CALFED Review

National Marine Fisheries Service (NMFS)

Upper Sacramento River Effects

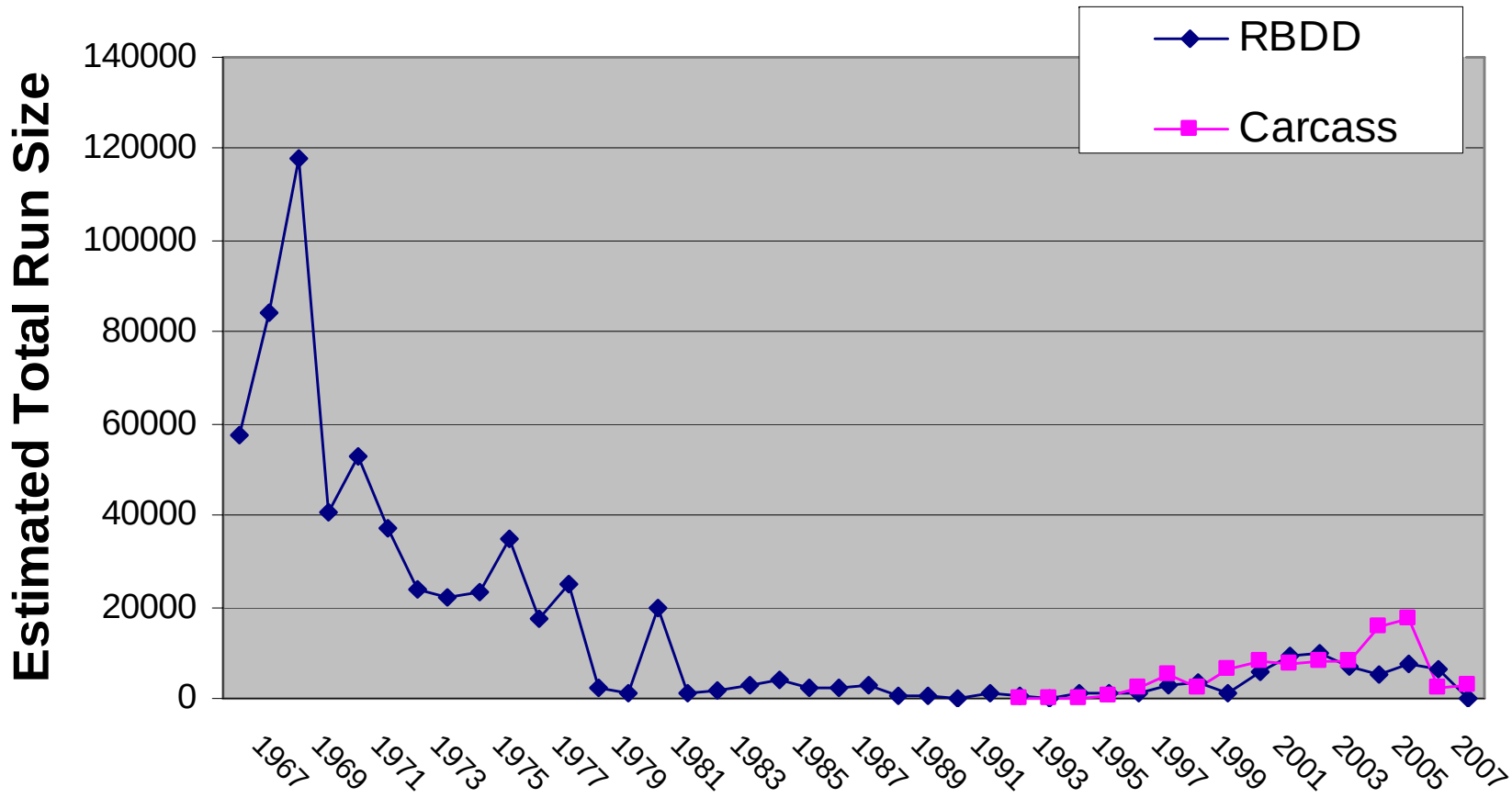
Bruce Oppenheim

NMFS

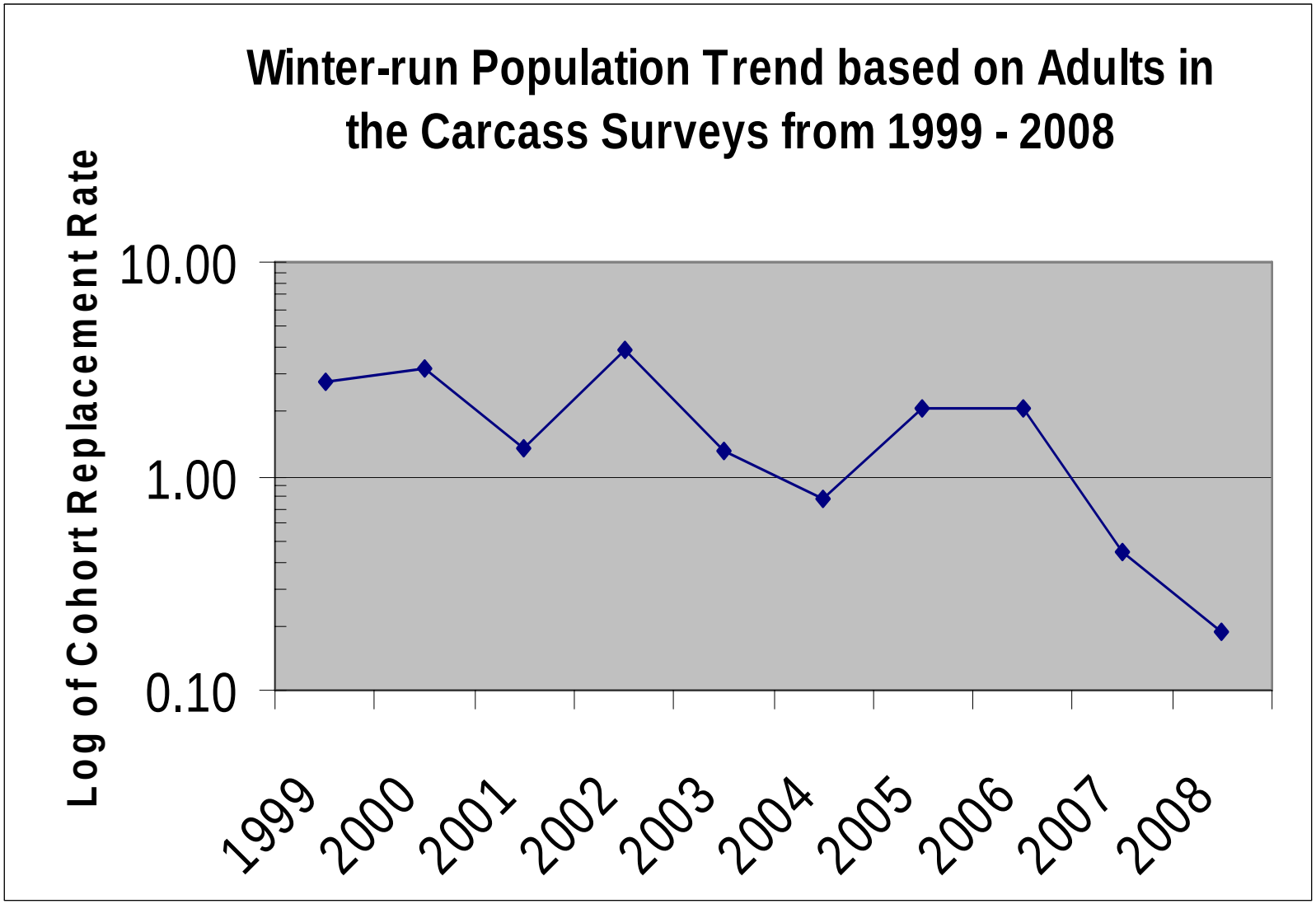
Significant Effects

- Water temperature (SRWQM)
- Carryover storage in Shasta (CALSIM)
- Egg and fry mortality (USBR Model)
- Truncated migration period (IPM)
- Red Bluff Diversion Dam (DFG data)
- Loss of Critical Habitat (SALMOD)
- Climate Change (USBR Model)

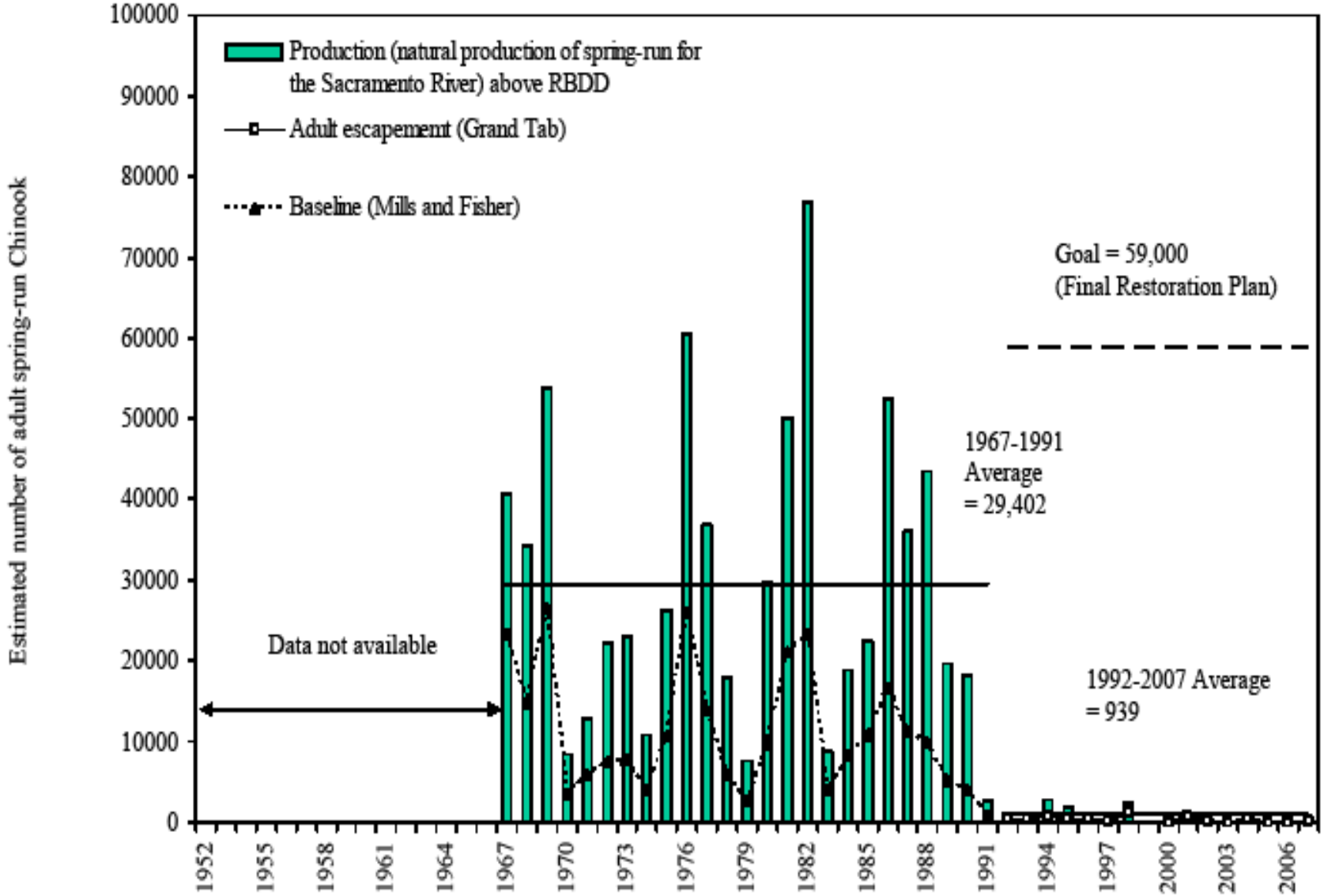
Adult Winter-run Chinook at Red Bluff Diversion Dam and Carcass Surveys from 1967 to 2008



