State of California The Resources Agency

Memorandum

To : Larry Chee,
Department of Water Resources

Date : January 25, 1991

From : Department of Fish and Game

Subject : Revised Striped Bass Yearling Equivalent Survival Factors

I have reviewed the table of striped bass yearling equivalent survival factors you transmitted to me in your 1-16-91 memo. The survival factors are correct. However, I had already made these revisions and submitted them to Pete through Dan last July, 1990 as a revised Appendix A. Apparently, that was lost in the works somewhere. I am enclosing a copy of my revised Appendix A.

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cc: Dan Odenweller, Bay-Delta Project
H.K. Chadwick, Bay-Delta Project

APPENDIX A

PART I ESTIMATION OF THE FIVE YEAR AVERAGE OF YEARLING EQUIVALENT LOSS OF STRIPED BASS (LARGER THAN 20 MM), CHINOOK SALMON, AND STEELHEAD LOST DURING FISH SALVAGE OPERATIONS AT THE INTAKE TO THE CALIFORNIA AQUEDUCT

GENERAL APPROACH

The number of fish lost at the intake to the State Water Project (SWP) export system is calculated from the estimated number of fish salvaged (collected) at the fish facility adjusted by factors affecting their survival. The number of fish salvaged during the first and second half of a month is estimated from a sampling program at the facility. The sampling program is based on fish counts made at fairly regular intervals during the day. Salvage is stratified by size group.

Losses occur both before and after fish are collected in the holding tanks where they are counted. Losses are estimated from the time fish are entrained into the forebay until they are transported and released back into the Delta. Fish entrained into the forebay are lost in two ways before they are collected in the facility; (i) predation loss (P) in the forebay, (ii) loss through the fish screens. After fish have been collected, some fish die as a result of the handling (H) and trucking (T) required to return them to the Delta.

Losses of fish are standardized to yearling equivalents by estimating the number which would have survived to that age.

Survival of striped bass to the yearling stage is a function of the growth and mortality rates of the various length groups the fish must live through to become yearlings. It is also a function of the time of year during which a given size fish is collected.

Instantaneous growth rates (G) and mortality rates (Z) for each length group were calculated from equations developed by Miller (ms):

$$\ln(Z) = -1.10957 - 0.04236 \times \text{FL mm}$$

$$\ln(G) = -2.78628 - 0.03245 \times \text{FL mm}$$

Daily growth was estimated at the mid-point of each length interval by the following equation, where (t2-t1) = 1 day:

$$L(t+1) = L(t) \times e^{G(t2-t1)}$$

The daily growth rate for each length group (i) was then calculated as the mean of the daily growth rates at the mid-points of length groups (i) and (i+1).

These relationships may be modified as additional information on mortality and growth become available. This data was used to calculate the survival rate for each length group and the number of days a fish spends in the group (Table 1). Yearling equivalent survival factors for striped bass are then calculated as the product of the individual survival rates for each length interval that a fish must live through to become a yearling (Table 2). Yearling status for the purposes of this model is defined as living to the first half of March or reaching the 141-150 mm length interval.

TABLE 1. STRIPED BASS SURVIVAL RATES FOR VARIOUS LENGTH GROUPS AND THE NUMBER OF DAYS SPENT IN EACH GROUP

Species	Length Interval (mm)	Survival [1] Rate	Number days in length Interval
STRIPED BASS	21 - 25	0.4082	7.2
	26 - 30	0.4892	7.1
	31 - 35	0.5562	7.2
	36 - 40	0.5005	10.5
	41 - 50	0.4477	16.4
	51 - 60	0.5453	18.9
	61 - 70	0.6247	22.4
	71 - 80	0.6898	27.0
	81 - 90	0.7416	33.2
	91 - 100	0.7835	41.4
	101 - 110	0.8182	52.0
	111 - 120	0.8467	65.9
	121 - 130	0.8701	84.1
	131 - 140	0.8896	108.0
	141 - 150	0.9058	139.5
	≥ 151		

[1] Survival rates refer to survival from the mid-point of the length interval to the mid-point of the subsequent interval.

