, at minimum, to begin to estimate the SJR striped bass population. This pilot study provides the foundation for future abundance estimates and a sampling platform for future studies on the life history characteristics of SJR striped bass.

Methods:

Site Selection

This study focused on the lower SJR between the Head of the Old River (HOR; RM 54.1) and the confluence with the Stanislaus River (RM 73.6), a stretch of approximately 20 river miles (Fig. 1). On February 19, 2013, we conducted a reconnaissance within this river reach to examine potential sites for stationing wire fyke traps. During the survey, the hourly flow at Vernalis was approximately 2,410 cfs and the river stage was 10.2 ft. (California Data Exchange Center; http://cdec.water.ca.gov). Sites were identified based on several criteria. A primary concern for site selection in this reach of the lower SJR was water depth; a sufficient depth will be needed to submerge the fyke traps, which are 10 feet in diameter. Traps may be fished in water slightly shallower than the diameter of the trap, but this is not ideal because it reduces the volume of water in the trap. Additionally, sites must allow for truck access, since a truck-mounted electrical winch will be used to deploy and retrieve the traps. Boat access may be needed to sample fish from the trap. Thus, primary criteria were boat and truck access and a minimum depth (> 8 ft.). Secondary concerns included potential interference with boat traffic and apparent fishing activity, which we considered a proxy for possible vandalism or gear interactions. Within the roughly 20 river miles that were surveyed, 11 potential sites were identified. Each site could accommodate at minimum one fyke trap, but most sites would allow for more than one simultaneous deployment. Two preferred sites that met the criteria were selected based on access (Fig. 2).

Site SJ073 ('Sturgeon Bend'). Sturgeon Bend is a well-known fishing site close to the Two Rivers boat ramp with levee road access (Latitude/Longitude: N37.67225/W121.24612). At a distance of about 15 ft. from the shoreline the depth averaged between 9-10 ft. during the site reconnaissance, with a maximum of 12 ft. An irrigation pump marks the downstream end of the site. The outside of the bend has a gradual rip-rap-lined levee bank with minimal vegetation. Approximately three fyke traps could be deployed at this site (assuming a distance of 50-150 ft.

Figure 1. Map of study area along the main steam San Joaquin River.