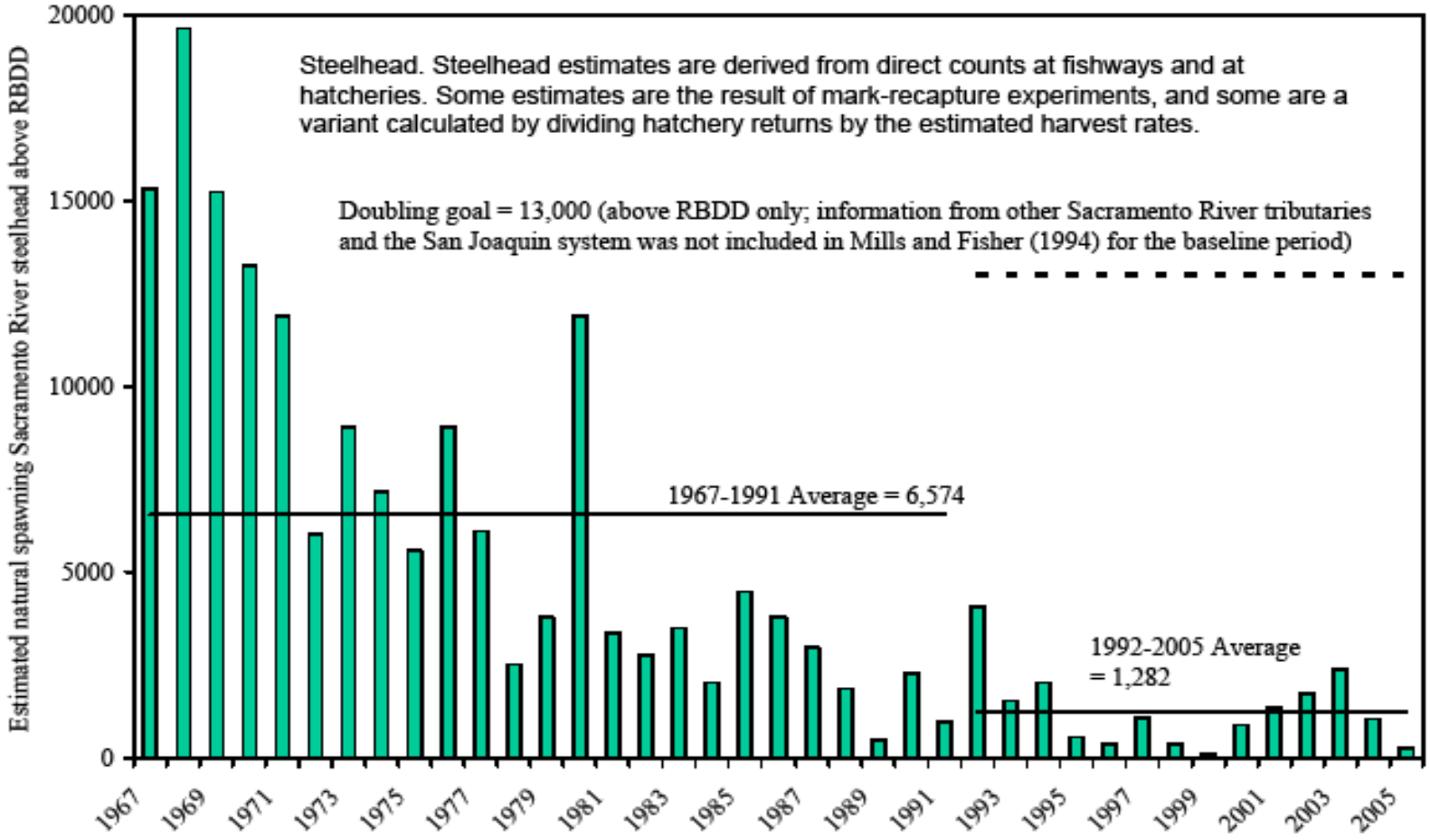
Source: CDFG GrandTab updated 3/7/08


Winter-run Population Trend based on Adults in the Carcass Surveys from 1999 - 2008
Log of Cohort Replacement Rate
10.00
1.00
0.10
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008

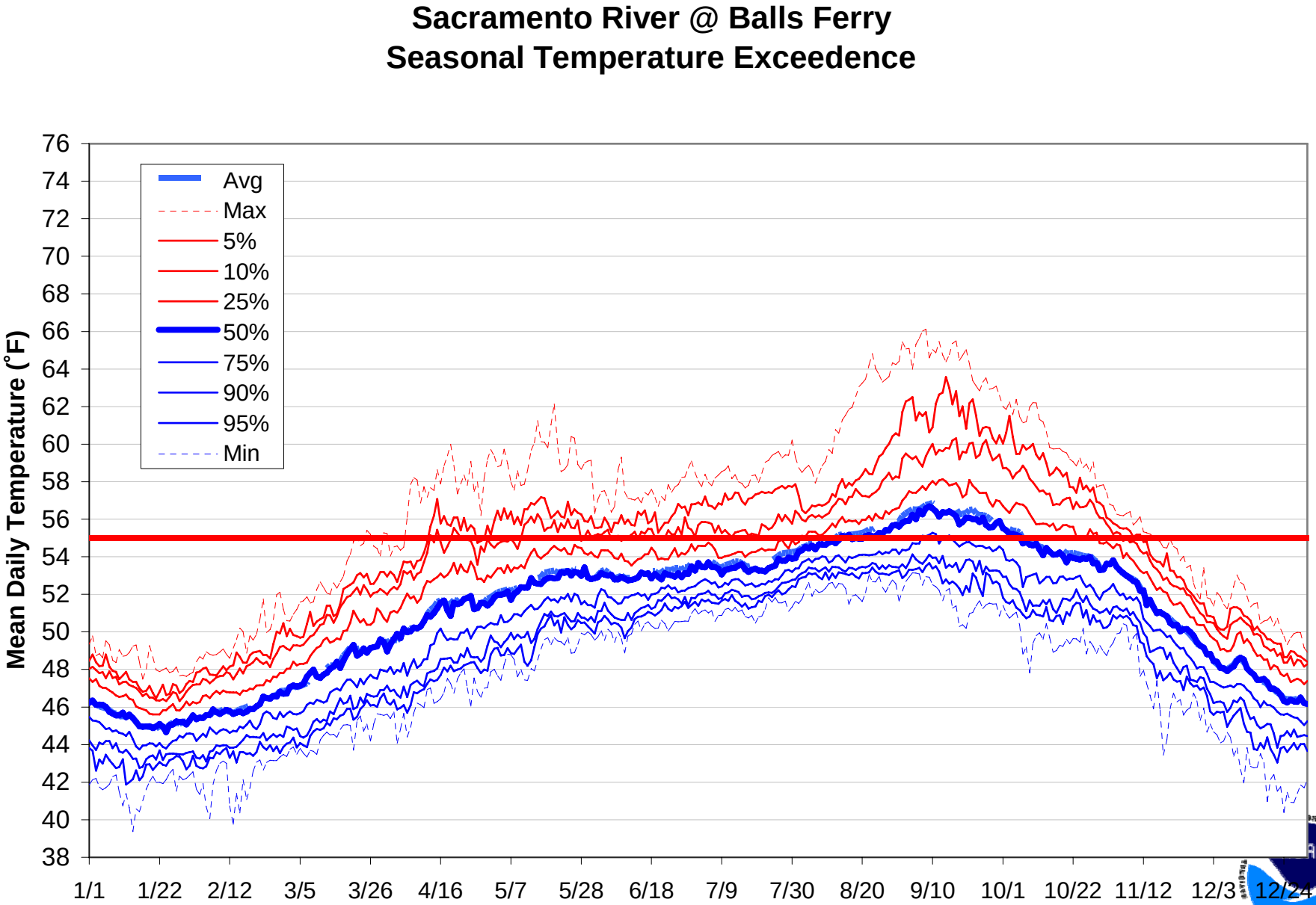
Spring-run escapement and natural production estimated above RBDD (Hanson 2008).



