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MANAGEMENT BRIEF

Evidence of Landlocked Chinook Salmon Populations in California

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Abstract

Natural reproduction of adfluvial Chinook Salmon *Oncorhynchus tshawytscha* has been documented in their native and introduced range but not in California, the southern end of their native range. A combination of anecdotal evidence and survey data suggests that successful spawning by Chinook Salmon reared in California reservoirs could be common. The planted juveniles are often from different basins and are genetically distinguishable from local salmon populations below reservoirs. Consequently, the possibility of behavioral and genetic interactions may lead to complications of restoration efforts via trap and haul programs. The full extent of this phenomenon needs to be documented before trap and haul programs are initiated to reintroduce salmon above reservoirs.

Chinook Salmon *Oncorhynchus tshawytscha* are anadromous, with native populations distributed throughout rivers and streams of the Pacific Coast. This includes central California, Canada, Alaska, Russia, and northern Japan (Moyle 2002). Self-sustaining landlocked populations are rare or absent in their native range, although such populations have become established through introductions in the Laurentian Great Lakes (Lever 1996; Crawford 2001; Landsman et al. 2011), in Lake Coeur D'Alene in Idaho (NPCC 2004), Lake Chelan and Lake Cushman in Washington (Quinn and Myers

2005), Lake Puyehue in Chile (Soto et al. 2007; Correa and Gross 2008), Green Peter Reservoir in Oregon (Romer and Monzyk 2014), and several lakes in New Zealand (Graynoth 1999; Quinn et al. 2001). Fish in these populations are adfluvial spawners and complete their entire life histories in freshwater. Landlocked reproducing populations have not been recorded from California, at the southern end of their range, although juvenile fall-run Chinook Salmon from hatcheries have been planted in reservoirs for decades to support sport fisheries. It was assumed that these fish would grow to harvestable size in reservoirs but no reproduction would take place. For example, in New Don Pedro Reservoir (Tuolumne River), hatchery Chinook Salmon have been planted periodically starting in 1982 (Turlock and Modesto Irrigation Districts 2011; Table 1). Here we provide evidence of spawning by adfluvial Chinook Salmon in six California reservoirs: New Don Pedro, Folsom, Trinity, Almanor, Pine Flat, and Shasta reservoirs (Figure 1).

STUDY AREAS

New Don Pedro Reservoir. —New Don Pedro Reservoir is a multipurpose reservoir located on the main stem of the Tuolumne River, in Tuolumne County, California. The reservoir has a maximum capacity of 2.50×10^9 m³ and is California's 6th largest reservoir in terms of storage. The reservoir has a

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TABLE 1. Juvenile Chinook Salmon stocking records from New Don Pedro, Folsom, Trinity, Almanor, Pine Flat, and Shasta reservoirs. All fish are diploid fish from the Iron Gate Hatchery, located on the Klamath River, unless otherwise noted.

Reservoir	Number of Chinook Salmon smolts stocked each year													
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
New	125,376 ^a	177,900	0	100,000	100,440	70,015	91,000	93,995	100,006	100,000	129,980	99,997	0	90,035 ^c
Don Pedro														
Folsom	0	100,800	0	0	73,470	117,800 ^b	0	0	0	0	0	0	0	99,990 ^c
Trinity	0	9,940	32,775	25,025	0	25,530	25,004	60,030	33,908	0	0	31,075	0	44,800
Almanor	163,800 ^a	100,008	0	176,100	60,420	43,560	60,270	59,994	33,792	60,000	65,030	59,993	0	53,985 ^c
Pine Flat	125,250 ^a	75,000	0	75,400	0	54,978	56,940	75,072	0	75,000	75,020	74,999	100,000	74,991
Shasta	36,720	48,843	50,500	67,182	54,270	72,982	56,745	46,100	53,350	87,840	94,500	0	0	12,338 ^c

^aFish from Nimbus Fish Hatchery on the American River.