TABLE 2. STRIPED BASS YEARLING EQUIVALENT SURVIVAL FACTORS STRATIFIED BY SIZE GROUP AND TIME OF YEAR ENTRAINED INTO THE STATE WATER PROJECT.

Semi-Monthly Period		21-25 mm	26-30 mm	31-35 mm	36-40 mm	41-50 mm
JAN	1	0.017741	0.034535	0.060131	0.092805	0.150022
	2	0.030892	0.055883	0.090934	0.129617	0.203513
FEB	3	0.072347	0.116592	0.168253	0.216577	0.308627
	4	0.205760	0.278857	0.355389	0.421823	0.503530
MAR	5	0.002157	0.005229	0.010560	0.018725	1
	6	0.002211	0.005360	0.010825	0.019195	1
APR	7	0.002270	0.005504	0.011115	0.019710	0.038623
	8	0.002327	0.005642	0.011394	0.020205	0.039593
MAY	9	0.002397	0.005784	0.011681	0.020713	0.040588
	10	0.002489	0.005996	0.012035	0.021233	0.041607
JUN	11	0.002592	0.006244	0.012531	0.022083	0.042878
	12	0.002692	0.006485	0.013015	0.022935	0.044534
JUL	13	0.002797	0.006735	0.013518	0.023821	0.046254
	14	0.002963	0.007070	0.014056	0.024741	0.048040
AUG	15	0.003152	0.007521	0.014952	0.026097	0.050022
	16	0.003340	0.007969	0.015843	0.027652	0.052950
SEP	17	0.003627	0.008528	0.016852	0.029414	0.056322
	18	0.003962	0.009316	0.018256	0.031403	0.059678
OCT	19	0.004328	0.010177	0.019944	0.034306	0.064306
	20	0.004936	0.011350	0.021787	0.037477	0.070250
NOV	21	0.005701	0.013108	0.025126	0.042267	0.077197
	22	0.006895	0.015319	0.028759	0.048378	0.087780
DEC	23	0.008475	0.018829	0.034896	0.056735	0.100472
	24	0.011576	0.024409	0.042968	0.069733	0.120391

TABLE 2. Continued.

Semi-Monthly Period		51-60 mm	61-70 mm	71-80 mm	81-90 mm	91-100 mm
JAN	1	0.267298	0.395377	0.517053	0.636937	0.732085
	2	0.328535	0.464298	0.591813	0.695812	0.775713
FEB	3	0.450597	0.578569	0.683508	0.777180	0.847867
	4	0.638145	0.745224	0.824871	0.881578	0.920797
MAR	5	1	1	1	1	1
	6	1	1	1	1	1
APR	7	1	1	1	1	1
	8	1	1	1	1	1
MAY	9	0.088168	1	1	1	1
	10	0.090383	1	1	1	1
JUN	11	0.092807	0.164786	0.253976	1	1
	12	0.095369	0.168926	0.260356	1	1
JUL	13	0.099052	0.173169	0.266896	0.370199	1
	14	0.102877	0.179686	0.273601	0.379499	1
AUG	15	0.107120	0.187097	0.282796	0.389676	0.497496
	16	0.111257	0.194322	0.293717	0.399465	0.509993
SEP	17	0.118007	0.202337	0.305831	0.414317	0.523670
	18	0.125039	0.212971	0.317641	0.430317	0.536824
OCT	19	0.132491	0.225663	0.331074	0.446934	0.554296
	20	0.142362	0.239111	0.350803	0.464193	0.575701
NOV	21	0.156441	0.256420	0.373146	0.487611	0.599445
	22	0.170902	0.280122	0.395383	0.516669	0.622594
DEC	23	0.193498	0.306016	0.428994	0.547459	0.649542
	24	0.221476	0.342336	0.468648	0.580084	0.688251

TABLE 2. Continued.