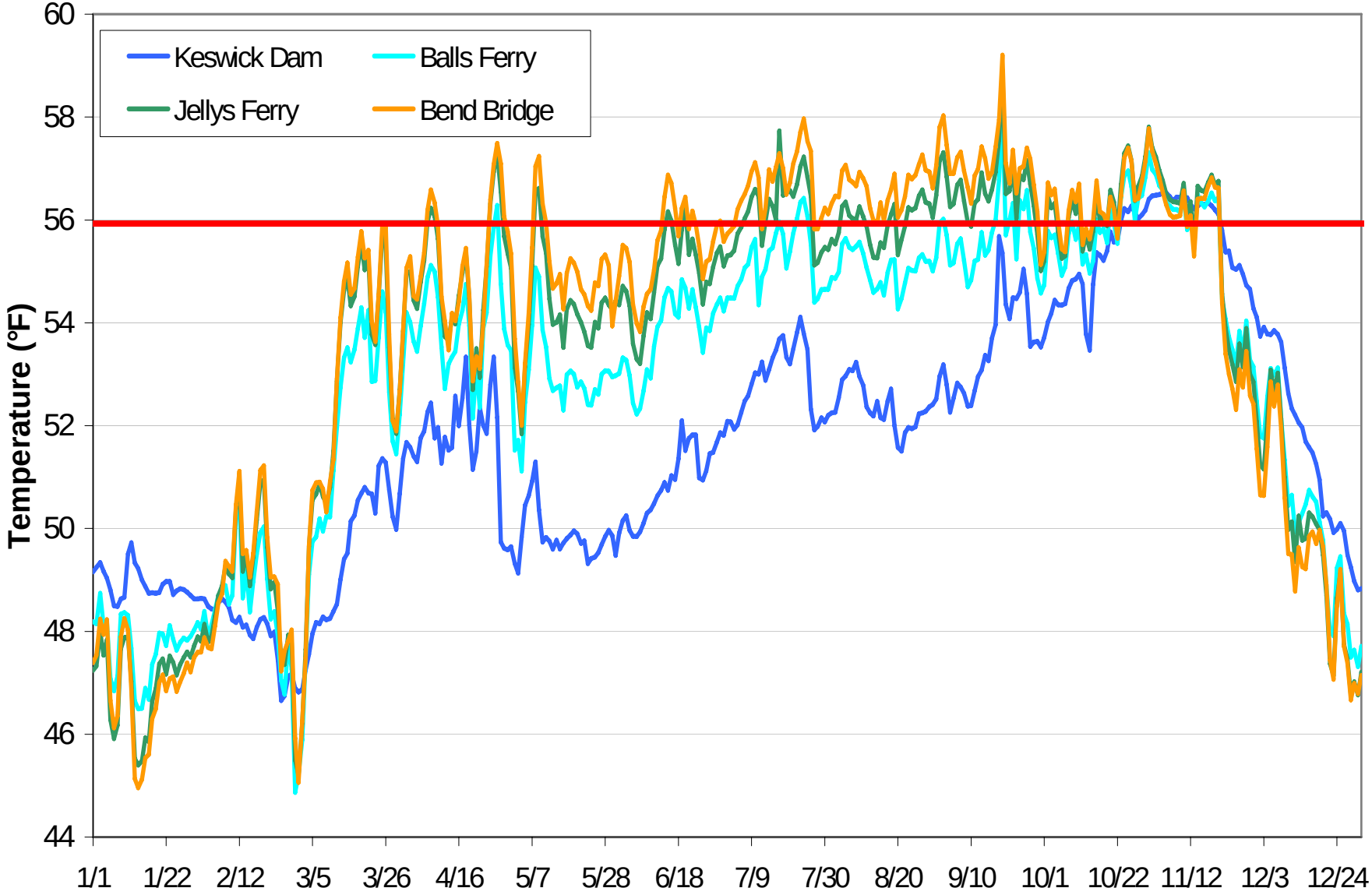
CV steelhead on the Sacramento River upstream of the RBDD 1967-2005. Data from 1992 to 2005 is based on



Calsim and SRWQM results under future conditions Study 8.0



2007
Sacramento River Mean Daily Temperature

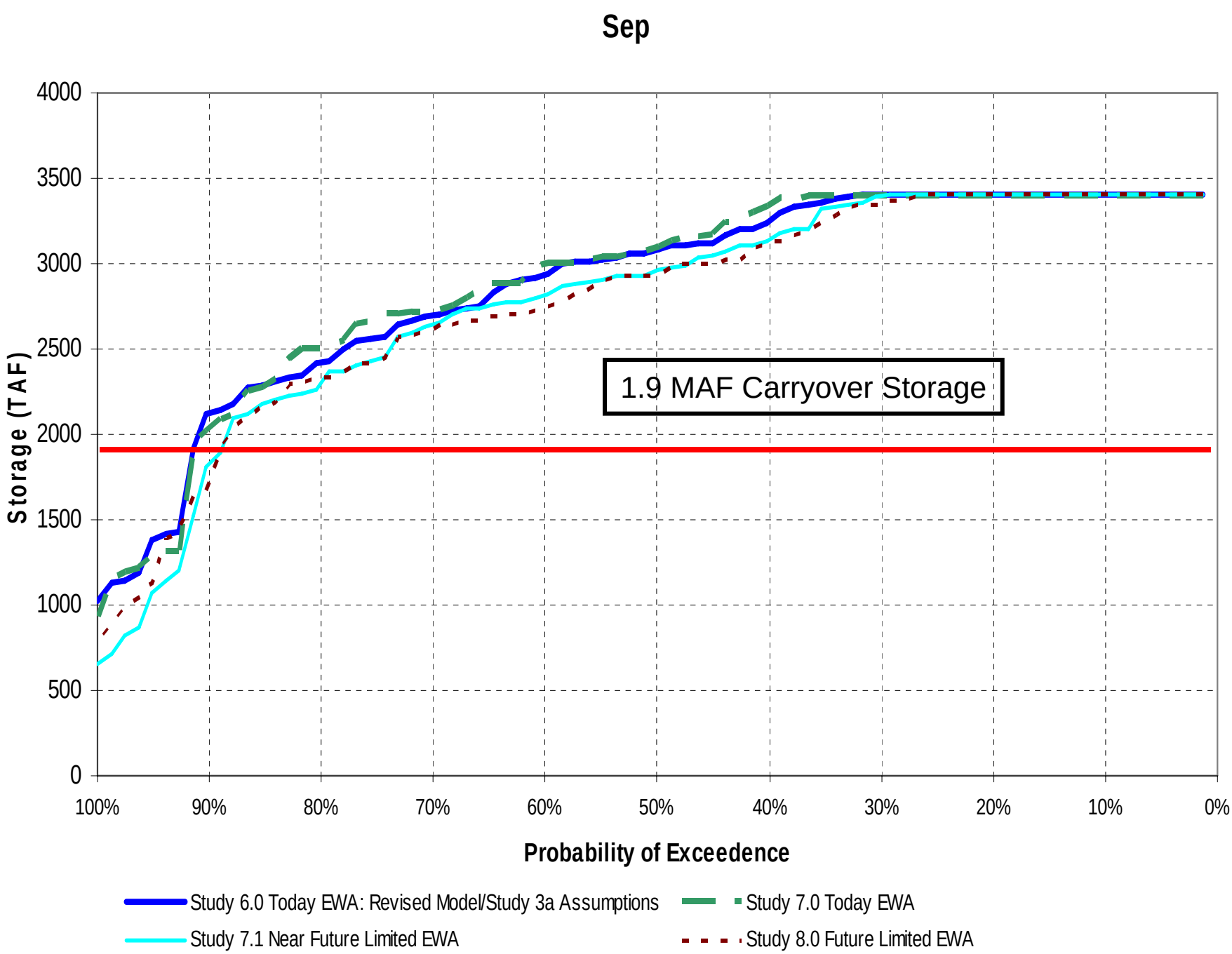


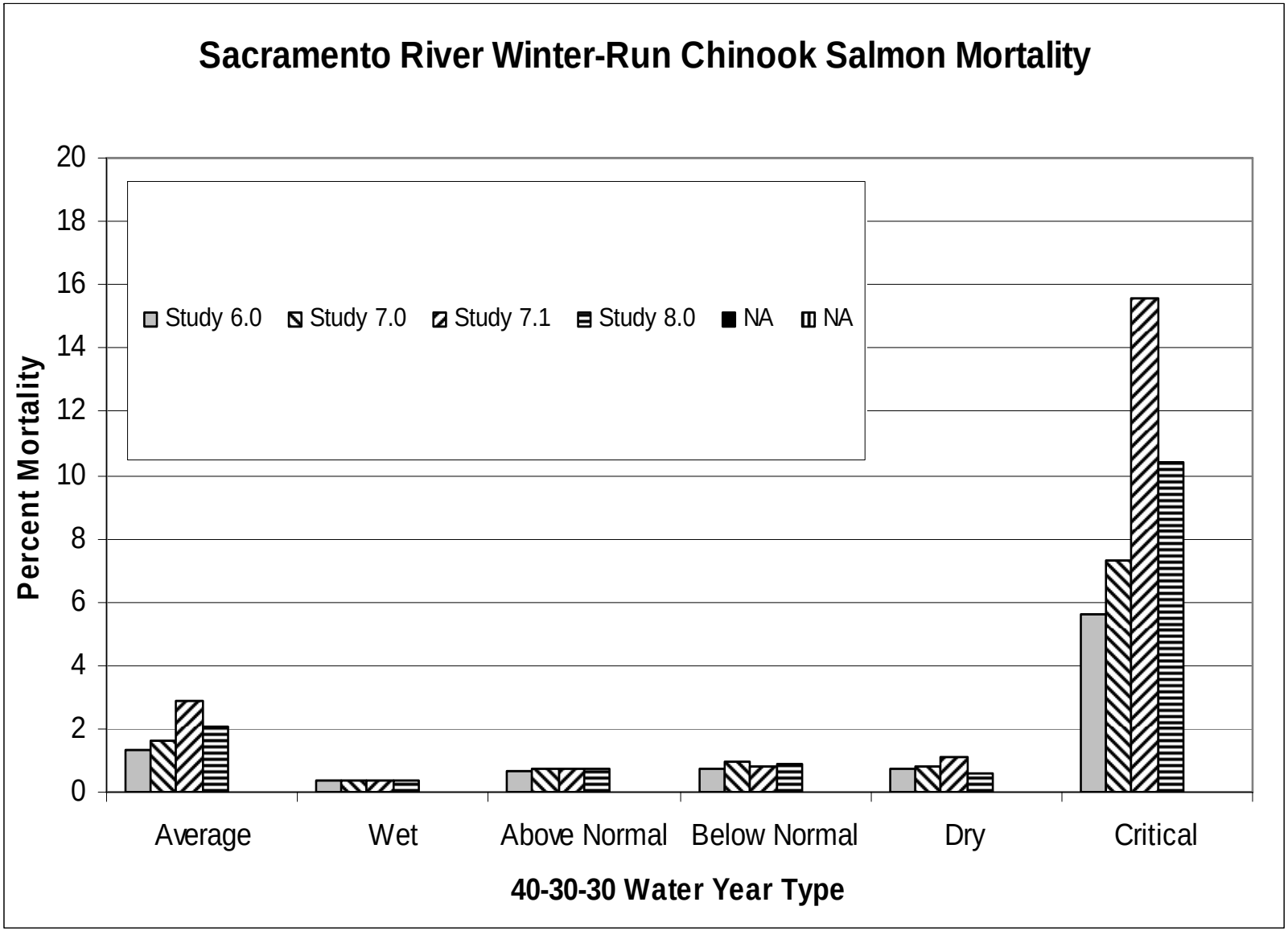
Carry over Storage in Shasta

Table 10-3. Long-term Average Annual and End of September Storage Differences for Shasta Storage, Spring Creek Tunnel Flow, and Keswick Release