^bFish from Feather River Hatchery.

^cSterile, triploid fish; M. Clifford, California Department of Fish and Wildlife, unpublished data.

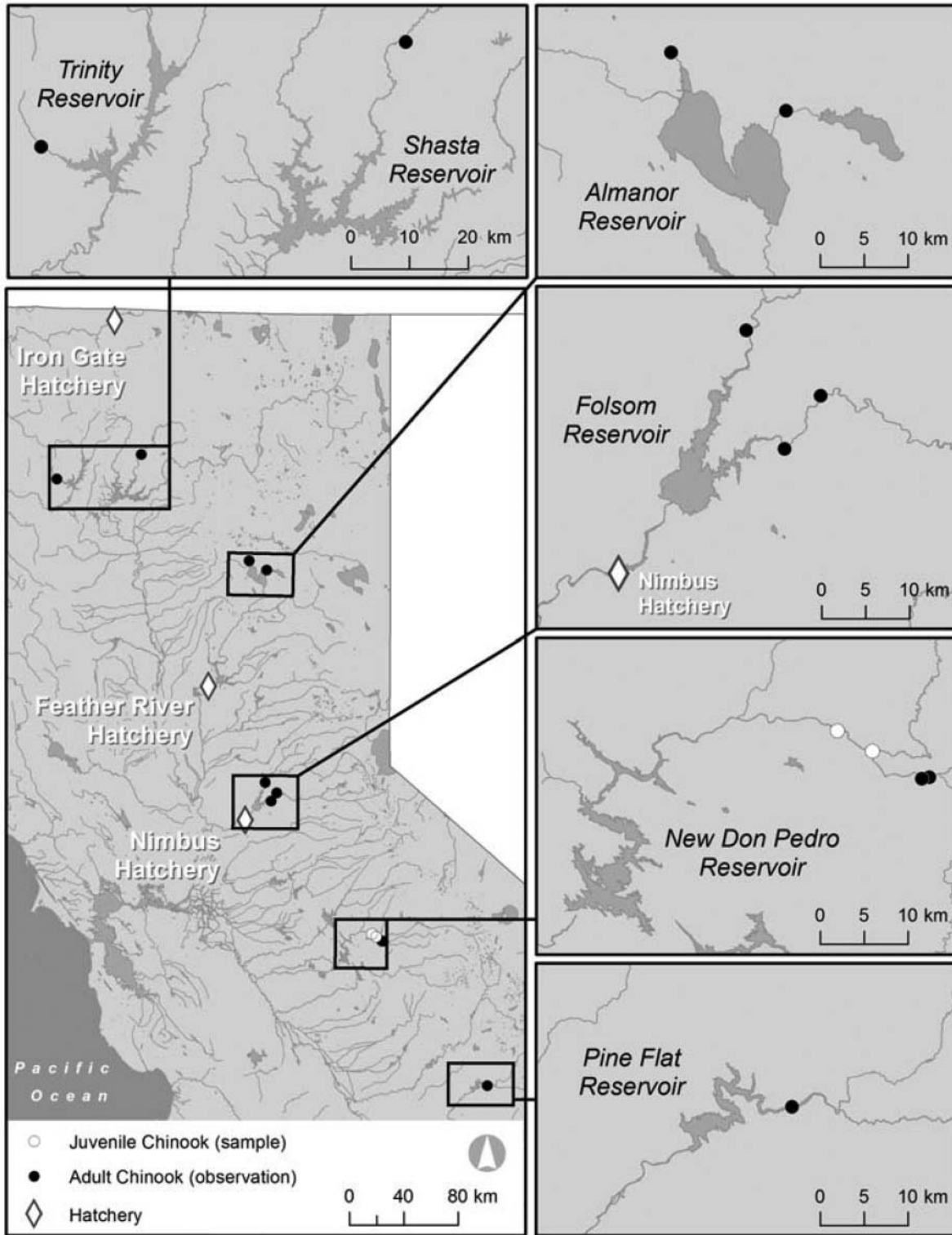


FIGURE 1. Map of California with locations of hatcheries, reservoirs, and observational data.