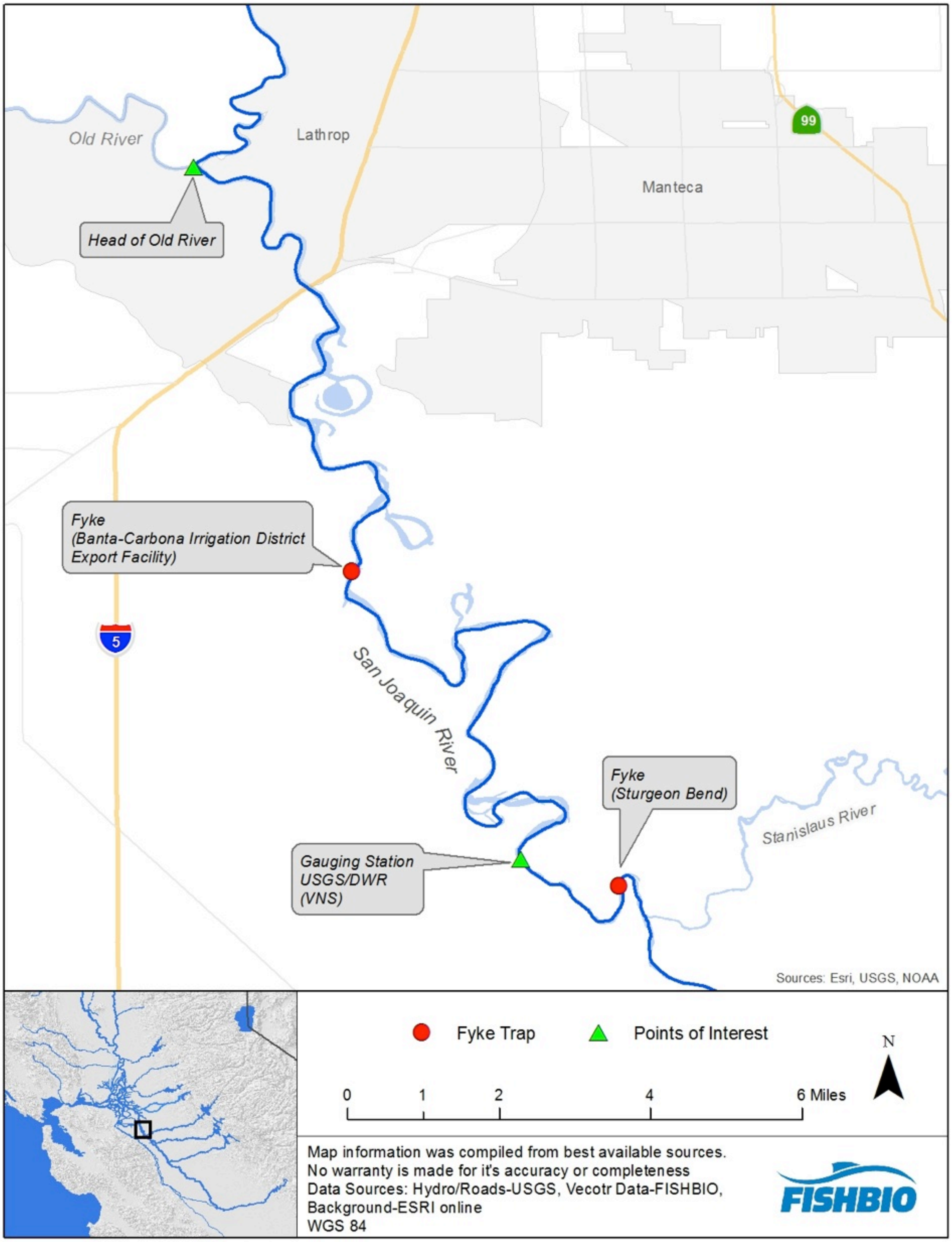

Figure 2. Left: Site SJ073, commonly known as 'Sturgeon Bend', located at river mile 73; Right: Site SJ063, Banta Carbona Irrigation District (BCID), located at river mile 63.

between traps). The main concern at Site 1 was interactions with fishers, who may get gear caught on the traps, or vandals who may damage the trap.

Site SJ063 ('BCID'). Through our existing relationship with Banta Carbona Irrigation District (BCID) we were granted secure access to the levee road near BCID's fish screen (Latitude/Longitude: N37.72836/W121.29866). At this site, the levee angle is gradual with minimal vegetation, and the depths estimated during reconnaissance ranged from 8-10 ft. at a distance of about 15 ft. offshore.

Operation of Fyke Traps:
Fishers and researchers have used fyke traps to capture large fish on the Sacramento River since the 1950s. The original design for the fisheries monitoring traps were based on traps used by salmon fishermen in the Sacramento. Over the years, the construction of these fyke traps appears to have changed very little (Hallock et al. 1957, McLaughlin and McLain 2004), and recent versions of the fyke trap used in the Central Valley are constructed using a steel frame with chain-link fence material walls (Harrell and Sommer 2003) and wooden supports (McLaughlin and McLain 2004). Fyke traps are currently the main method of striped bass sampling used in the Sacramento River for DFW's annual striped bass population study. The design of the two fyke traps constructed for this study was based on the DFW traps. FISHBIO fabrication experts measured and photographed the DFW traps, then replicated and modified the design. FISHBIO's cylindrical traps had a diameter of approximately 3 m (10 ft.) and a length of 6.85 m (22.5 ft.) including the nose cone, with an opening at the downstream end and two interior funnels that narrowed towards the upstream end. The two interior funnels and the nose cone of the trap were covered with 20-mm square plastic mesh. FISHBIO technicians slightly modified the DFW design: we added two additional wooden supports for a total of six supports.

Fyke traps were fished for 24-hour periods Monday through Friday (i.e., traps were deployed on Monday, sampled Tuesday through Friday, and pulled completely out of the water on Friday). Thus, there were four fish sampling days per week. Traps were deployed and anchored in place using a series of cables and a truck-mounted winch, based on a similar deployment system used by the Department of Water Resources (DWR). Traps were deployed by rolling them down the bank along the cables (Fig. 3). Traps must be fully submerged or almost entirely submerged to

Figure 3. Fyke Trap deployed at BCID (Left) and a close up of the nose cone of the fyke trap at Sturgeon Bend with fish splashing inside the trap.

function properly. Sampling may be delayed or terminated due to inadequate depth. Several ropes and cables guided each trap; two guide ropes were used, one on each end of the trap. The nose guide rope was tied to a ring on the nose of the trap and the other guide rope was wrapped around the back end of the trap. The other ends of both ropes were tied to two T-bars placed approximately 15 yards up on the bank. Two stainless steel guide cables (1/4 in. galvanized cable) were wrapped around the trap so that they ran along the ground. These were placed about a third of the way from the nose and a third of the way from the rear of the trap. The other ends of each cable were fastened to one T-bar each up on the bank. One stainless steel pull cable (1/4 in. galvanized cable) was wrapped along the center of the trap, coming off the top of the trap. During trap deployment or retrieval, a tension clamp was used to attach this pull cable to the cable on the 12,000 lb. capacity, truck-mounted winch (Badland Winches, Camarillo, CA, USA).