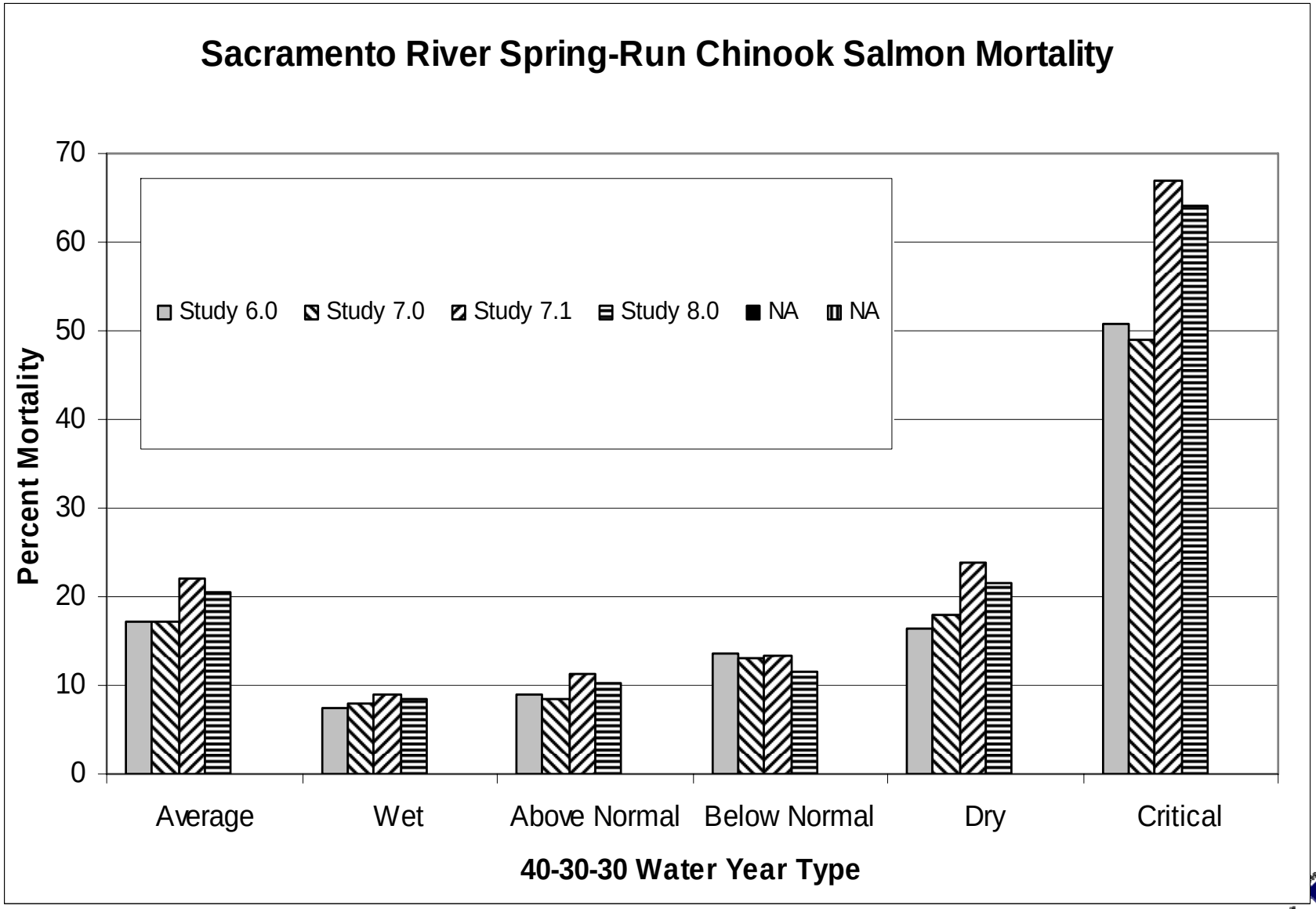
Long term Annual Average

Difference in Thousands of Acre-feet [TAF]	Study 7.0 - Study 6.0	Study 7.1 - Study 7.0	Study 8.0 - Study 7.0	Study 8.0 - Study 7.1
Shasta End-of-September Storage	26	-121	-121	0
Annual Keswick Release	1	8	6	-2
Annual Spring Creek Powerplant Flows	3	-1	-2	-2

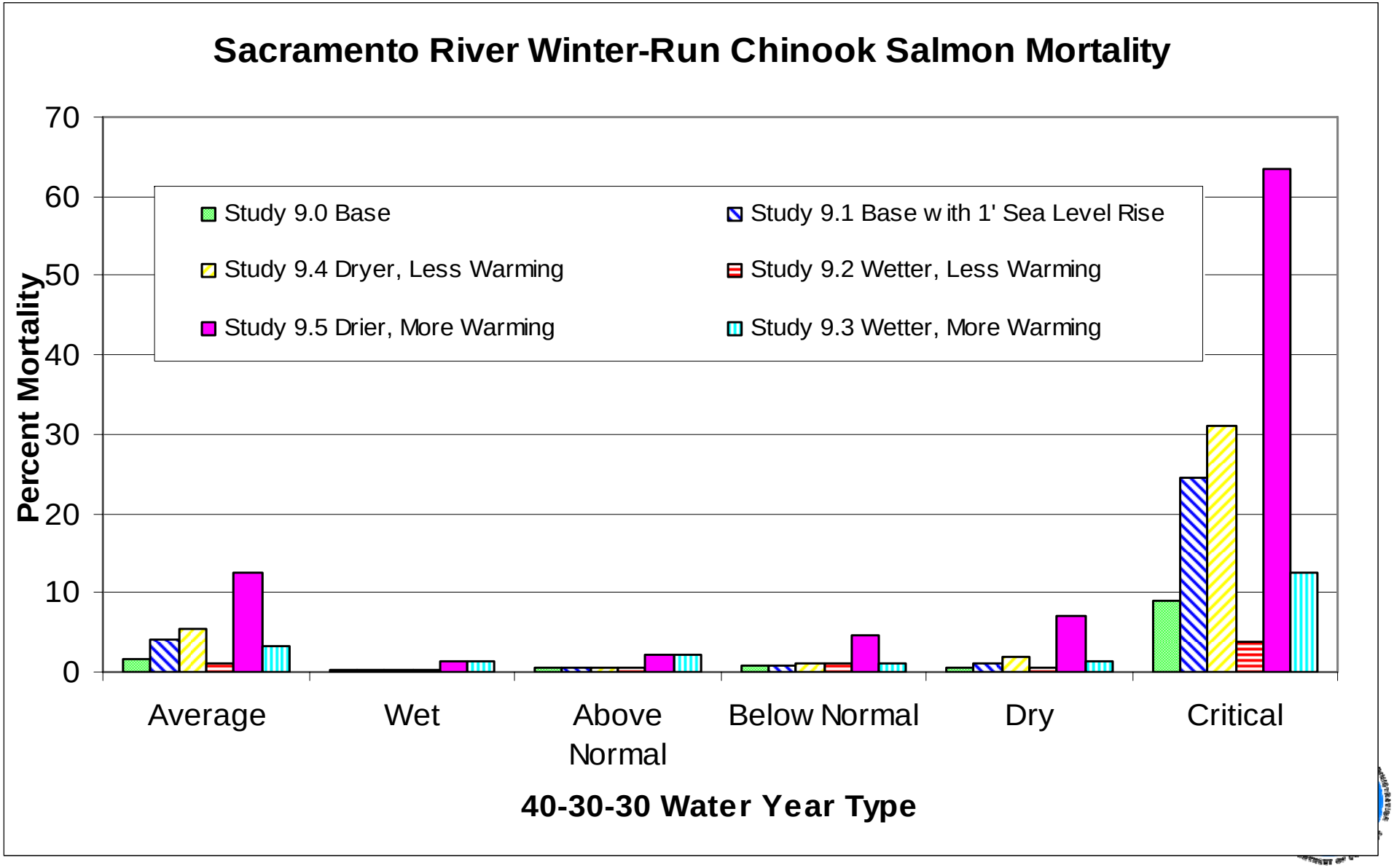

Sep
4000
3500
3000
2500
2000
1500
1000
500
0
Storage (TAF)
1.9 MAF Carryover Storage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Probability of Exceedence
Study 6.0 Today EWA: Revised Model/Study 3a Assumptions
Study 7.0 Today EWA
Study 7.1 Near Future Limited EWA
Study 8.0 Future Limited EWA

