Final Report

San Francisco Bay Estuary Acclimation of Central Valley Hatchery Raised Chinook Salmon Project

Prepared by

Fishery Foundation of California
MB 330
8698 Elk Grove Blvd.
Elk Grove, CA. 95624

Prepared for

California Department of Fish and Game
830 S Street
Sacramento, CA 95814

Funded by

Bay Delta Sport Fishing Enhancement Stamp
and the
Commercial Salmon Trollers Stamp

September, 2007

Final Report Salmon Acclimation Project

Introduction

In the Spring of 2007, the Fishery Foundation of California (FFC) received a grant from the State of California, the Resources Agency, Department of Fish Game pursuant to Fish and Game Code Section §1501.5(b), to acclimate Central Valley hatchery raised Chinook salmon upon transport by hatchery truck to San Francisco Bay. The Bay Delta Sport Fishing Enhancement Stamp and California Commercial Salmon Trollers Salmon Stamp provided the Grant funds. The purpose of acclimation is to reduce the transport stress of the young salmon before release into the Bay where they are subject to salinity and temperature shock and intense predation by birds, predatory fish, and marine mammals. In all but one of the twelve years prior to 2007 acclimation was achieved by releasing salmon smolts from hatchery trucks directly into net pens at a receiving site in the Bay. In 2003, salmon were acclimated in an experimental tank mounted on a barge. The barge system was tested as a means of cutting costs and further improving survival of trucked salmon. Tank acclimation, it was thought, might reduce stress and mortality of trucked salmon over pens by acclimating the salmon released from the trucks to Bay water conditions over a short period of time, as opposed to directly releasing the salmon into the Bay from the trucks or into pens. The experiment was successful but proved logistically difficult and so was abandoned in the following years. Prior to 1995, hatchery trucks released fish directly into the Bay or Delta locations. In 2007, the foundation chose to acclimate salmon using the net pen system.

Trucking and net pen acclimation is generally considered a major factor in dramatically increased escapement of hatchery fish to Central Valley Rivers. Trucking has proven effective at increasing survival by reducing losses between the hatcheries and the Bay to poor water quality, water diversions, and predation. Previous tagging studies by DFG indicated that survival is also enhanced up to several fold by net-pen acclimation of trucked salmon smolts[1]. Trucking and pen acclimation offer tremendous survival advantage over releasing young salmon at the hatcheries. The hatchery system is a controlled environment that allows a salmon to develop from an egg to a smolt in a safe, predation free background. Unlike in a river, hatchery pools afford fish with ample food and almost no predation pressure. In the hatchery there is no need for the young salmon to hide from predators and they develop without “learning” about the perils that are present in a natural aquatic environment. When these unsuspecting fish are released into a hostile environment such as a river or estuary they are easy prey for predatory birds and fish.

Despite the obvious survival advantage of trucking and pen acclimation there remain opportunities to further improve survival of hatchery salmon. One of these is barge acclimation. The potential advantage of barge over pen acclimation is a reduction in temperature or osmotic shock from direct release from trucks into pens. While direct

[1] Multiple paired lots of code-wire-tagged salmon smolts were released: one lot of a pair was released directly into the Bay from a truck and a second from a truck into net pens for several hours acclimation before mid channel release. Tag returns in the ocean fishery were up to three time higher for pen acclimated salmon. (DFG unpublished data)

transfer of Chinook salmon smolts from freshwater to saltwater generally is considered safe, there have been studies that show that direct transfer leads to shock and increased vulnerability to predators (Robertson and Bradley 1991; Smith et al. 1999a and 199b; and Carranza et al. 1994). Salmon migrating naturally downstream gradually move from freshwater to saltwater. The degree of osmotic shock is considered most severe in when juvenile salmon are transferred from freshwater to seawater directly, without the moderating influence of gradual transition to full salinity seawater afforded in nature. The scientific literature indicates that direct transfer increases salt levels in blood and tissues of young salmon and can disrupt biochemical processes and lead to stunted growth or even death. Although most species of salmonids undergo a physiological transformation that prepares them for the transition from freshwater to life in the dehydrating marine environment, a gradual rise in plasma ion concentration occurs as they experience an osmotic shock over several days. Young salmon gradually develop the ability to relieve their blood and tissue of salt by excreting salt via their kidneys and taking on more water through their gills and by drinking. The literature indicates that mortality from osmotic shock from direct transfer is on the order of 10 to 20 percent depending on circumstances. Some research indicates that the multiple stresses of transferring fish from hatcheries to salt-water exacerbates the stresses and leads to higher mortalities. In a conventional salmon farm, it's not unusual for up to 10 percent of the fish to die from osmotic shock, the trauma of being transferred from fresh to saltwater. Another 5 to 10 percent will become stunted. It also takes time for the survivors to adapt to their new surroundings and start growing again. And osmotic shock can stress fish and put them at risk for disease and predation.