To retrieve the traps and sample fish, the traps were pulled partially up the bank using the winch until the trapped fish were concentrated in just enough water to facilitate removing them, but also minimize fish stress (about 3 ft., depth). Depending on the environmental conditions, the traps were either sampled from the shore or from a boat. The majority of the time, traps were pulled almost entirely out of the water and processed from shore, following DWR protocol. On occasion, the traps were sampled from the boat with the door of the trap facing the river, following DFW protocol. The protocol used depended on the water level in reference to the location of the doors on the trap. Fish were removed one at a time through a door in the trap body using a long handled dip net. Once all the fish were processed following protocols below, traps were cleaned to remove all debris from all trap surfaces and from within the trap. The amount of debris load on the surface of the nose cone of the trap was estimated (% of surface covered) and recorded. Once cleaned, the traps were re-deployed if scheduled to fish for the next 24 hours, or were pulled all the way out of the water and secured to T-bars on the terrace level if not scheduled to fish for the next 24 hours. Trap retrieval and deployment times were recorded and used to calculate the soak time of each trap deployment.

Environmental Conditions:

Environmental variables were measured daily Monday through Friday. Instantaneous turbidity was measured in Nephelometric Turbidity Units (NTU) using a turbidity meter (LaMotte, Model

2020e, Chestertown, MD, USA). Instantaneous water temperature was measured with a glass mercury thermometer. Instantaneous conductivity was recorded using a Waterproof ExStik® II pH/Conductivity Meter (Extech Instruments Corporation, Nashua, NH, USA). Average daily flow and river stage data were downloaded from the California Data Exchange Center (CDEC, Station ID: VNS, RM 70.8). Water velocity was measured above and below the trap before trap retrieval.

Fish Sampling:
Fish processing was conducted Tuesday through Friday. All fish captured were identified and enumerated. All fish collected in the fyke traps were identified to species and measured (fork length and total length to the nearest mm). Predatory fish species were carefully examined for an external tag (e.g., floy, disk, etc.) and were scanned for a PIT tag (regardless of whether it had an external marking), since ongoing studies by DWR in the South Delta region have involved tagging predatory fishes with PIT tags only. If the fish was previously tagged, all relevant tag information (i.e., tagging organization, tag number, etc.) was recorded on the datasheet. Once fish were processed they were released just upstream of the trap. Any fish with questionable species identification were noted and photographed.

Catch-per-unit-effort was calculated as the number of fish caught per hour of trap soak time. The exact soak time was recorded for each day-long trap set based on trap deployment and retrieval. The total number of fish of each species was summed for that set and divided by the number of hours of soak time.

Striped Bass Tagging:
All striped bass collected in the fyke traps were measured (fork length and total length to the nearest mm), identified to sex, and carefully examined for an external and an internal tag (e.g., PIT, acoustic, floy, disk, etc.). It is not possible to determine sex of striped bass based on external features. Sex is determined somewhat subjectively based on the spawning condition of the fish. Using the method employed by DFW, if the fish produces milt it is considered a male, if not it is considered a female. All healthy striped bass of legal size[1] (greater than or equal to 460 mm total length / 420 mm fork length) that did not already carry a tag were tagged before release. Striped bass were placed individually in the yellow sling with the hood over the head of the fish during tagging. The through-back method of tagging was used to attach a 1” diameter Peterson disk-dangler tag (*Floy Tag* & Mfg. Inc., Seattle, WA, USA) to the flesh just below the base of the anterior[2] dorsal fin, following similar protocols used by DFW (Fig. 4). About 9 inches of wire (302 or 304 alloy stainless steel, 0.02 inch diameter, sourced from DFW) was cut, folded in half, and twisted around the disk tag three or four times, so that the two ends of the wire were about 3 to 4 inches long. Two 17-gage hypodermic needles were inserted (from the fish’s left side to right side) about 1 cm or less apart (one under the 4th anterior dorsal fin ray and one under the 6th-8th fin ray) in the musculature under the base of the fin, well above the lateral line. The

[1] In the future we may decide to tag sub-legal fish as well; DFW has only recently started tagging sub-legal fish

[2] Tags placed under the posterior dorsal fin experiences higher loss rates (Smith 1978)

 

Figure 4. Striped bass Peterson disk tag application (left) and PIT tag insertion (right).

two wire ends were fed through each needle, the needles were removed, and the ends of the wire were twisted together 4 to 5 times. The wire ends were twisted centimeter or two away from the fish's body, leaving enough space for the fish to grow, but not so much space that the tag could get caught on debris. The extra wire was cut with a diagonal cutter and the twisted end was folded down against the body of the fish.

In addition to the disk tag, the fish were also implanted with a 2.15 mm diameter half-duplex PIT tag (Oregon RFID, Portland, OR, USA). PIT tags were scanned with a PIT tag reader prior to implantation to ensure that they were functioning. Tags were injected into the abdominal cavity of the striped bass using a syringe injector fitted with a lock needle appropriate for the diameter of the tags (Fig. 4). Tags were scanned with a reader after implantation to ensure the tag was detectable, and the tag number was recorded. Hypodermic needles, wire, and PIT tags were sterilized with NOLVASAN® S (chlorhexidine diacetate) before tagging to prevent bacterial growth. The overall condition of tagged striped bass was assessed and recorded (i.e., good, fair, poor) just after release. Under certain circumstances striped bass were not tagged: fish in poor condition were released without a tag, as were undersized fish (fish less than 460 total length).