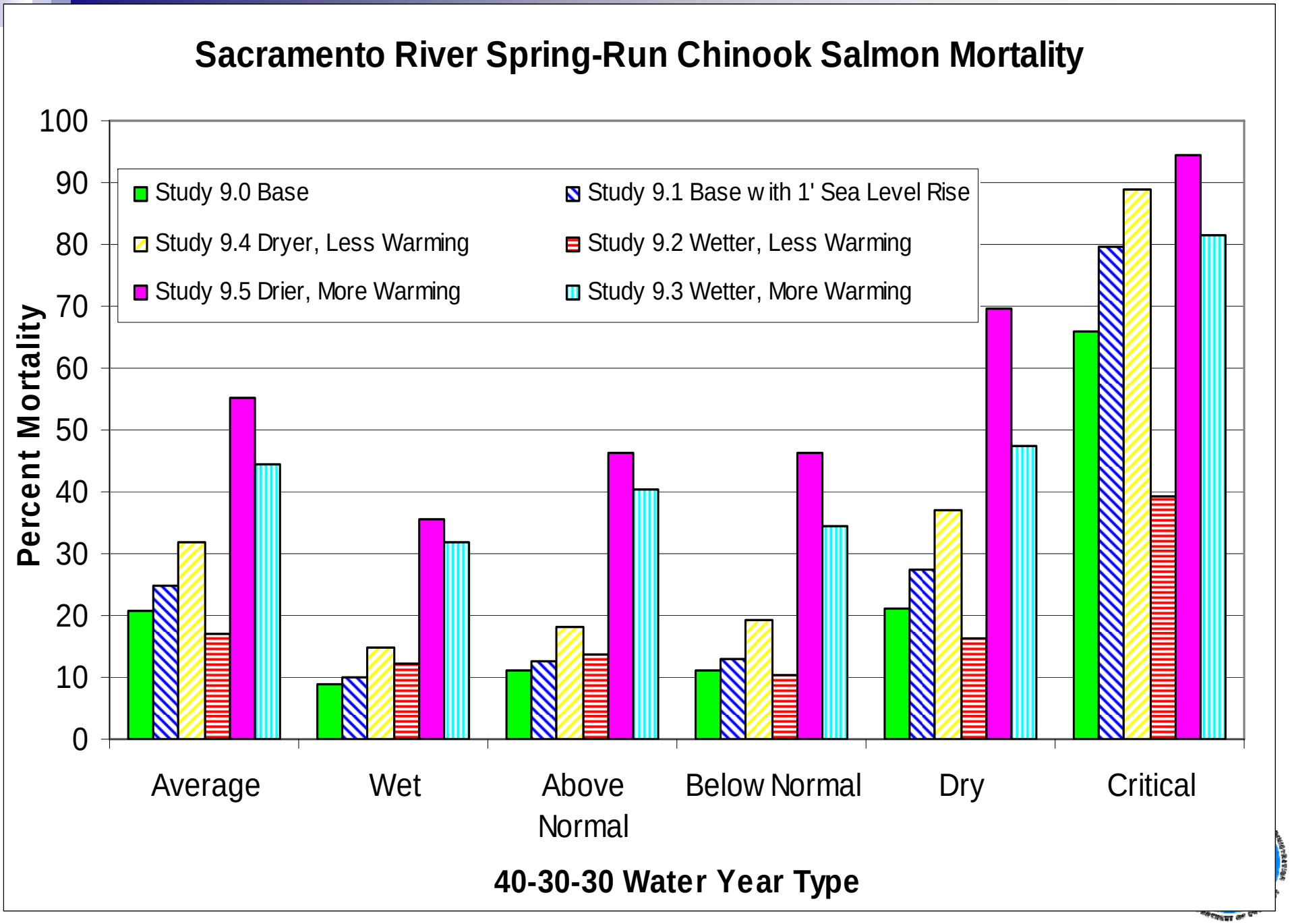


Egg and Fry Mortality by water year type at Balls Ferry. Study 6.0 represents 2004 operations, study 7.0 represents current operations, 7.1 represents near future operations, and 8.0 represents future operations.

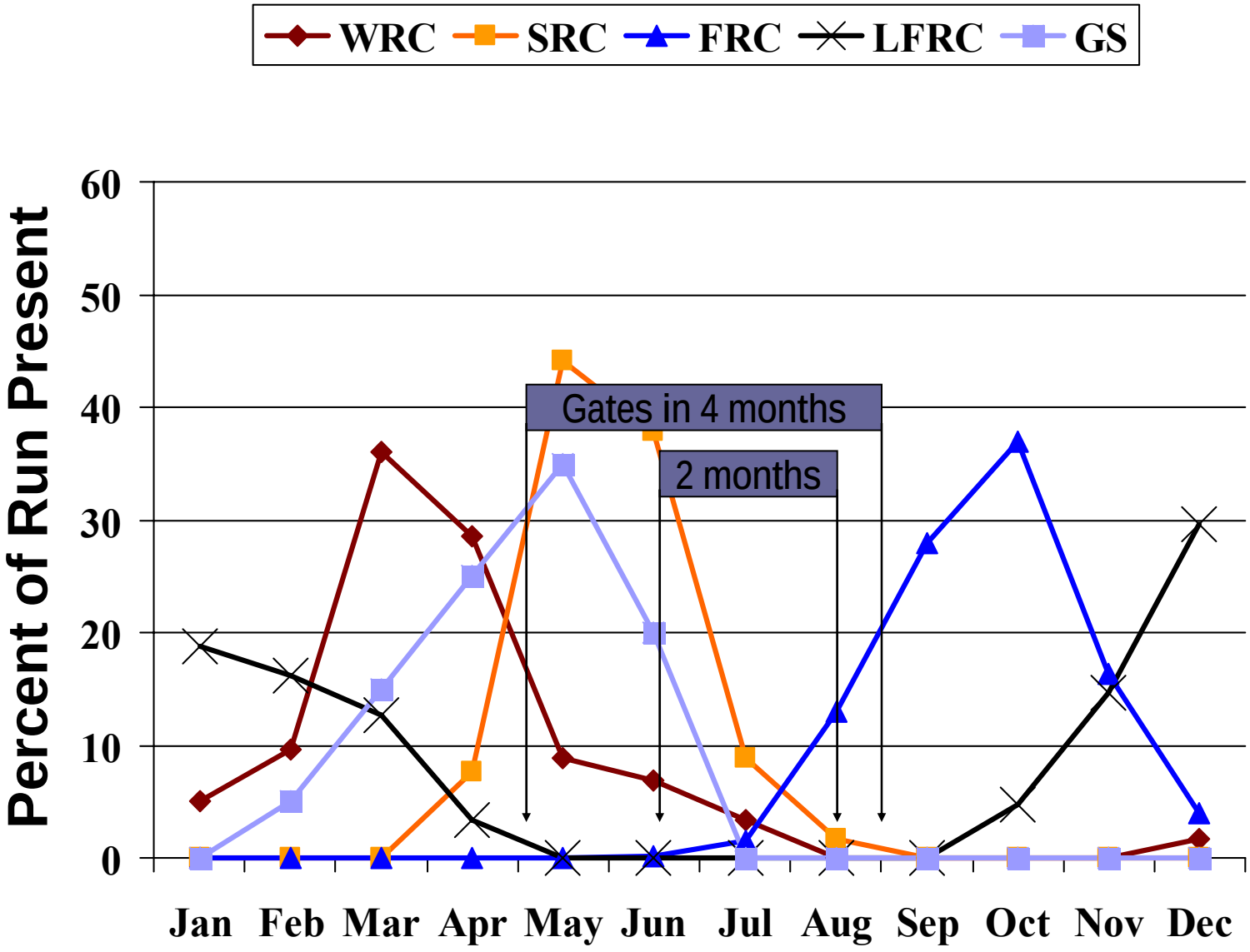

Sacramento River Spring-Run Chinook Salmon Mortality
Percent Mortality
70
60
50
40
30
20
10
0
Study 6.0
Study 7.0
Study 7.1
Study 8.0
NA
NA
Average
Wet
Above Normal
Below Normal
Dry
Critical
40-30-30 Water Year Type

Temperature effects with Climate Change




Sacramento River Spring-Run Chinook Salmon Mortality
Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
Study 9.0 Base
Study 9.1 Base with 1' Sea Level Rise
Study 9.4 Dryer, Less Warming
Study 9.2 Wetter, Less Warming
Study 9.5 Drier, More Warming
Study 9.3 Wetter, More Warming
Average
Wet
Above Normal
Below Normal
Dry
Critical
40-30-30 Water Year Type

Adult Species at RBDD



Adults delayed at RBDD on average 21 days

- Winter-run 15.1% of total population
- Spring-run 70.3% of upper Sacramento
- Steelhead 16.6% of upper Sacramento
- Fall-run 24.8% of upper Sacramento
- Green sturgeon 35% of total population completely blocked from 60 miles of best spawning habitat. Note: earlier gate closures increase green sturgeon blocked to 55%

Summary of Significant Effects

- Long-term average loss of 121 TAF September carry-over storage will reduce the ability to control water temperatures in the Sacramento River in all years.
- Loss in storage will reduce the suitability of spawning and rearing habitat for juvenile winter-run, spring-run, and fall run salmon.

RBDD effects

- Adults delayed an average of 21 days for winter-run, spring-run, and CV steelhead. Majority of green sturgeon completely blocked.
- Largest, most fecund adult green sturgeon are killed trying to pass under gates. Adult females separated from males.
- Higher predation rates on juvenile winter-run, steelhead, and green sturgeon as they pass through Red Bluff Lake and the diversion gates (*i.e*., 45% to 50% during May).
- Adverse modification of 6 miles of critical habitat from inundation behind RBDD and ACID dams.

Temperature effects

- Chinook spawning criteria exceeded 55% years in September and 30% of years in August. Greatest impact to spring-run.
- Highest increase in egg mortality occurs in critically dry years when winter-run mortality increases from 6 to 16%, spring-run increases from 50 to 68%, and steelhead increases from 2 to 3% compared to baseline (2004 conditions)

Long-term outlook

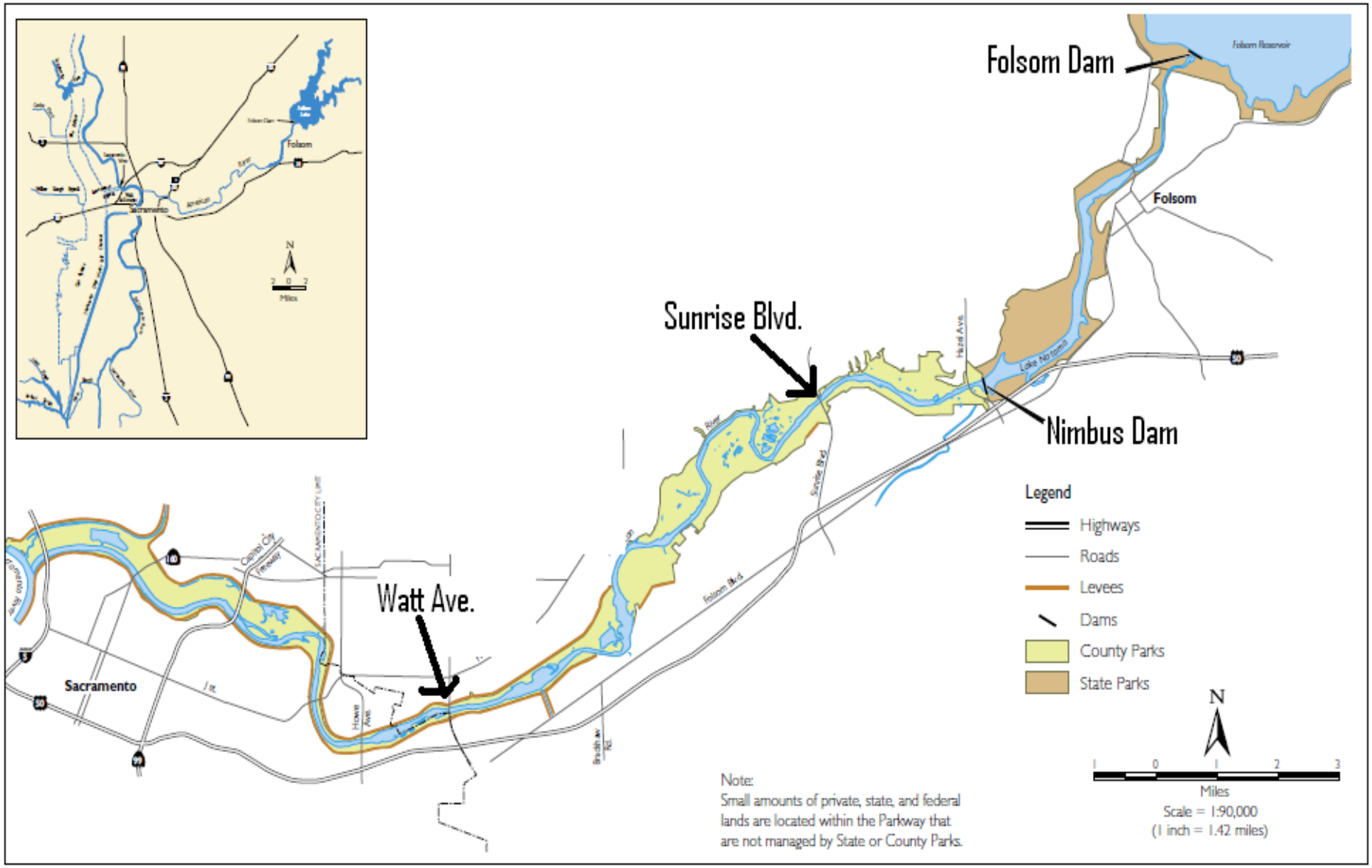
- Spring-run spawning eliminated in mainstem
- Winter-run spawning habitat will be reduced to a smaller area
- Critical habitat function reduced by RBDD
- Shorter emigration period, lower survival
- Climate change will double average mortality in all years (i.e., Critical years increases to 65% for winter-run, 95% for spring-run (Sac. R mainstem only), and 4% for steelhead (based on Late-fall Chinook as a surrogate).