Semi-Monthly Period		101-110 mm	111-120 mm	121-130 mm	131-140 mm	141-150 mm
JAN	1	0.803845	0.861540	0.907024	0.938102	0.959032
	2	0.843837	0.894810	0.929809	0.953466	0.969286
FEB	3	0.897581	0.931715	0.954744	0.970131	0.980344
	4	0.947408	0.965254	0.977110	0.984952	0.990123
MAR	5	1	1	1	1	1
	6	1	1	1	1	1
APR	7	1	1	1	1	1
	8	1	1	1	1	1
MAY	9	1	1	1	1	1
	10	1	1	1	1	1
JUN	11	1	1	1	1	1
	12	1	1	1	1	1
JUL	13	1	1	1	1	1
	14	1	1	1	1	1
AUG	15	0.596247	1	1	1	1
	16	0.607762	1	1	1	1
SEP	17	0.624061	0.712355	0.783436	1	1
	18	0.639737	0.724022	0.796267	1	1
OCT	19	0.655808	0.735879	0.809308	0.862891	0.905856
	20	0.672282	0.753957	0.822562	0.872116	0.908079
NOV	21	0.690310	0.774176	0.836940	0.882066	0.918439
	22	0.715664	0.793623	0.850647	0.892512	0.928259
DEC	23	0.743301	0.813559	0.864579	0.907130	0.938183
	24	0.772005	0.833996	0.883336	0.921986	0.948214

The Yearling Equivalent Survival Factor (YESF) for young-of-the-year (YOY) chinook salmon (1-100 mm) is defined as the ratio of the ocean contribution rate of YOY salmon reaching the Delta (0.96%) to the ocean contribution rate of yearling salmon (>100 mm) not impacted by Delta pumping (3.0%):

$$0.96 / 3.0 = 0.32$$

The above ocean contribution rate of 0.96% was developed by Hallock (1979) for hatchery smolt-sized (YOY) chinook salmon from the Sacramento River system. The ocean contribution rate of 3.0% is based on ocean recoveries of coded wire tagged yearling fall run chinook salmon reared at the Feather River and Mokelumne River hatcheries and released at Rio Vista and Vallejo.

The Yearling Equivalent Survival Factor (YESF) for yearling chinook salmon (>100 mm) is defined as 1.0.

Adequate information is not available for steelhead, therefore, chinook salmon data is used to estimate the YESF. The YESF for YOY steelhead (1-100 mm) is defined as the ratio of the ocean contribution rate of YOY salmon reaching the Delta (0.96%) to the ocean contribution rate of yearling salmon (>100 mm) impacted by Delta pumping (1.1%):

$$0.96 / 1.1 = 0.8727$$

The above ocean contribution rate of 1.1% is based on ocean recoveries of coded wire tagged yearling fall run chinook salmon reared at the Merced River Hatchery and released in the Merced River.

The Yearling Equivalent Survival Factor (YESF) for yearling steelhead (>100 mm) is defined as 1.0.

Species	Length Interval (mm)	Survival Rate
CHINOOK SALMON	1 - 100	0.32
	≥ 101	1.0000
STEELHEAD	1 - 100	0.8727
	≥ 101	1.0000

ESTIMATION PROCESS

Loss estimates are generated for each time interval, species, and size group. These are summed over time to estimate semi-monthly and annual losses. Each year's replacement obligation is the average of the annual loss estimates for the previous five years.

EFFICIENCY OF FISH SCREENS

Parameters used to calculate screening loss are influenced by the size of the fish and the velocity of water passing through the fish screens. Regression equations predicting screening efficiencies for different length intervals of fish, based on primary water velocity (fps), were developed from data collected during a field testing program at the fish facility in 1970-71:

Striped Bass

Length Interval (mm)	
A) 21 - 30	Eff(A) = 0.935 - (0.149 x Velocity)
B) 31 - 40	Eff(B) = 0.806 - (0.0431 x Velocity)
C) ≥ 41	Eff(C) = 0.945 - (0.0717 x Velocity)

Chinook Salmon and Steelhead

Length Interval (mm)	
A) 1 - 100	Eff(A) = 0.630 + (0.0494 x Velocity)
B) ≥ 101	Eff(B) = 0.568 + (0.0579 x Velocity)