Results:

Fyke Trap Operation

One fyke trap each was deployed at Sturgeon Bend and BCID on May 6, 2013. The trap at BCID was fished according to schedule until it was removed on May 16, one week ahead of schedule, due to changes in environmental conditions at the site; river flows began to drop and the trap was no longer fishing at a suitable depth. The trap at Sturgeon Bend was fished according to the established schedule until it was removed on May 24. A total of 12 fish sampling days (days that the trap was tended) occurred at Sturgeon Bend (275 hrs. total, average soak time = 22.91 hrs.), and 7 sampling days occurred at BCID (162.5 hrs. total, average soak time = 23.21 hrs.).

Environmental Conditions:

The main environmental change that occurred during the study was a decline in river flow throughout the month of May. Flow at Vernalis dropped from a high of 3,954 cfs on May 1 to a low of 859 cfs on May 31 (Fig. 5), with a corresponding increase in instantaneous water temperatures (Fig. 6).

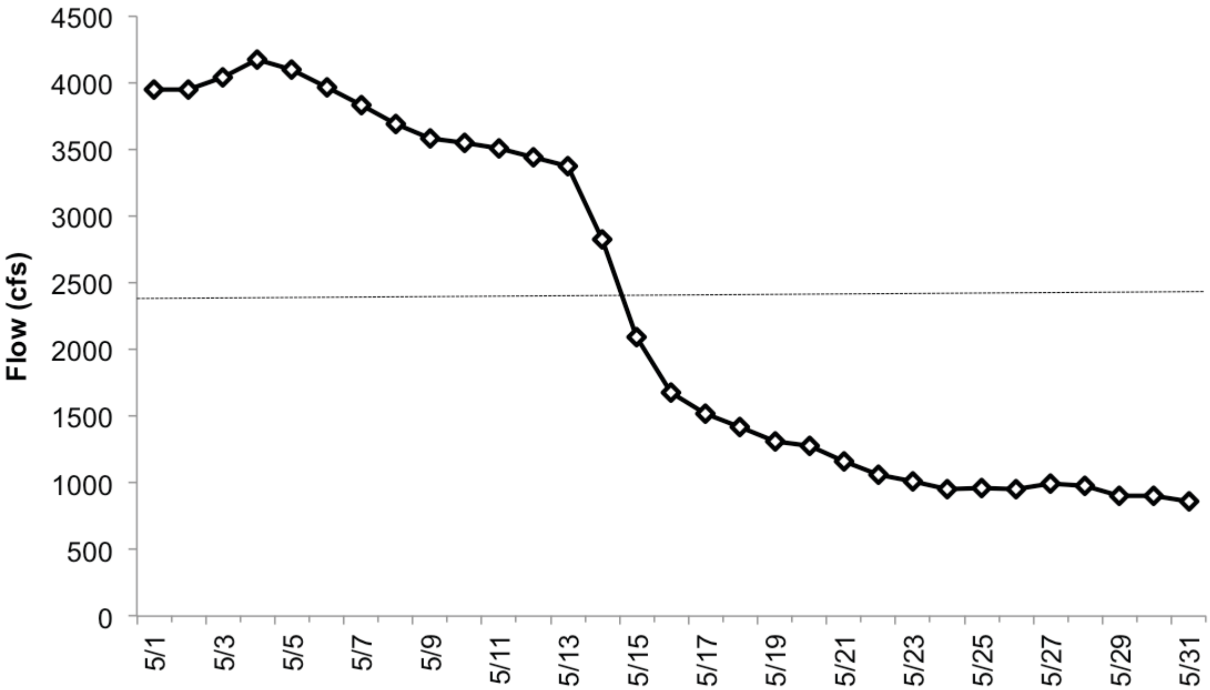

Figure 5. Daily average flow measured at Vernalis (RM 70.8) for May 2013, dashed line represents the daily average flow during the site reconnaissance on February 19, 2013.