Lower American River

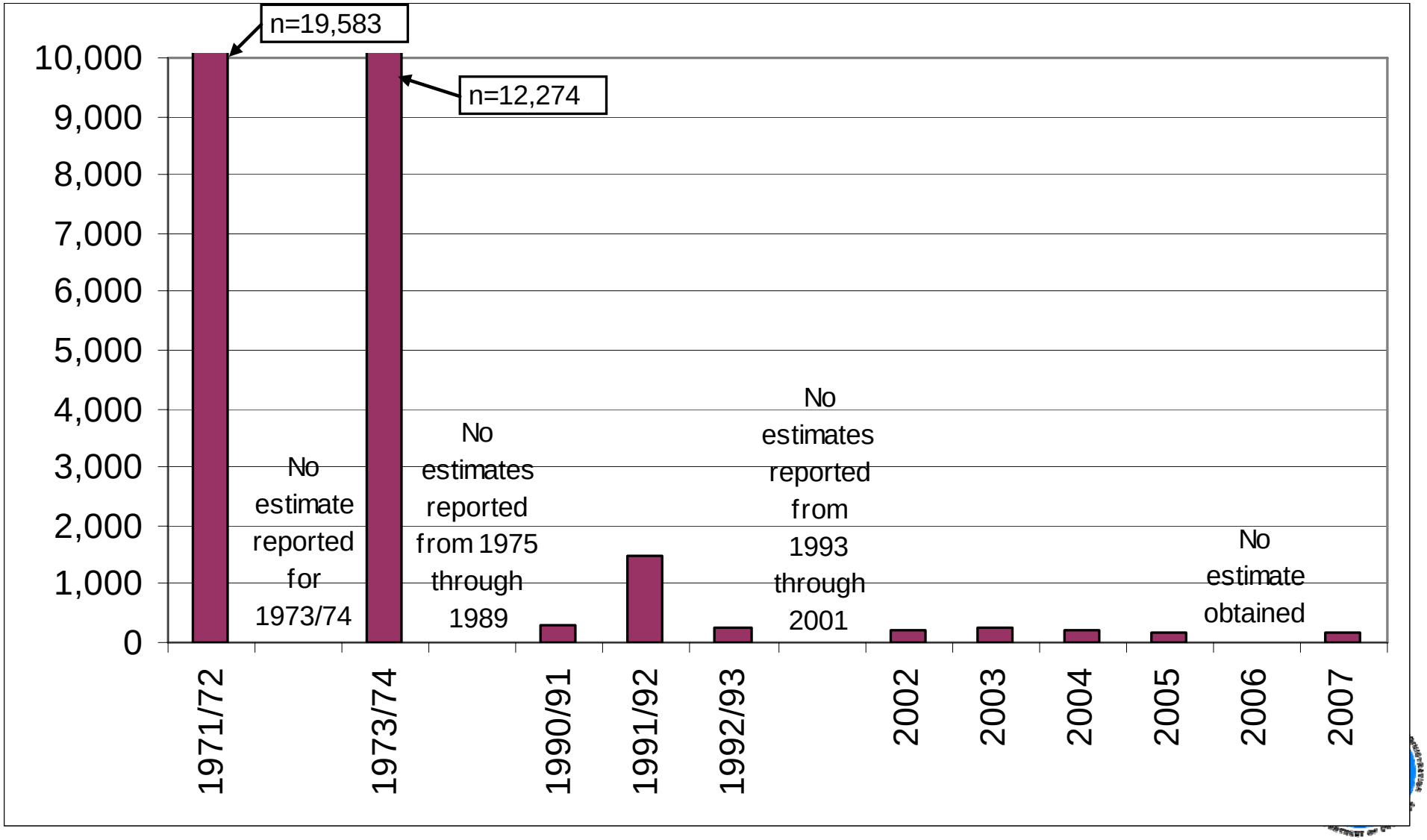
Brian Ellrott

NMFS

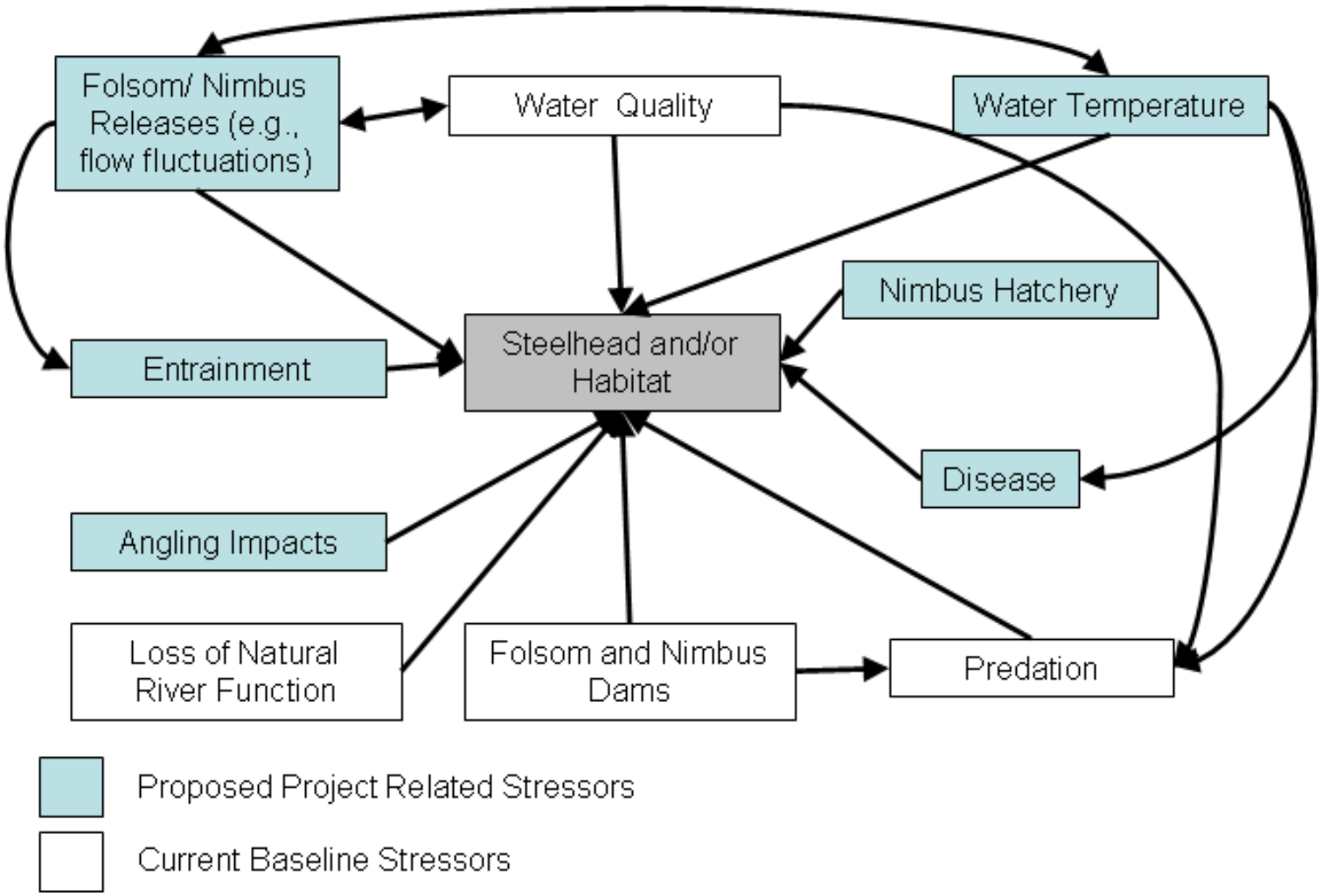
Lower American River (LAR)



