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Salvage of Hatchery-Released Juvenile Steelhead at the State Water Project and Central Valley Project Fish Facilities.

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Introduction

Four Central Valley anadromous fish hatcheries release Central Valley steelhead into the Sacramento and San Joaquin rivers or their tributaries (McEwan 2001). Coleman National Fish Hatchery (a federal hatchery located on Battle Creek in the upper Sacramento River), Nimbus Hatchery (located on the American River), and the Feather River Hatchery all release steelhead yearlings directly into the Sacramento River or its tributaries. The Mokelumne River Fish Installation releases steelhead into the Mokelumne River, a tributary of the San Joaquin River that flows directly into the interior Delta.

Two large fish salvage facilities in the southern Delta of the San Francisco Bay Estuary, the Central Valley Project's (CVP) Tracy Fish Collection Facility and the State Water Project's (SWP) Skinner Delta Fish Protective Facility, divert (salvage) fish from exported water. Both facilities use a louver-bypass system to collect fish, which are then transported to release sites in the Delta. Although the salvage process does reduce the losses of steelhead, SWP and CVP water diversions from the Sacramento-San Joaquin Delta-estuary adversely affect steelhead through increased exposure to predators, disruption of their migration route, and through direct mortality from salvage operations. To date, no studies on the effect of the Delta water operations on emigrating hatchery-released steelhead have been done.

Mokelumne River hatchery releases accounted for about 7% (0-10% annually) of hatchery steelhead released in the Central Valley between 1998 and 2003 (DFG unpublished data). A relatively high percentage of these releases are expected to be salvaged at the south Delta export facilities due to the proximity of the release site to those facilities. Delta hydrology also makes fish released in the Mokelumne River more vulnerable to salvage at the facilities, since a relatively high proportion of the San Joaquin tributary flows are entrained by the export facilities compared to Sacramento River flows. Steelhead from all the other hatcheries are released either directly into the Sacramento River or into Sacramento River tributaries far upstream of the Delta. For these fish to make their way to the export facilities, they must enter the interior Delta through either the Delta Cross Channel, Georgiana Slough or near the confluence of the Sacramento and San Joaquin rivers.

The analysis reported here has two objectives: 1) determine which hatcheries are contributing most to the salvage of steelhead at the water export facilities; and 2) calculate transit times from release to salvage at fish facilities.

Methods

The analysis presented here is based on the source identification of salvaged steelhead with coded wire tags (CWT) applied at the various hatcheries from 2000 to 2004. Salvaged steelhead were examined for adipose fin clips and scanned by a metal-detecting wand for the presence of CWTs. If CWTs were detected, fish were sacrificed for later tag removal. Criteria for sacrifice of CWT steelhead varied. In 2000, all fish with a CWT were sacrificed, but after 2000, only fish 300 mm or smaller were sacrificed.

CWTs from hatchery-released steelhead were extracted and their codes recorded. Release dates for groups of CWT steelhead were obtained from the Regional Mark Information System (RMIS) website. Transit times were calculated by subtracting the date of salvage from the date of release.

From 2000 to 2003, only two hatcheries used CWTs to mark hatchery fish, Coleman National Fish Hatchery and Feather River Hatchery. In 2004, Mokelumne Fish Installation applied CWTs (as did Coleman), but Feather

River Hatchery did not tag any steelhead with CWTs, apparently due to funding restrictions (Bob Kano, personal communication). No steelhead were tagged with CWTs at Nimbus Hatchery in any year.

Fish entrained into the water export system were sampled at the SWP and CVP fish facilities at regular intervals by diverting the entire fish salvage flow into a separate holding tank. All steelhead in each sample were counted and measured. Although counts are typically used to estimate total salvage by multiplying the observed number of fish by the total minutes pumping divided by the sample length, counts were not expanded for this analysis.

Relationships between median annual transit times and Delta outflow were analyzed by simple correlation. Daily Delta outflow was obtained from DAYFLOW (CDWR 1986) and were averaged for the months of January and February of each year.

