



Residence of Juvenile Winter-Run Chinook Salmon in the Sacramento-San Joaquin Delta: Emigration Coincides with Pulse Flows and Floodplain Drainage

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Abstract

The Delta provides essential habitat for juvenile Sacramento River winter-run Chinook salmon as they rear and physiologically transform for ocean life. We identified patterns of juvenile migration entering and exiting the Delta by using monitoring data from the lower Sacramento River at Knights Landing and in the western Delta at Chippis Island. Average residence time in the Delta ranges from 2.5 to 3 months, and generally spans from November through April, with the majority of the population leaving in March. The onset of emigration to the Delta at Knights Landing is cued by upstream flows of 15,000 cfs at Wilkins Slough, and emigration from the Sacramento River to Chippis Island follows pulse flows of 20,000 cfs at Freepoint. Smolts exit the Delta later in years when the Yolo Bypass floods. Understanding how flows affect residence of winter-run Chinook Salmon in the Delta is crucial to informing current water management decisions seeking to balance water demands and species conservation.

Introduction

Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) are endemic to California's Central Valley. Only one population of winter-run remains since their freshwater range has been limited from the upper Sacramento River below Keswick Dam to the Sacramento-San Joaquin Delta (Delta). The population's endangered status provides them protection under the federal Endangered Species Act, which affects natural resource uses in the Central Valley. Their sole route from freshwater to the ocean involves rearing and migrating through the Delta. Managing the Delta for this endangered species requires knowledge of when winter-run are in the Delta and how long they rear in the Delta.

Data Sources

Data on size, relative abundance, and residence time in the Delta were obtained for winter-run-sized fish from the following monitoring stations:

- Knights Landing, rotary screw trap, 1996-2008, California Department of Fish and Game.
- Sherwood Harbor, midwater and kodiak trawl survey, 1995-2008, U.S. Fish and Wildlife Service.
- Chippis Island, midwater trawl survey, 1995-2008, U.S. Fish and Wildlife Service.

Results and Discussion

1. Size and relative abundance show winter-run rear in the Delta.

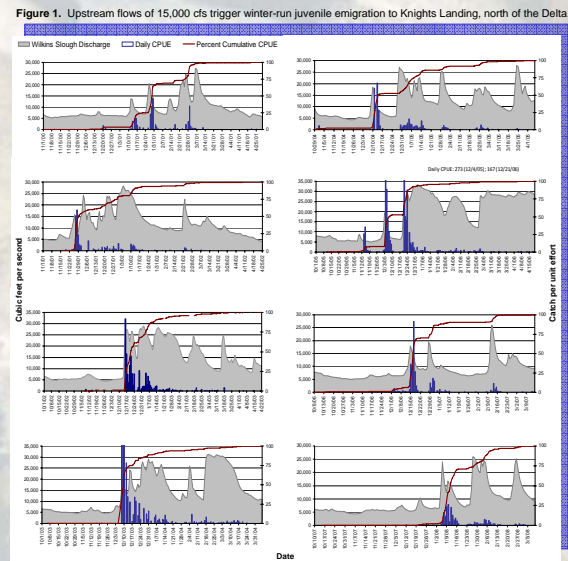
Table 1. Mean Fork Length (mm) for Juvenile Winter-run Chinook salmon in the Delta, 1995-2008

Monitoring Site	Oct	Nov	Dec	Color Key for Relative Abundance					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
				High	Medium	Low	None/Rare											
Knights Landing (River Mile 51.5)	47	66	74	87	95	100	127											
Sacramento Trawl (River Mile 55)	44	74	85	107	104	114												
Chippis Island (River Mile 5)			59	104	115	118	137	140										

Winter-run smolts stay in the Delta an average of 2.5 to nearly 3 months. Early fry-sized (<70 mm) winter-run are detected in and north of the Delta starting in October followed by smolt-sized winter-run (>70 mm) starting December through April. These early fry migrants may be the first juveniles detected at Chippis Island in December where they are captured as smolts. The size distribution patterns as juveniles enter and exit the Delta suggest winter-run successfully rear and grow in the Delta. The monthly fork length distributions at the monitor sites indicate growth as the juveniles transit the Delta en route to the estuary. The large smolt-sized juveniles passing Knights Landing in April are likely the bulk of the May population caught at Chippis Island. Data from the monitoring sites clearly indicate rearing occurs in the Delta.

2. Upstream flows drive winter-run juvenile migration into the Delta.

The first autumn pulse flow exceeding 15,000 cfs triggers 50 percent of the population to enter the Delta on average four days following the event. The early migration pattern is abrupt as shown by the steep slope of cumulative catch per unit effort (Figure 1). The key management implication is that flows should be maintained to create sufficient rearing and migratory habitats in the Delta upon the abrupt entry of juveniles into the Delta triggered by pulse flow events.



3. Floodplain inundation influences timing of Delta exit.

A secondary rearing and migratory route into the Delta becomes available to juvenile winter-run Chinook salmon in the Yolo Bypass during flood stage events in the Sacramento River. Chinook salmon rear in the Yolo Bypass floodplain each season it is inundated, and catch at the downstream end of the floodplain was greatest during the receding limb of the floodplain hydrograph (Sommer et al. 2005, North American Journal of Fisheries Management 25:1493-1504).