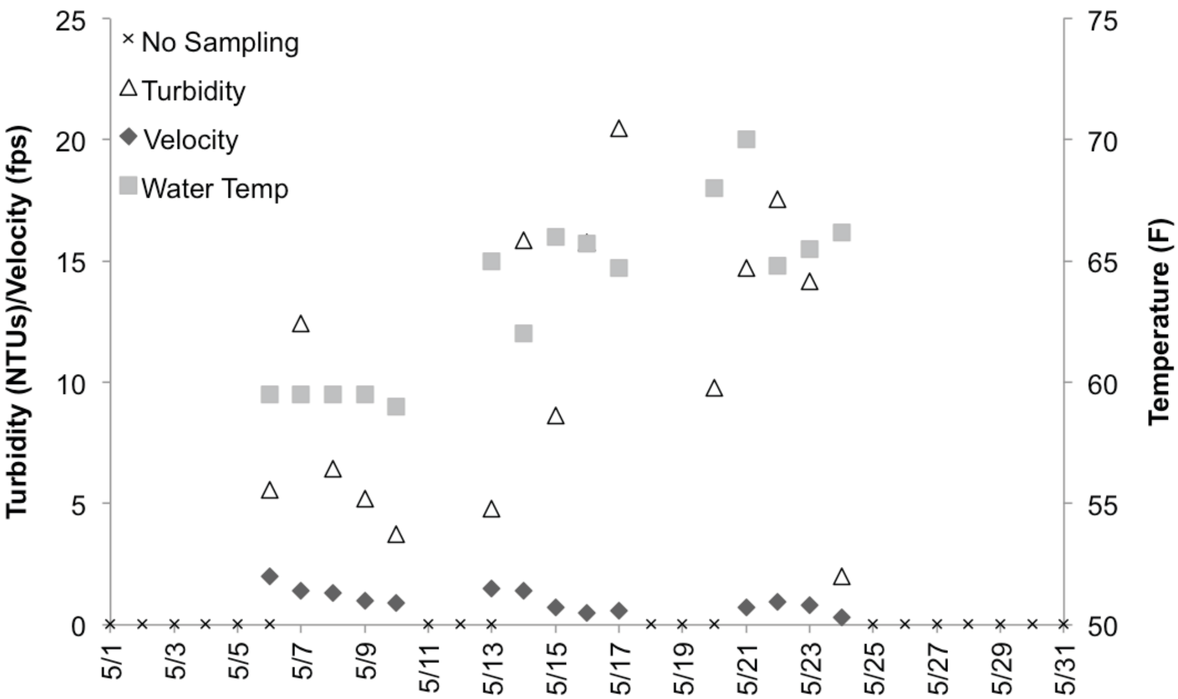

Figure 6. Instantaneous environmental variables measured at the Sturgeon Bend site in May 2013.

Table 1. Count of fish captured by species and by site between May 6 and May 24.

Common Name	Scientific Name	BCID	Sturgeon Bend	Total
American Shad	*Alosa sapidissima*		6	6
Common Carp	*Cyprinus carpio*		1	1
Channel Catfish	*Ictalurus punctatus*		19	19
Chinook Salmon	*Oncorhynchus tshawytscha*		2	2
Largemouth Bass	*Micropterus salmoides*	1	3	4
Sacramento Sucker	*Catostomus occidentalis*		2	2
Striped Bass	*Morone saxatilis*	7	38	45
White Catfish	*Ameiurus catus*	4	11	15
Grand Total		12	82	94

Fish Sampling:

Overall, 45 striped bass and 49 bycatch fishes were captured (Table 1). No tags were found on any captured fish. Overall catch was higher at the Sturgeon Bend site, and certain species were only captured at Sturgeon Bend (i.e., American shad, common carp, channel catfish, Chinook salmon, and Sacramento Sucker). After striped bass, catfishes were the second most abundant catch, with 19 channel catfish and 15 white catfish captured. Channel catfish ranged in size from 144 to 740 mm forklength (FL) (mean = 457 mm FL) and white catfish ranged from 305 to 522 mm FL (mean = 378 mm FL). Six American Shad were captured at Sturgeon Bend, ranging from 340 to 439 mm FL (mean = 377 mm FL). One common carp measured 538 mm FL, two Sacramento suckers each measured 450 mm FL, and four largemouth bass ranged from 352 to 432 mm FL (mean = 383 mm FL).

Two Chinook salmon were captured in the trap (one on May 16 and one on May 24). An additional salmonid, believed to be a Chinook, was captured on May 16, but it escaped through a small hole in the trap mesh before species identification was confirmed. The two measured Chinook were 850 and 865 mm FL and both had intact adipose fins.

The majority of the striped bass captured were between 350 and 700 mm FL, with only four larger fish captured at Sturgeon Bend (Table 2, Fig. 7). Seven sub-legal fish were captured during the course of the study, making up 15.5% of the striped bass captured. Positive identification of male striped bass was recorded for 38 of the 45 individuals; in all cases male bass readily secreted milt during routine handling of the fish for measuring and tagging. Two striped bass captured at Sturgeon Bend were recorded as females (964 and 1015 mm FL), due to a lack of milt secretion. Five striped bass (three at BCID and two at Sturgeon Bend) were assigned to the category “unknown,” but were likely females. The male-to-female sex ratio was highly skewed at 19:1.

Table 2. Minimum, maximum, and mean forklengths (mm) for female, male, and unknown sex striped bass.