Results

Of the two hatcheries releasing CWT steelhead from 2000-2003, more salvaged steelhead came from Feather River Hatchery each year (Table 1). In 2003, almost 92% of CWT steelhead salvaged at the fish facilities were from the Feather River Hatchery (Table 2). In 2004, the first year that Mokelumne steelhead were tagged, about 91% of salvaged hatchery steelhead were from the Mokelumne hatchery and no CWT steelhead from the Feather River Hatchery were salvaged.

Median annual transit days from release to salvage ranged between 28.5 days and 75.0 days for Coleman Hatchery steelhead and between 38.5 days and 55.0 days for Feather River Hatchery steelhead (Table 3). Annual median transit time was greatest in 2003, especially for steelhead released from Coleman Hatchery. In 2004, median transit time was 25.0 days for steelhead released in the Mokelumne River. Transit times for individual fish varied substantially, from 6 to 409 days. Two fish salvaged in 2000 had transit times greater than 365 days,indicating possible overwintering.

Table 1 Annual numbers of hatchery-released CWT steelhead salvaged at CVP and SWP fish facilities.

Sample Year	*Coleman*	*Feather*	*Mokelumne*	*Total*
2000	44	55	N/A	99
2001	19	52	N/A	71
2002	14	20	N/A	34
2003	9	97	N/A	106
2004	9	N/A	93	102
Total	95	224	93	412

Table 2 Annual percent of salvaged CWT steelhead from each hatchery.

Sample Year	*Coleman*	*Feather*	*Mokelumne*	*Total*
2000	44.4	55.6	N/A	100.0
2001	26.8	73.2	N/A	100.0
2002	41.2	58.8	N/A	100.0
2003	8.5	91.5	N/A	100.0
2004	8.8	N/A	91.2	100.0

Median annual transit times for Coleman Hatchery steelhead were weakly positively correlated with January-February mean Delta outflow ($r = 0.12$) and median annual transit times for Feather River Hatchery steelhead also were weakly positively correlated with January-February mean Delta outflow ($r = 0.34$).

In 2004, Mokelumne River steelhead took about 5 days longer, on average, to arrive at the SWP facility than the CVP (Table 4), but for salvaged steelhead from other hatcheries there was no discernable trend in transit times between the two facilities.

Table 3 Median number of days between release and salvage at fish facilities.

Salvage Year	*Coleman*	*Feather*	*Mokelumne*
2000	42.0	46.0	N/A
2001	28.5	38.5	N/A
2002	46.0	43.0	N/A
2003	75.0	55.0	N/A
2004	31.0	N/A	25.0

Table 4 Median transit days for CVP and SWP facilities

		CVP			*SWP*	
Salvage Year	*Coleman*	*Feather*	*Mokelumne*	*Coleman*	*Feather*	*Mokelumne*
2000	34.0	49.5	N/A	43.0	46.0	N/A
2001	28.0	40.5	N/A	29.0	38.0	N/A
2002	38.0	38.5	N/A	47.0	49.0	N/A
2003	80.0	57.0	N/A	69.5	54.0	N/A
2004	31.0	N/A	23.0	26.5	N/A	28.0

Discussion

The salvage of two large fish (409 mm and 333 mm), over a year after release, indicates the possibility that there may be overwintering or residence in the Delta or its tributaries. A second possibility is that these fish were returning adult spawners. Other fish larger than 300 mm may have been salvaged after 365 days from release, but they would not have been sacrificed due to a change in protocol after 2000. Also, 20 of the 308 steelhead salvaged from 2000 to 2003 had transit times greater than three months indicating that some steelhead may be using the Delta for rearing habitat.

Differences in Delta outflow did not explain differences in annual median transit times for steelhead released from Coleman and Feather River hatcheries. A more detailed analysis of relationships between transit time and flow, water exports, and other water conveyance variables may be fruitful.

Steelhead did not take longer to arrive at the SWP facility than at the CVP facility, since there was no discernable trend in the median annual transit. Longer travel times to the SWP might be expected, since Clifton Court Forebay presents an additional obstacle for entrained juvenile steelhead.