NUMBER OF FISH ENCOUNTERING FISH SCREENS

The number of fish encountering the screens after crossing the forebay is calculated by dividing the number of fish salvaged by the screening efficiency (Eff):

#Encountering Screens = #Salvaged / Eff

PREDATION LOSS IN CLIFTON COURT FOREBAY

The number of fish entrained into the forebay is calculated by dividing the number of fish encountering the screens by the proportion of fish which survive crossing the forebay (1-P):

$$\#Entrained = \#Encountering\ Screens\ /\ (1-P)$$

HANDLING AND TRUCKING LOSSES

The number of fish released alive is calculated by multiplying the number of fish salvaged by the survival rates for the handling (1-H) and trucking (1-T) operations:

$$\#Alive = \#Salvaged \times (1-H) \times (1-T)$$

SYSTEM LOSS

The number of fish lost due to SWP operations is calculated as the difference between the number of fish estimated to have been entrained into the forebay and the number of fish released alive back into the Delta:

$$System\ Loss = \#Entrained - \#Alive$$

TABLE 3. PRE-SCREENING LOSS RATE (P), HANDLING LOSS RATE (H), AND TRUCKING LOSS RATE (T) USED AS DEFAULT PARAMETERS IN THE YEARLING EQUIVALENT LOSS MODEL FOR EACH LENGTH GROUP (I).

	I	P(I)	H(I)	T(I)
Striped Bass	1	0.99	0.47	0.43
	2	0.99	0.45	0.41
	3	0.99	0.42	0.39
	4	0.99	0.40	0.36
	5	0.93	0.37	0.34
	6	0.83	0.35	0.31
	7	0.75	0.32	0.29
	8	0.68	0.30	0.26
	9	0.60	0.26	0.23
	10	0.50	0.21	0.18
	11	0.42	0.16	0.13
	12	0.35	0.11	0.08
	13	0.29	0.06	0.03
	14	0.23	0.01	0.00
	15	0.18	0.00	0.00
	16	0.14	0.00	0.00
	17	0.1	0.00	0.00
	18	0.06	0.00	0.00
	19	0.03	0.00	0.00
Chinook Salmon	20	0.75	0.02	0.00
	21	0.75	0.00	0.00
Steelhead	22	0.75	0.02	0.00
	23	0.75	0.00	0.00

YEARLING EQUIVALENT LOSS

The number of fish lost as a result of entrainment into the SWP intake is calculated by multiplying the system loss by the appropriate yearling equivalent survival factor:

Yearling Equivalent Loss = System loss x Survival Factor

Annual losses are averaged over the previous five years to compute the annual replacement obligation. For Part I, sufficient information is available to compute a running five year average starting in 1986.

PART II ESTIMATION OF THE YEARLING EQUIVALENT LOSS OF STRIPED BASS (LESS THAN 21 MM) LOST ANNUALLY DURING FISH SALVAGE OPERATIONS AT THE INTAKE TO THE CALIFORNIA AQUEDUCT

GENERAL APPROACH

The densities of striped bass eggs and larvae in Old River in the vicinity of the intake to Clifton Court Forebay will be monitored during the striped bass spawning period. Those densities will be used to estimate the number of eggs and larvae entrained into the forebay, based on the assumption that water drawn into the forebay contains the mean densities of eggs and larvae measured in Old River.

All eggs and larvae drawn into the forebay are assumed to be lost. The number lost is converted to yearling equivalents based on values used by Baracco (1983).

Length Group	Survival Rate to Yearlings
Eggs	0.000047
3-6 mm	0.000124
7-10 mm	0.000338
11-14 mm	0.002509
15-18 mm	0.006415
19-20 mm	0.020414

Since direct measurements of egg and larval losses started in 1985, the 1986 replacement obligation will be the 1985 loss estimate. Each subsequent year through 1990 the obligation will be the average of

prior annual losses. Commencing in 1991, a running five year average will be used.

LITERATURE CITED

Hallock, R.J. 1979. The status of inland habitat and the factors adversely impacting salmon resources. Calif. Dept. Fish and Game Memorandum Report, Sacramento.