surface area of roughly 53 km² and a maximum water height of 253 m. The reservoir's main purpose is to store water for agricultural, industrial, and municipal uses, as well as for flood management. The reservoir also provides recreational and

environmental flows, in addition to hydroelectric power generation (Turlock and Modesto Irrigation Districts 2011). New Don Pedro Reservoir has been regularly stocked with juvenile Chinook Salmon, quite heavily in some years (Table 1). These



FIGURE 2. A juvenile Chinook Salmon, about 9 cm FL, from the Tuolumne River above New Don Pedro Reservoir, May 18, 2012.

juveniles are fall-run Chinook from Iron Gate Hatchery on the Klamath River (M. Clifford, California Department of Fish and Wildlife [CDFW], personal communication). New Don Pedro Dam is impassible for salmon migrating upstream. However, prior to construction in the late 1870s of LaGrange Dam, located downstream of New Don Pedro Dam, Chinook Salmon presumably used the upstream region for spawning and rearing (Yoshiyama et al. 1998).

Eight Chinook Salmon juveniles were collected in the Tuolumne River above the reservoir in 2012. Sampling was conducted after sundown with a 30-ft bag seine and was landed on gravel bars. On May 18, 2012, six of the fish were collected on the downstream end of a gravel bar directly across from where Indian Creek meets the Tuolumne River ($37^{\circ}53'04''\text{N}$, $120^{\circ}09'10''\text{W}$), about 14 km above the reservoir. On June 19 and 20, 2012, two juveniles were collected on the left bank above the confluence of the Tuolumne River and the Clavey River ($37^{\circ}51'49''\text{N}$, $120^{\circ}07'00''\text{W}$). All fish appeared to be in good condition and ranged in length from 65 to 100 mm fork length (FL; Figure 2). The collected fish were silvery bright, which suggests they were smolts moving downstream to the reservoir. In October 2009, three adult Chinook Salmon in spawning colors were observed around Lumsden campground ($37^{\circ}50'13''\text{N}$, $120^{\circ}03'31''\text{W}$; $37^{\circ}50'08''\text{N}$, $120^{\circ}03'58''\text{W}$), about 8 km upstream from where the smolts were collected. All fish observed were between 250 and 450 mm standard length (Weaver and Mehalick 2009).

Folsom Reservoir.—Folsom Reservoir is located just below the confluence of the North and South Fork of the American River in Placer, Sacramento, and El Dorado counties, California. The reservoir is California's 9th largest reservoir with a capacity of $1.20 \times 10^9 \text{ m}^3$ and a surface area of 46 km^2 . The main functions of the reservoir are to generate hydropower, provide flood protection, provide recreational and environmental flows, and enhance water quality downstream (U.S. Department of the Interior and U.S. Bureau of Reclamation 2012). Folsom Reservoir has been periodically stocked with fish from Iron Gate Fish Hatchery, located on the Klamath River, and from Nimbus Fish Hatchery, located on the

American River, just downstream of the reservoir. The most recent stocking of reproductively viable fish took place in 2006, with 117,800 American River Chinook Salmon juveniles being released (Table 1; Clifford, unpublished data).

California Department of Fish and Wildlife biologists conducted snorkel surveys of the South Fork American River on October 4 and 21 2010, in response to reports from fisherman catching small adult Chinook Salmon in Folsom Reservoir, 4 years since the last known stocking event. The snorkel survey confirmed the presence of Chinook Salmon in significant numbers; 106 salmon were observed over 10 km of the South Fork of the American River. Roughly 66% of Chinook Salmon surveyed were $> 450 \text{ mm}$ standard length; the rest of the fish ranged from 305 to 450 mm standard length. A single redd was observed in the uppermost reach of the survey. In addition, gravid females were collected during 2009 and 2010 CDFW electrofishing surveys in the North Fork and South Fork of the American River (J. Rowan and K. Thomas, 2010 file memorandum to the CDFW, on snorkel survey and electrofishing data). This strongly suggests that there have been at least 2 years in which these Chinook Salmon spawned in numbers great enough to sustain a small population in freshwater.