LAR O.mykiss abundance



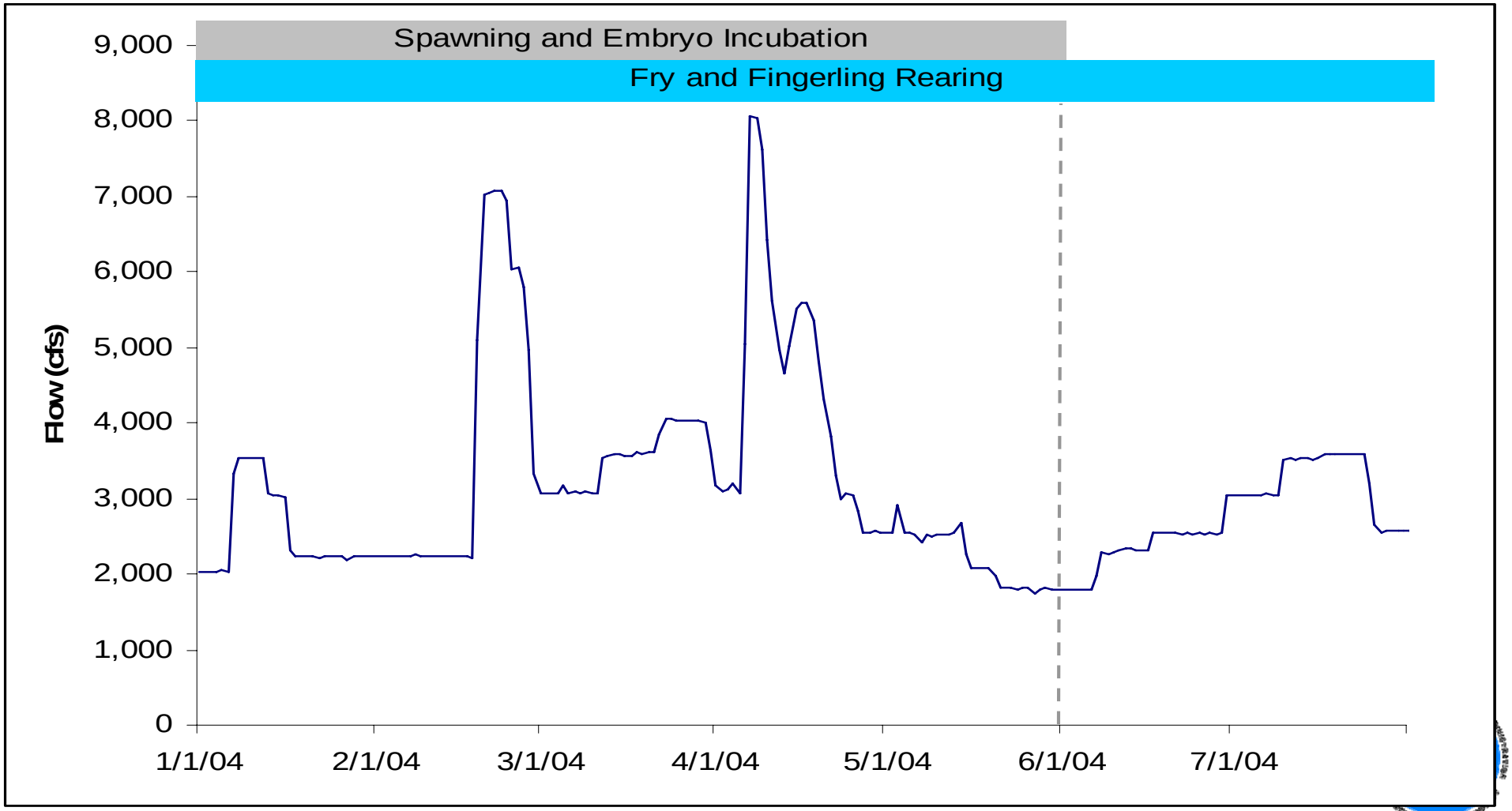
Assess Species Exposure



Project Effects on LAR Steelhead

Life Stage/ Location	Life Stage Timing	Stressor	Response	Probable Fitness Reduction
Spawning Primarily upstream of Watt Ave. area	Late-December through early April	Nimbus Hatchery – natural-origin steelhead spawning with hatchery O. mykiss	Reduced genetic diversity	Reduced reproductive success
		Angling impacts – catch-and-release impacts, illegal harvest	Mortality if hooked in critical areas (e.g., gills) or if illegally harvested	Reduced survival
		Folsom/Nimbus releases – flow fluctuations	Redd dewatering and isolation prohibiting successful completion of spawning	Reduced reproductive success

Project Effects on LAR Steelhead – Flow Fluctuations

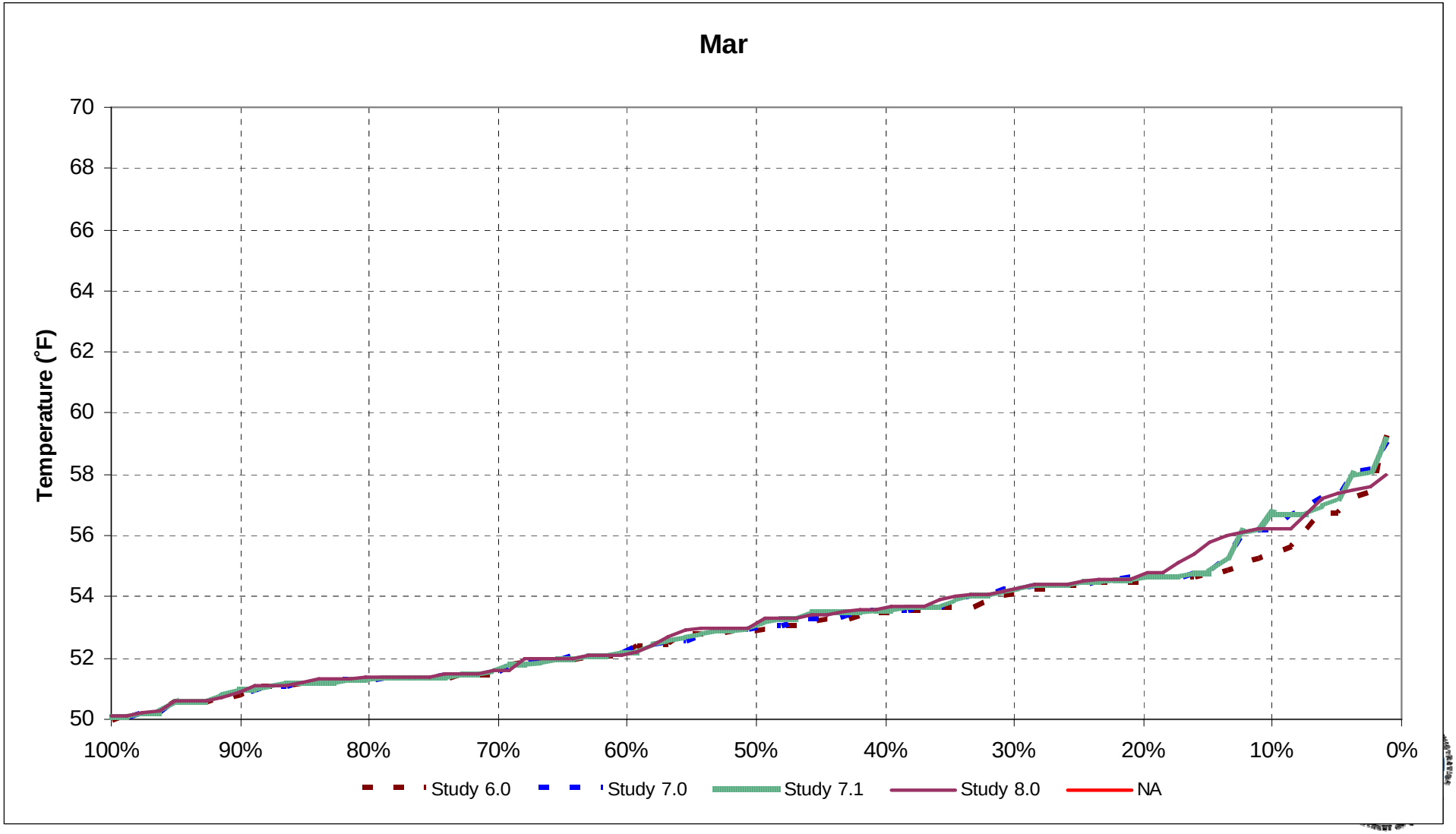


Project Effects on LAR Steelhead

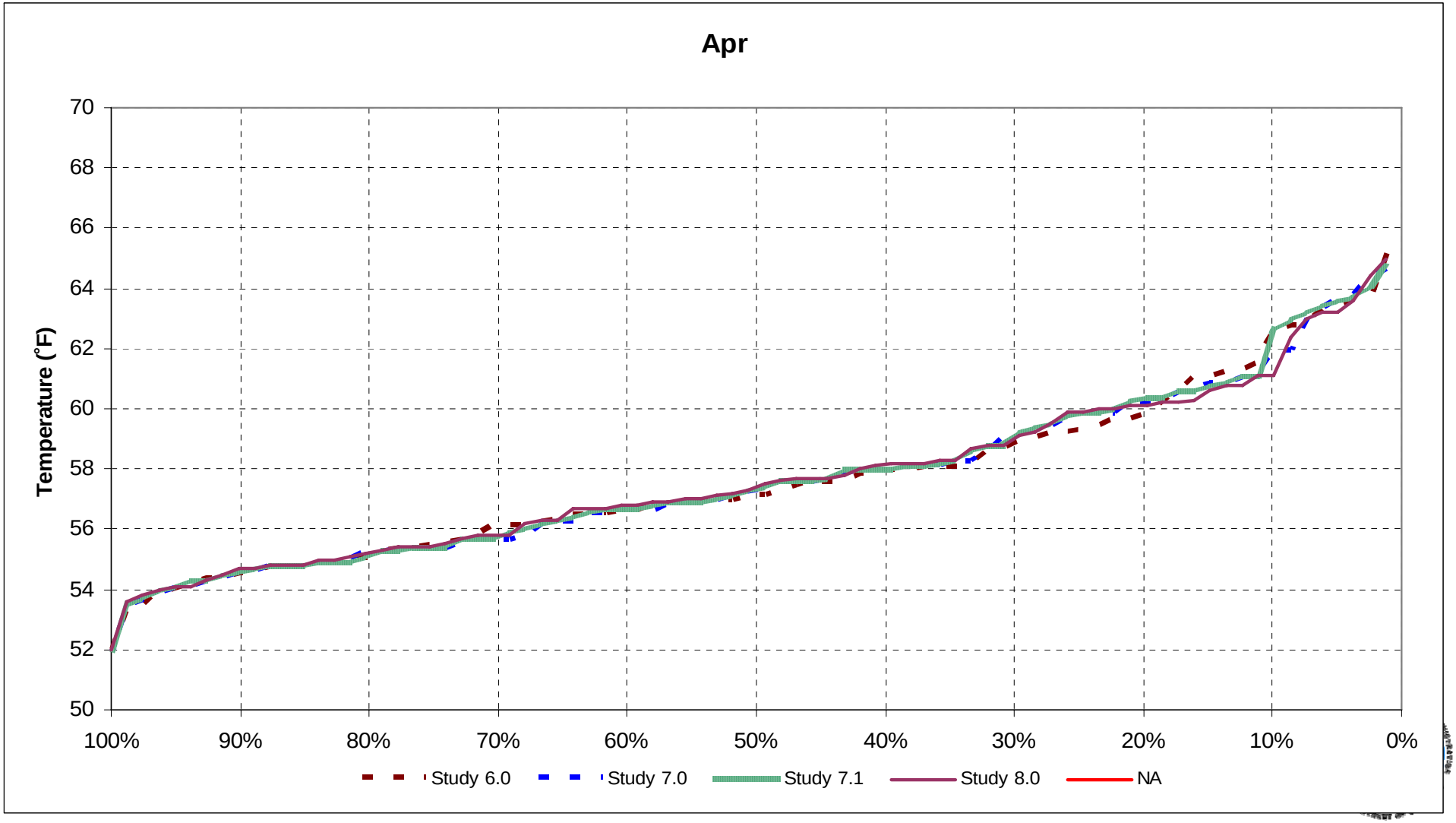
Life Stage/ Location	Life Stage Timing	Stressor	Response	Probable Fitness Reduction
Embryo incubation Primarily upstream of Watt Ave. area	Late-December through May	Folsom/Nimbus releases – redd scour	Egg and alevin mortality	Reduced survival
		Water temperatures warmer than life stage requirements	Reduced early life stage viability; direct mortality	Reduced survival