	BCID				Sturgeon Bend			
	Min FL	Max FL	Mean FL	Count	Min FL	Max FL	Mean FL	Count
Female	-	-	-	0	964	1015	990	2
Male	385	630	475	4	390	1075	531	34
Unknown	375	555	471	3	610	760	685	2

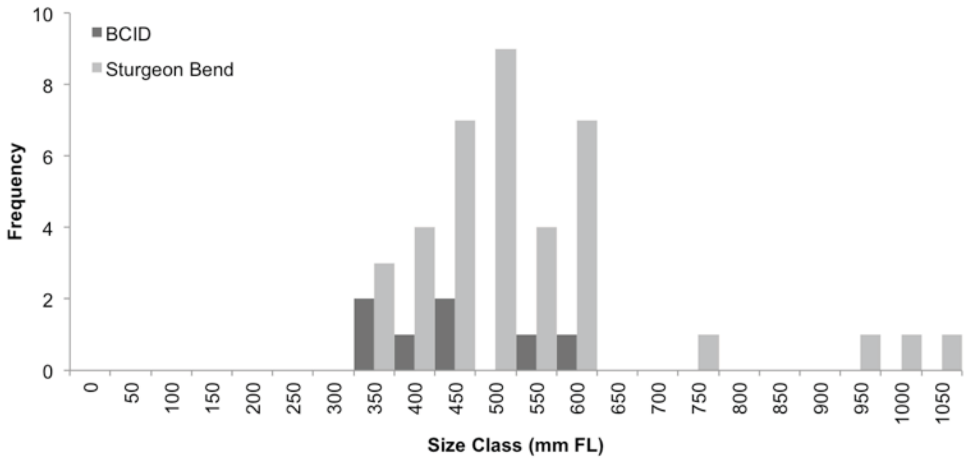

Figure 7. Length frequency of striped bass (n=45) captured in the fyke traps between May 6 and May 24.

Table 3. A comparison of catch-per-unit-effort (CPUE) between Knights Landing (DFW), Banta Carbona Irrigation District (BCID), and Sturgeon Bend. Values for Knights Landing were gathered from annual reports (DuBois and Mayfield 2009, DuBois et al. 2010, 2011, 2012). The rage of CPUE values was not available for 2010-2012, but was estimated based on the report graphs.

CPUE	Knights Landing (DFW)					BCID (FISHBIO)	Sturgeon Bend (FISHBIO)
	2009	2010	2011	2012	2013	2013	2013
Max	0.97	>4	>4	>5	t.b.a.	0.12	0.94
Min	0.00	n.d.	n.d.	n.d.	t.b.a.	0.00	0.00
Mean	0.22	1.17	1.50	1.40	t.b.a.	0.04	0.14

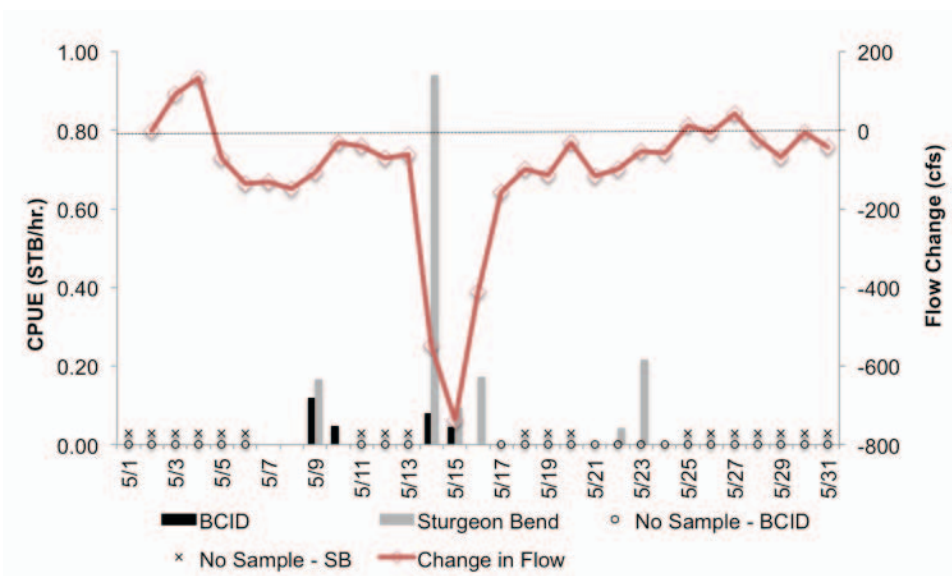

Figure 8. Catch-per-unit-effort (CPUE) measured in striped bass caught per hour of soak time. Days in which the traps were not sampled are denoted as unfilled circles for BCID and small x's for Sturgeon Bend. Change in mean daily flow from the previous day's mean daily flow as measured at Vernalis (cfs). Negative flow change values indicate a decrease in mean flow and positive values indicate an increase in mean flow.

Striped bass CPUE was calculated for each day-long trap set, and ranged from 0 to 0.12 STB/hr. for BCID and 0 to 0.94 STB/hr. for Sturgeon Bend (Table 3, Fig. 8). Due to the small sample size of CPUE values calculated and the correlation among environmental variables, no statistical analyses were conducted. However, it is notable that a single day at Sturgeon Bend (May 14) had substantially higher CPUE and corresponded to the period with the greatest decrease in mean daily flow (Fig. 8). Average CPUE in the SJR (BCID = 0.04, Sturgeon Bend = 0.14) was much lower than recently reported CPUE at Knights Landing in the Sacramento River (Table 3).