Like salinity shock, thermal shock is another possible effect of direct transfer of salmon from trucks to the Bay, pens, or tanks. Thermal shock would occur if the receiving water is too warm – stress occurs as water temperature exceeds 65F and mortality occurs at about 77F. Mortality can occur at sub lethal temperatures if the change in temperature exceeds 20F. Generally temperature is not considered a factor in trucking; however, some trucking of hatchery salmon is conducted as late as July. During the present 2007 study water temperature of the receiving water in the Bay was consistently 67F, a stressful temperature for young salmon. Temperature in the trucks was generally about 60F.

The purpose of this report is to describe the results of the 2007 net pen acclimation program. Our objectives do not include an assessment of the merits of trucking or its effect on salmon populations, wild stocks, or straying.

Background

Hatchery Chinook salmon production in California in recent years has been approximately 48 million smolts. Approximately 12 million of these have been transported by truck and released in upper San Francisco Bay (San Pablo Bay). Three California State hatcheries located in the Central Valley (Feather, Mokelumne, and

Nimbus hatcheries) account for roughly 99% of these off-site releases in the Bay. The young salmon are transported to the Bay to reduce or eliminate the mortality associated with moving from the rivers through the Delta. Transported fish may contribute to ocean fisheries at rates of three fold and higher compared to fish released upstream or at the hatchery. Unpublished data from the DFG's CWT database show substantial increases in both ocean contribution rate (1153%) and hatchery recoveries (259%) for Feather River Hatchery smolts released in the western Delta. Average ocean fishery contribution rates by release location were 0.310% for Battle Creek, 0.369 for RBDD, 0.318 for Princeton, and 0.947 for Benicia in the upper Bay (USFWS, unpublished data). These differences in ocean contribution rates were observed during years of drought and below average flows in the Sacramento River and were prior to pen acclimation that began in the mid 1990's. There has been no subsequent information on contribution rates, except as mentioned earlier, more recent studies of pen acclimation by DFG indicate that acclimation increases contribution up to threefold. Overall the increase in ocean contribution from trucking and pen acclimation may be as high as tenfold. Increases in adult escapement to rivers are believed to be less because of extensive straying of off-site released (trucked) fish. Straying of these fish has been estimated to be as high as 70%.

The Chinook salmon smolts that are released off-site in the Bay come only from State hatcheries at Nimbus, Feather River, and Mokelumne hatcheries. These fish are for mitigation or enhancement from losses from dams and water diversions. The California Department of Water Resources provides funds for the Feather River Hatchery for mitigation of the State Water Project. The Salmon Stamp Program provides funding for enhancement fish for the Mokelumne and Feather River hatcheries. The Bureau of Reclamation provides funds for Nimbus hatchery fish. The East Bay Municipal Utility District provides funding for Mokelumne hatchery fish. The Four-Pumps Program of the State Water Contractors provides funding for Feather River hatchery fish through the Delta Fish Protection Agreement.

2007 Acclimation Program

The 2007 called for receiving up to 12 million salmon smolts into mobile net pens at the standard release site at the Wickland Oil Refinery dock on the southeast shoreline of San Pablo Bay. The salmon were to be delivered by trucks from the three state salmon hatcheries from late April to early July.

Net pen reconstruction began in late April and repairs were completed on May 7th. Construction of the platform for the receiving tube was not completed by CDFG until May 15th. The FFC received salmon from May 17th through June 27th. In total, the FFC received 89 truckloads in 27 acclimation days. FFC crews were unable to take fish on three occasions. One missed day was due to three nets being stolen off of the pens and the others were due to inclement weather and dangerous conditions. Fish were delivered from Feather, Nimbus, and Mokelumne River Hatcheries. Daily truck loads ranged from one to six and averaged 3.3 truckloads per day. The Feather River Hatchery delivered 49 truck loads for a total of 5,137,100 fish. Nimbus hatchery delivered 28 truckloads totaling 3,807,100 fish. Mokelumne, due to the late project start, was only able to deliver 12 truckloads containing 821,700 fish (Appendix A).