The close proximity of the Mokelumne River Fish Installation to the fish facilities resulted in quicker transit of fish released from that hatchery, generally less than 4 weeks.

The relatively low and variable proportion of steelhead currently marked at Central Valley hatcheries results in a lack of reliable data to use in understanding the vulnerability of steelhead from various parts of the central valley to SWP/CVP entrainment. At present, there are some hatcheries that do not use CWTs and others that use a proportion that varies annually, making it impossible to estimate the relative contribution of each hatchery to the fish salvage. A constant fractional marking program for Central Valley steelhead would permit an analysis of which hatchery steelhead were most vulnerable to entrainment at the salvage facilities. Under such a program, all or a constant fraction of steelhead released from Central Valley hatcheries would be uniquely marked with origin site, release date, and site information.

Potentially, hatchery releases and water management practices, particularly SWP/CVP exports, could be coordinated so that direct seaward emigration of smolts is maximized. CWT steelhead recoveries in 2004 show the potential of water export facilities to influence the migration of hatchery fish, particularly for those released from Mokelumne River Hatchery. Water export reductions during and after Mokelumne River hatchery releases could benefit smolts by reducing the probability of their appearance at the Delta export facilities.

References

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Subregions of the Sacramento-San Joaquin Delta: Identification and Use

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Introduction

In recognition of the pervasive importance of phytoplankton in ecosystem processes, variables related to phytoplankton abundance and growth rate have been measured in San Francisco Estuary monitoring programs extending back to the 1960s, including biomass as chlorophyll *a*, taxonomic composition, vertical light attenuation and a variety of nutrients. Currently, these variables are measured in the upper estuary (Sacramento-San Joaquin Delta through upper San Pablo Bay) under the auspices of the Interagency Ecological Program (IEP) for the San Francisco Estuary. The IEP has among its goals the determination of trends in ecological resources and the factors underlying these trends. The IEP Environmental Monitoring Program includes both routine monitoring and special studies to achieve these goals.

It is important to estimate phytoplankton biomass and production trends at the system-wide scale, in addition to specific locations: System-wide averages provide indices of ecosystem services such as net carbon sequestration and food production for fisheries. They also enable the construction of mass balances that improve understanding of processes at the ecosystem scale. Ideally, the average should be determined from a probability-based sample, i.e., a random sample in which every location has a known probability of being sampled. Only a probability-based sample eliminates the risk of bias from subjective sample selection and is independent of an assumed model. Moreover, valid confidence levels can be placed on the estimates, enabling the objective detection of system-wide trends. The historical collection of stations in the IEP Environmental Monitoring Program represent a judgment sample, however, not a probability sample. The stations were chosen to cover the spectrum of water quality behavior in the estuary, but not necessarily to provide system-wide statistics with confidence levels.

System-wide averages must therefore be determined by assuming some kind of model. For example, a station or subgroup of stations is assumed to be representative of a preselected homogeneous subregion within the estuary. The averages for the subregions are then weighted by the respective subregion areas or volumes, depending on the variable, and combined to provide a system-wide estimate. Such a stratification of the estuary can provide a more precise estimate of the system-wide mean if the within-subregion variability is reduced relative to the between-subregion variability (Thompson 1992). If stations do fall into relatively homogeneous groups that are stable in time, then it might also be possible to identify redundancy among the stations and reduce their overall number. Jassby and Cloern (2000) made system-wide estimates of primary productivity, chlorophyll *a*, and TSS in this manner, based on subregions suggested by Lehman (1996). Although confidence intervals and bias cannot be evaluated without a probability sample for comparison, any division of the stations into purported homogeneous subregions should exhibit consistency with the data. How well do the historical data in fact support this concept of relatively homogeneous subregions that are stable over time?

A second reason to divide the estuary into subregions is for the purpose of understanding local variability processes. In this case, values for stations within the same region are not necessarily similar in magnitude. Rather, they are correlated in time, a sign that they are responding to the same underlying variability mechanisms. Stations within such subregions can be viewed as equivalent or redundant for some data analysis and modeling activities. This implies that, instead of needing to understand vari-