Striped Bass Tagging:
Of the 45 striped bass captured, none had been previously tagged, and only five were released un-tagged. These five were all less than 434 mm FL, and were thus less than or close to the legal size limit of 420 mm FL. Three sub-legal striped bass were tagged on May 9. Only two of the 40 tagged fish were given a criteria of "fair" upon release, due to light bleeding after the external or internal tagging. Otherwise, fish were released in "good" condition.

Tagged Striped Bass Recaptures:
No tagged fish were recaptured in the fyke traps during the course of the pilot study, indicating a minimum of 40 legal-sized striped bass were present in the study area over the course of the three weeks. A fisher reported one striped bass carrying tag #039 was captured and retained on June 10 at Windmill Cove in San Joaquin River near the city of Stockton. This tag was applied to a 510 mm FL (552 mm TL) male striped bass on May 23 at Sturgeon Bend. Size at recapture was reported as 22.5" (571.5 mm) and 4 lbs, indicating an approximate growth of 21.5 mm over the 18-day period the fish was at large (assuming accurate and precise measurements were taken).

Additionally, a striped bass bearing a yellow disk tag was visually identified in video footage from the Stanislaus River weir Vaki Riverwatcher system on June 5, indicating that at least one tagged striped bass entered the Stanislaus River (Fig. 9).

Figure 9. Still photo of striped bass passing through Vaki Riverwatcher video system displaying yellow disk tag.

<u>Discussion:</u>

The capture and release of 45 healthy striped bass over the course of three weeks of sampling demonstrates the successful use of fyke traps to capture live striped bass in the mainstem of the

San Joaquin River. However, the lack of recaptured striped bass indicates that a much greater effort (through increasing the number of traps and the number of days of sampling) would be needed for a successful mark-recapture study. The average trap soak time for both BCID and Sturgeon Bend was similar to that of DFW, but the number of traps fished and the overall number of days fished were much lower (DuBois and Mayfield 2009, DuBois et al. 2010, 2011, 2012).

A sampling season of five trap-tending days per-week for two months (40 days total), fishing five traps, would produce an effort of about 4,582 trap hours (22.91 hr./day*40 days*5 traps = 4,582 trap hours). Given the CPUE of approximately 0.14 fish per trap hour (average of the Sturgeon Bend trap) and a similar fish abundance, we would expect to capture about 641 fish (4,582 trap hrs.*0.14 fish per trap hr. = 641 fish). To estimate the amount of effort needed to assess the population of striped bass in the SJR, we would need more information regarding the potential recapture rate. Since no fish were recaptured in the fyke traps during this pilot study, we cannot make an accurate estimation of the trapping effort needed for a mark-recapture study. As an example, DFW captured 2,952 striped bass in 2010 over 125 trap-days (# days* # traps), but only 5 fish were recaptures (DuBois et al. 2010). Thus, about 1 fish in 590 striped bass was a recapture. Likewise in 2012, DFW captured 6,671 striped bass over 214 trap days, but only 29 fish were recaptures; thus, about 1 fish in every 230 striped bass was a recapture (DuBois et al. 2012).

Based on the CPUE values for the SJR during this pilot study, it appears that the abundance of striped bass in the SJR is less than the abundance in the Sacramento River. This is in agreement with previous studies that indicated fewer fish spawn in the SJR. DFW studies found a subtle shift in the 1960s and 70s in spawner abundance, with fewer fish spawning in the San Joaquin River and Delta, and more spawning in the Sacramento River, presumably due to poor water quality (e.g., higher salinity) in the San Joaquin (Turner 1976). However, a full effort towards a mark-recapture program in the San Joaquin River would be necessary to provide an estimate of the population.

Juvenile salmon survival has been extremely low over the past ten years in the SJR and South Delta relative to results of similar studies conducted in the Sacramento River, regardless of flow and water exports (Perry et al. 2010, San Joaquin River Group Authority 2013), and some researchers believe that predation has played a role. To understand whether predation by striped bass or other piscivorous fishes may be having a different impact on outmigrating smolt populations in the SJR in comparison to the Sacramento River, it is not the absolute abundance of striped bass in each basin that is important to estimate, but rather the abundance of striped bass relative to the abundance of outmigrating salmon smolts. For example, there may be more striped bass present in the Sacramento River, but also many more salmon smolts present, in the spring compared to the SJR basin. Several years of rotary screw trap data have been collected in both river basins, which can be used to inform estimation of this ratio. This underscores the need for a long-term monitoring study of the abundance of not only salmon smolts, but also striped bass and other predators in the SJR. These data could then be compared to the predator abundance and smolt abundance data collected in the Sacramento River at Knights Landing.