Trinity Reservoir.—Trinity Reservoir is located on the Trinity River, in Trinity County. The reservoir has a maximum capacity of $3.02 \times 10^9 \text{ m}^3$ and a surface area of 63 km^2 . The main function of the reservoir is to produce hydroelectric power and to act as water storage. Trinity Reservoir is stocked with juvenile Chinook Salmon from Iron Gate Hatchery on the Klamath River (Clifford, personal communication; Table 1).

Spawning Chinook Salmon were observed in Stuart's Fork of the Trinity River in October 2011 and November 2012. Observed fish had spawning colors and appeared to be ready to spawn. Males had developed kypes and females appeared to be gravid (J. Muegge, recreational fisherman, personal communication). In addition, on November 15, 2012, fish exhibiting spawning behavior, several carcasses, and about 24 redds were observed in a 3.5 km reach of the Stuart's Fork (B. Aguilar, CDFW, personal communication).

Other reservoirs.—Adult Chinook Salmon have also been observed above Almanor Reservoir around Hamilton Branch (J. Rowan, unpublished observations). Photos of inland Chinook Salmon in spawning colors were taken recently in Last Chance Creek above Almanor Reservoir (M. Fish, CDFW, personal communication). A pair of Chinook Salmon on a redd in Kings River above Pine Flat Reservoir was observed in 1986 (K. Murphy, CDFW, personal communication). Healey and Rode (1994) reported seven adult Chinook Salmon passing through a weir on the McCloud River above Shasta Reservoir in 1986, the only year the weir was working. Authors noted that fish appeared to be in prespawning condition. Additionally, Moyle (2002) reported observations of adult Chinook Salmon in streams above Shasta and Almanor reservoirs.

DISCUSSION

While the evidence we present here is limited to observational data, we have confirmed that spawning by land-locked Chinook Salmon occurs in several California reservoirs. Given that the observations are all of fish in rivers once used by anadromous fishes, occurrence of natural spawning above reservoirs should not be too surprising, especially given the high frequency of planting of juvenile Chinook Salmon in reservoirs. Determining if these populations are self-sustaining is an important next step. The only population that we can say has been maintaining itself is the Folsom Reservoir population. The reservoir had received Chinook Salmon juveniles 4 years prior to sampling by CDFW, which observed numerous adult salmon migrating to rivers, a single redd and gravid females. This strongly suggests that Chinook Salmon have reproduced naturally in great enough numbers to sustain a small recreational fishery. This sets Folsom Reservoir apart from New Don Pedro in particular, which has received constant stocking on an annual basis. Thus, the spawning runs from Folsom Reservoir indicate that a self-sustaining population can become established.

In 2014, a program of planting sterile triploid juvenile Chinook Salmon was initiated for New Don Pedro and Folsom reservoirs, providing an opportunity to discover or confirm whether the existing populations are reproducing themselves (Clifford, personal communication). Trapping adult salmon below dams and trucking them to upstream spawning areas, followed by capture of juveniles and trucking them to downstream areas, is being proposed as a conservation strategy for Central Valley Chinook Salmon. Surveys of possible spawning and rearing areas for Chinook Salmon of reservoir origin could provide insights into the potential for success of this strategy, as an indication of the extent and quality of spawning and rearing habitat. Such surveys could also indicate the potential for behavioral and genetic interactions between “natural” and planted fish. This is important because most salmon planted in Central Valley reservoirs originate from the Klamath River and are genetically distinguishable from other California Chinook Salmon (Waples et al. 2004). In a trap-and-haul operation, it can be difficult to distinguish between juveniles of different origins, including hybrids.

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