Bird predation observations were conducted twice over the survey period. Observations were made as follows: The number of hatchery trucks was recorded and an initial count was taken of all predatory birds present at the site as the fish were deposited. Each observer tracked exactly one bird and recorded all successful attempts at predation until the flock dispersed. A successful attempt was defined as a bird removing a fish from the water and eating it. Fish that were immediately dropped by birds were not considered.

On May 16th five trucks dumped directly into the bay without net pens. The bird count was approximately 400 gulls. There were two observers present. Bird one (gull) ate 9 fish, gull two ate 10 fish. Based on those numbers average predation rate would be 9.6 fish per bird, so 3,440 fish were likely lost to predation assuming a similar predation rate.

Again, on June 19th, one truck dumped without net pens. The truck had two holding tanks each with 2300lbs @ 46 fish per lb and discharged each separately. The bird count was approximately 354 birds (300 gulls, 4 egrets, and 50 terns). Three observers were present and the two loads were observed independently.

On the first load bird one (gull) ate 3 fish, bird two (egret) ate 2 fish and bird 3 (gull) ate one fish. Average was 2.7 fish per bird, so approx. 956 fish.

For load two bird one (gull) ate 3 fish, bird two (tern) ate 4 fish and bird three (tern) ate 0 fish. Average is 2.3 fish per bird so approx. 814 fish. Averaging the two observations we get a loss of approximately 935 fish lost to predation out of 211,600.

In general predation rate appeared to vary among birds and species. Gulls were the most abundant bird and represent the majority, followed by terns which were frequent and then egrets which were relatively few in number. In all cases there were aggressive birds which ate more fish and a few complacent birds which did not appear to compete. Terns appeared to be the most successful at hunting, but sheer numbers of gulls made them the top predators as they made more attempts and prevented others form reaching the prey.

No specific bird counts were done during release of acclimated fish due to lack of availability of unoccupied observers. Both deckhands and the boat captain were fully engaged in the release process. However the following general observations were made. Bird nets prevented predators from reaching fish in the net pens and while some birds followed the net pens into the strait while acclimation took place, overall numbers were lower by about one half to three quarters.

As fish acclimated they schooled and swam below the surface making them less vulnerable to bird predators upon release.

When fish were released birds returned in numbers and appeared to follow the plume of released fish but in most cases had to dive below the surface to successfully hunt fish making it much more difficult for the gulls which were present in greater numbers than other birds.

Egrets tended to hitch a ride on the net pen waiting for a chance to strike but presence of bird nets and crew were enough of a deterrent in most cases.

Mortality in the net pens was not a significant factor. Most fish when given time to acclimate recovered from disorientation caused by transport along with temperature and osmotic shock. The fish from Nimbus and Mokelumne hatcheries appeared to transition more quickly than the Feather River fish. Possible reasons are a shorter trip and, according to Terry West, Nimbus increased salinity of transport water to reduce osmotic shock.

In one special case mortality was significant however it was due to a pre-existing condition. Feather River notified us and sent two truck loads of fish with a fungus and mortality was observed upon arrival. A majority of those fish did survive the trip however and after a period of acclimation regained fitness in the salt water environment.

Literature Cited

Robertson, J.C. and **Bradley, T.M**. 1991. Hepatic ultra structure changes associated with par-smolt transformation of Atlantic salmon (Salmo salar). J. Exp. Zool. 260:135-148.

Smith, T.R., Tremblay, G.C. and **Bradley, T.M**. 1999. Hsp70 and osp54 are induced in salmon (Salmo salar) in response to osmotic shock. J. Exp. Zool. 284(3):286-298.

Smith, T.R., Tremblay, G.C. and **Bradley, T.M**. 1999. Characterization of the heat shock protein response of Atlantic salmon (Salmo salar). Fish Physiol. Biochem. 20:279-292.

Carranza, M.L, Allen, J.A. and Bradley, T.M. 1994. The effects of smoltification and seawater adaptation on pancreatic B-cells of Atlantic salmon. Aquaculture 121:157-170.

Appendix A

Daily acclimation totals by hatchery.