The sex-ratio of striped bass captured in this study was highly skewed towards males (19:1), but this is in agreement with the DFW data, which indicate that males are much more abundant than females in the Sacramento River. The sex-ratio of males to females at Knights Landing has ranged from 12:1 to 60:1 over the past four years (DuBois and Mayfield 2009, DuBois et al. 2010, 2011, 2012).

It is noteworthy that the single day at Sturgeon Bend with substantially higher CPUE (May 14) corresponded to the period with a sudden decrease in mean daily flow. It is possible that the change in flow triggered an upstream movement of striped bass, but the data are too limited to support this hypothesis.

This pilot study provided an opportunity to learn how to adapt DFW's protocols to the San Joaquin River. Some lessons learned include:

- Fyke traps set to the same specifications of the traps used in the Sacramento River by DFW were deemed too large in the present study. The San Joaquin River is generally quite shallow during the late spring. During the pilot study there happened to be unusually high flows at the start of the sampling period. However, as the flows dropped throughout May, the traps became increasingly more exposed, until water depth at the trap at BCID was deemed too low and the trap was removed. This demonstrated the challenge of using DFW's trap design in the SJR. Due to the lower water depth in the SJR, we recommend reducing the trap diameter from 10 feet to 8 feet. Although this will reduce the volume within the live box of the trap, based on the number of fish captured during the pilot study, we do not feel that the reduction in volume would endanger the health of any fishes captured in the trap.

- Side-scan sonar was used to assist in site selection at the Sturgeon Bend site, but not at the BCID site. We recommend the use of sonar to determine depth and substrate levelness for future fyke trap sampling in the San Joaquin River due to the relatively low river depths, and uneven substrate. There were occasional issues at the BCID site with levelness that caused the trap to deploy askew. This issue could be avoided with more informed trap placement.

- We recommend reinforcing the wooden supports with 1/8" channel. After the wooden supports had been soaking in the river, they occasionally broke during trap deployment and retrieval.

- Ideally, the study should have started in April to coincide with the timing of DFW's striped bass sampling program, and the presumed time of striped bass spawning in the San Joaquin River. Our permit allowed us to sample in April and May, but delays in the construction of the traps set the starting date back, and limited the total number of sampling days.

- The number of days the trap is fished each week could be increased with minimal staff overtime by deploying the traps on Sunday mornings. Under this scenario, the trap would be checked 5 days per week. This would likely add an additional 3 hours of work for the crew each weekend (depending on the number of traps fished).

- There are two types of population modeling approaches: models that assume the population is "open" (i.e., movement occurs in an out of the sampling area), and models that assume the population is "closed" (with no movement in and out of the sampling area). Given the mobility of striped bass, we would assume an open population to specifically estimate the abundance of striped bass in the San Joaquin River (i.e., fish can be "lost" to or "gained" to/from the rest of the Central Valley). If the SJR population is an open population, more parameters are estimated, and the resulting abundance estimates will be less precise than those based on a closed model. A recent study in the Central Valley demonstrated that resident subpopulations exist in the Delta (Walsh 2011), and striped bass movement studies (i.e., telemetry approach) are needed to better understand whether the SJR population should be treated as an open or closed population. We recommend that if this pilot study is implemented as a full-scale study in the future, an acoustic telemetry component should be included. There are already several agencies using VEMCO acoustic technology throughout the SJR basin (including two receivers in the Sturgeon Bend reach) for the San Joaquin River Restoration Program fisheries projects, and the study may be able to coordinate with these projects to optimize receiver placements and data sharing.

- Evidence that at least one of the tagged striped bass passed through the Stanislaus River weir indicates that the addition of PIT tag antennas to all the weirs in the SJR basin could provide valuable information on the striped bass population. PIT tag antennas could also be designed to sample across shallow portions of the tributaries. Since PIT tags are uniquely coded, antenna detections can provide information on how often an individual striped bass moves into/out of the tributary, how long a striped bass stays in the tributary, whether the same individual moves between tributaries, and whether the same individual returns to the same tributary each spring. These residency rates can inform management decisions regarding the feasibility of predator removal programs, which have been proposed for the SJR basin. Furthermore, the PIT tags should remain viable in the striped bass throughout the life of the fish, thus there is high potential for long-term data collection on individual predator fish. This kind of information can be paired with predator diet sampling studies so that an individual's movements could possibly be linked to their diet inside the tributaries.

The results of this pilot study have demonstrated the successful use of fyke traps to capture live striped bass in the mainstem of the San Joaquin River. This method, which has been used for decades in the Sacramento River basin, is minimally invasive, and has minimal impacts on other species such as listed salmonids (all captured salmonids were released in good condition). The challenges associated with the lower water depths of the San Joaquin River may be overcome by improved site selection (i.e., using side-scan sonar) and re-sizing of the traps (i.e., 8 foot diameter traps). The mark-recapture of striped bass would not only provide an estimate of population abundance, but the sampling could also provide a platform for other valuable research on striped bass movements using PIT and acoustic telemetry technologies.

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