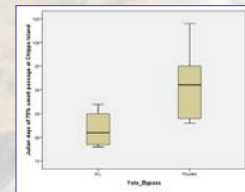
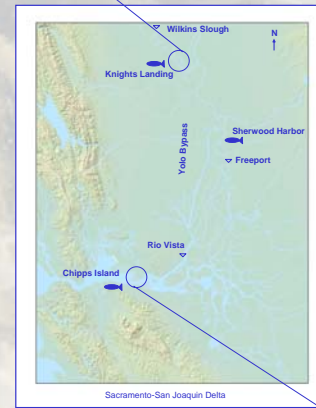


Figure 2. Smolts pass Chippis Island later in years when Yolo Bypass inundates (T-test, p = 0.03, n=4 for dry years; n=6 for flooded years).

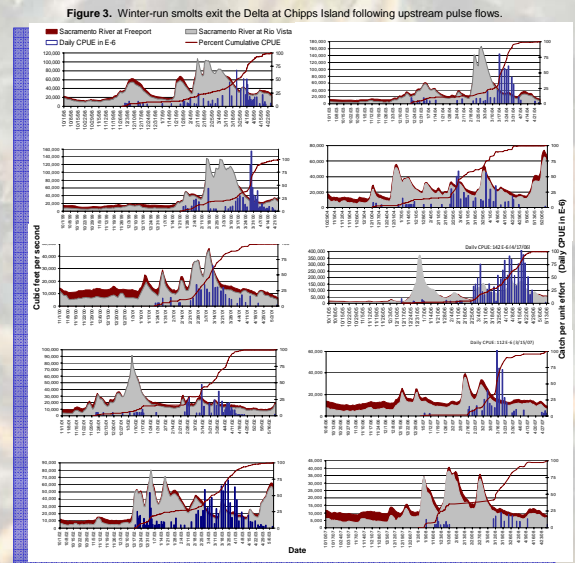
Table 2. Juvenile winter-run emigration to Chippis Island in the month of March.

Year	Percent of total population exiting in March	Cumulative percent of population captured at		March Freepoint flow		March Rio Vista flow	
		March 1st	March 31st	Minimum (cfs)	Maximum (cfs)	Minimum (cfs)	Maximum (cfs)
1996	52	50	65	34,000	74,700	21,420	132,000
2000	56	19	75	27,500	81,500	22,410	132,000
2001	57	31	86	14,400	46,200	11,300	44,300
2002	36	29	65	17,270	28,800	13,900	20,900
2003	43	43	66	15,800	30,600	12,440	39,210
2004	78	16	86	24,400	71,200	16,000	144,200
2005	33	14	77	18,500	53,900	14,900	47,400
2006	37	9	46	57,500	71,500	60,130	150,000
2007	78	14	80	12,500	33,700	9,700	28,370
2008	45	42	87	30,200	28,000	2,100	20,700
mean	50	38	76	22,754	52,881	20,140	72,456
median	44	29	62	18,400	53,900	14,240	40,000



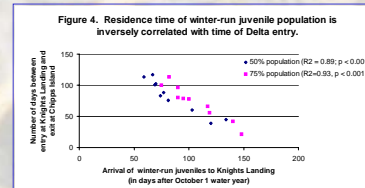
4. Delta exit follows pulse flows, with majority leaving in March.

The first emigration to Chippis Island occurs on average 9 days following Sacramento River flow events exceeding 20,000 cfs, measured at Freepoint (Figure 3). These early emigrants represent passage through the only available route along the lower Sacramento River and North Delta distributaries since the secondary route through Yolo Bypass becomes available upon inundation later in the season. In a typical year, 50 percent of the population leaves the Delta at Chippis Island during the month of March (Table 2). During this month, smolts migrating through the North Delta experience Sacramento River flow ranging from median flows of 18,240 cfs to 50,050 cfs, measured at Freepoint.



5. The earlier winter-run enter the Delta, the longer they stay.

Juvenile residence time in the Delta is a function of time of entry into the Delta, which is triggered by upstream Sacramento River flows. Given the consistency in timing of smolt exit from the Delta in March (Table 2, Figure 3), the earlier in the season juveniles enter the Delta, the longer their residence time in the Delta (Figure 4). In a two-way ANOVA, residence time is significantly related to arrival time (p < 0.001) and flooding of the Yolo Bypass (p = 0.10).



Conclusions

- Winter-run Chinook salmon rear in the Delta an average of 2.5 to 3 months starting in the late fall through early spring. Half of the population exit the Delta at Chippis Island between March 1 and 31.
- Autumn upstream flows exceeding 15,000 cfs trigger a large portion of the emigrating juvenile population into the Delta on average four days after the event.
- Emigrating smolts start leaving the Delta in the late winter on average nine days after pulse flows exceeding 20,000 cfs, measured at Freepoint.
- The early emigrating smolts leaving the Delta at Chippis Island have only the Sacramento River system available as their migratory route.
- Residence time in the Delta is a function of when juveniles enter the Delta and flooding of the Yolo Bypass. Earlier arrival to the Delta yields longer residence time. Availability of floodplain rearing habitats provide for longer residence time.

These findings can help managers provide for rearing and migratory habitats in the Delta while winter-run Chinook salmon are present.