Salmon Acclimation 2007

date	total lbs	# per lb	total fish	Hatchery
5/17/2007	2300	29	66700	Feather
5/17/2007	2300	29	66700	Feather
5/18/2007	2300	30	69000	Feather
5/18/2007	2300	30	69000	Feather
5/18/2007	2100	30	63000	Feather
5/21/2007	2200	29	63800	Mokelumne
5/21/2007	2200	29	63800	Mokelumne
5/21/2007	2100	29	60900	Mokelumne
5/22/2007	2300	25	57500	Feather
5/23/2007	2500	29	72500	Mokelumne
5/23/2007	2500	29	72500	Mokelumne
5/23/2007	1500	29	43500	Mokelumne
5/24/2007	1500	29	43500	Mokelumne
5/24/2007	2600	34	88400	Mokelumne
5/24/2007	2500	34	85000	Mokelumne
5/24/2007	2300	54	124200	Feather
5/24/2007	2200	25	55000	Feather
5/24/2007	2200	25	55000	Feather
5/25/2007	2600	34	88400	Mokelumne
5/25/2007	2600	34	88400	Mokelumne
5/25/2007	1500	34	51000	Mokelumne
5/30/2007	2300	50	115000	Nimbus
5/30/2007	2300	50	115000	Nimbus
5/31/2007	2300	53	121900	Nimbus
5/31/2007	2300	53	121900	Nimbus
5/31/2007	2300	54	124200	Feather
5/31/2007	2300	54	124200	Feather
6/1/2007	2300	52	119600	Nimbus
6/1/2007	1600	52	83200	Nimbus
6/1/2007	700	78	54600	Nimbus
6/1/2007	2300	54	124200	Feather
6/1/2007	2300	54	124200	Feather
6/1/2007	2300	54	124200	Feather
6/4/2007	2300	70	161000	Nimbus
6/4/2007	2300	72	165600	Nimbus
6/4/2007	2300	54	124200	Feather
6/4/2007	2300	54	124200	Feather
6/4/2007	2300	54	124200	Feather
6/5/2007	1500	55	82500	Nimbus
6/5/2007	800	72	57600	Nimbus
6/5/2007	2300	72	165600	Nimbus
6/5/2007	2300	48	110400	Feather
6/5/2007	2300	48	110400	Feather
6/7/2007	2300	48	110400	Feather

6/7/2007	2300	48	110400	Feather
6/8/2007	2400	77	184800	Nimbus
6/8/2007	2300	80	184000	Nimbus
6/8/2007	2300	80	184000	Nimbus
6/9/2007	2300	77	177100	Nimbus
6/9/2007	2300	77	177100	Nimbus
6/9/2007	2300	77	177100	Nimbus
6/9/2007	2300	77	177100	Nimbus
6/11/2007	2300	70	161000	Nimbus
6/11/2007	2100	68	142800	Nimbus
6/11/2007	1500	70	105000	Nimbus
6/12/2007	1500	70	105000	Nimbus
6/12/2007	1750	70	122500	Nimbus
6/12/2007	2300	60	138000	Feather
6/12/2007	2300	60	138000	Feather
6/13/2007	2300	40	92000	Feather
6/13/2007	2300	40	92000	Feather
6/14/2007	2300	52	119600	Feather
6/14/2007	2300	52	119600	Feather
6/14/2007	1400	72	100800	Nimbus
6/14/2007	2400	73	175200	Nimbus
6/15/2007	1500	73	109500	Nimbus
6/15/2007	2200	73	160600	Nimbus
6/15/2007	2300	54	124200	Feather
6/15/2007	2300	54	124200	Feather
6/15/2007	1400	57	79800	Feather
6/19/2007	2300	46	105800	Feather
6/19/2007	2300	46	105800	Feather
6/20/2007	2300	46	105800	Feather
6/20/2007	2300	60	138000	Feather
6/20/2007	2300	60	138000	Feather
6/20/2007	500	46	23000	Feather
6/20/2007	500	60	30000	Feather
6/25/2007	2300	53	121900	Feather
6/25/2007	2300	53	121900	Feather
6/26/2007	5100	46	234600	Feather
6/26/2007	1800	48	86400	Feather
6/27/2007	2300	45	103500	Feather
6/27/2007	2300	45	103500	Feather
6/27/2007	2300	45	103500	Feather
6/28/2007	2300	40	92000	Feather
6/28/2007	2300	45	103500	Feather
6/29/2007	2300	48	110400	Feather
6/29/2007	2300	48	110400	Feather
6/29/2007	2300	48	110400	Feather