- Steelhead egg survival declines as water temperature increases past 50°F (Myrick and Cech 2001)
- Steelhead egg and alevin survival declines with exposure to constant water temperatures above 53.6°F (EPA 2001)
- Temperatures of 52°F or lower are best for steelhead egg incubation. However temperatures less than 56°F are considered suitable (OCAP BA 2008)
- Less than four percent embryonic mortality of steelhead incubated at 42.8, 48.2, and 53.6°F, but noted an increase to 15 percent mortality at 59°F (Rombough 1988)
- Higher mortality and structural asymmetry for steelhead incubated at 64.4°F compared to at 46.4°F (Turner *et al*. 2007)

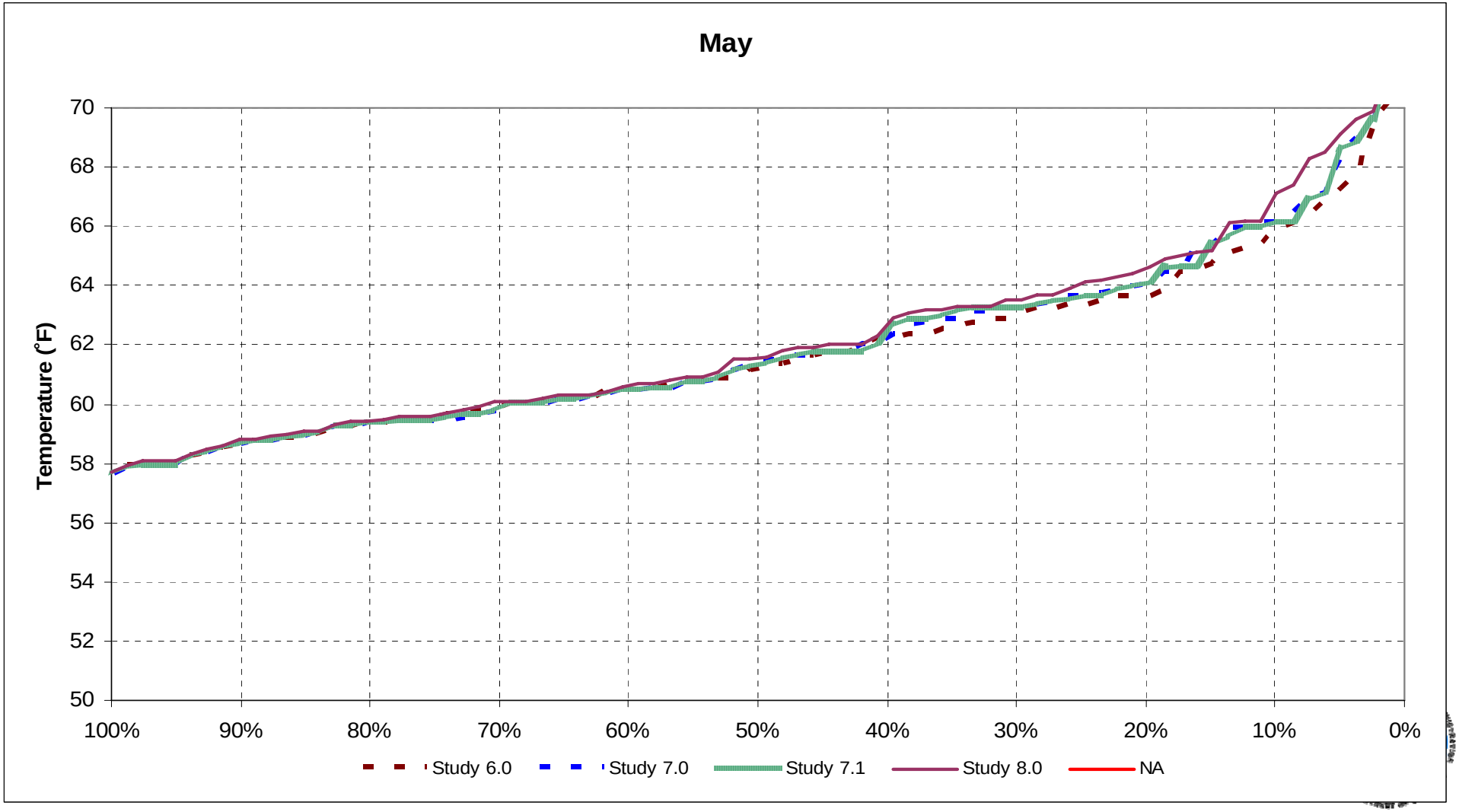
Water Temperature
March



Water Temperature
April



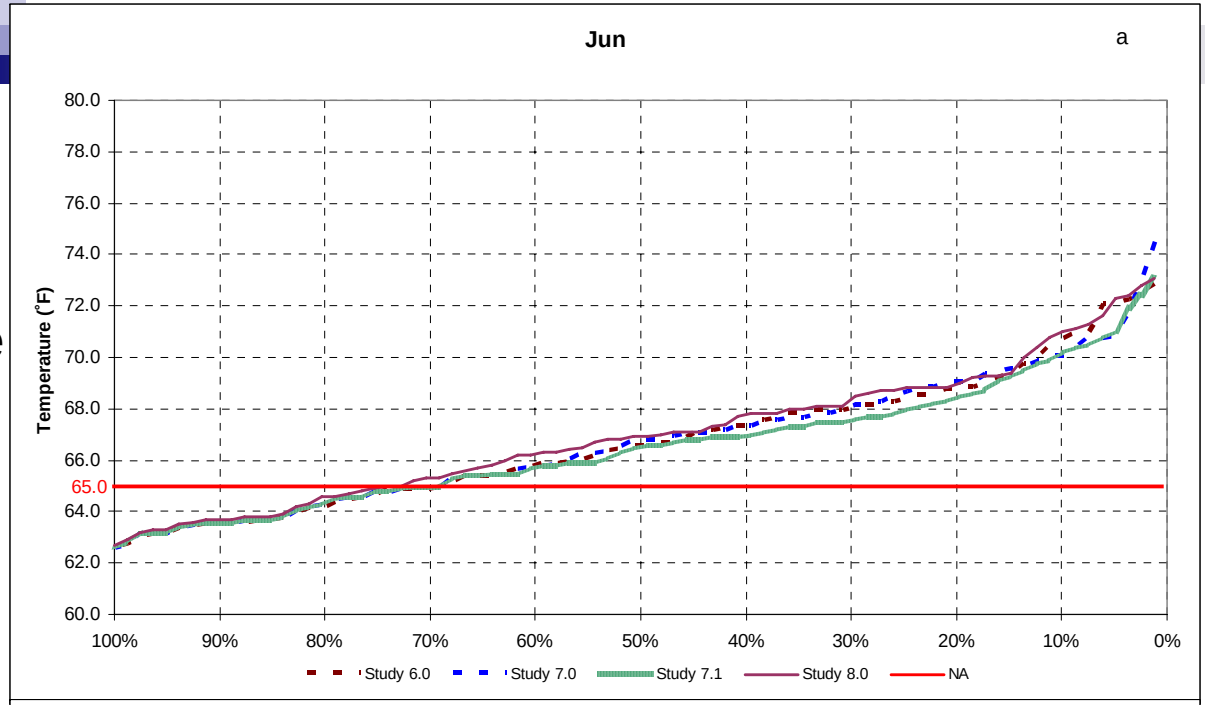
Water Temperature
May



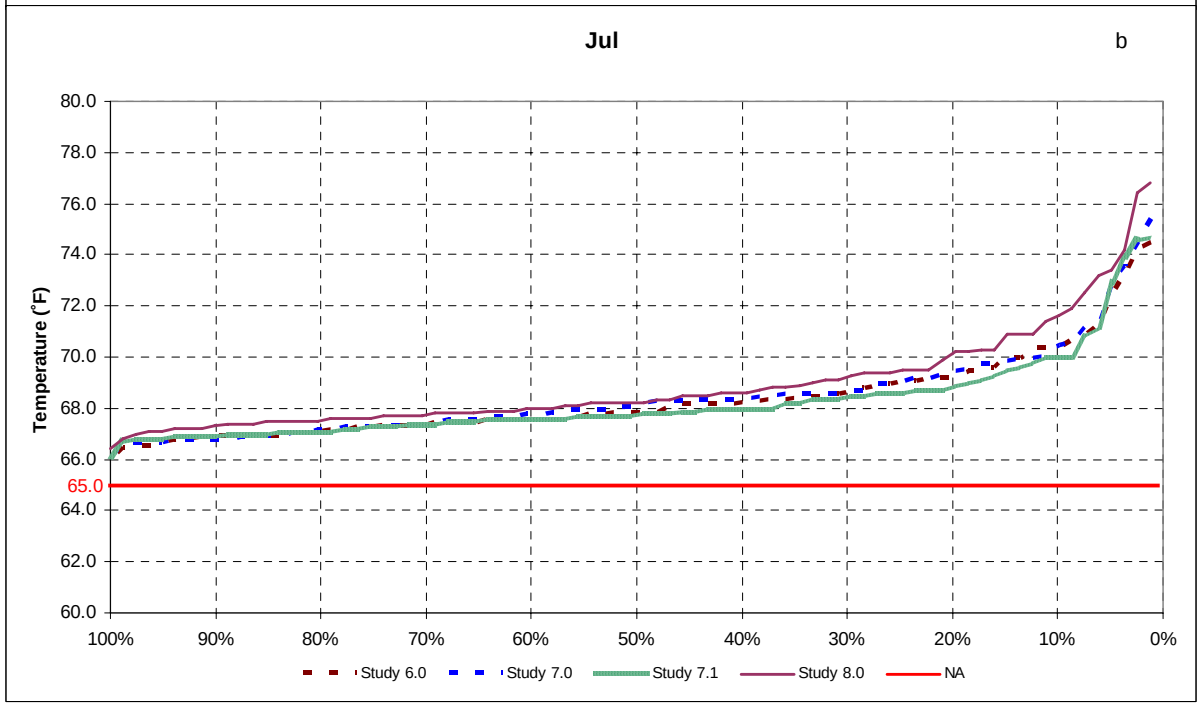
Project Effects on LAR Steelhead

Life Stage/ Location	Life Stage Timing	Stressor	Response	Probable Fitness Reduction
Juvenile rearing Primarily upstream of Watt Ave. area	Year-round	Folsom/Nimbus releases – flow fluctuations; low flows	Fry stranding and juvenile isolation; low flows limiting the availability of quality rearing habitat including predator refuge habitat	Reduced survival
Juvenile rearing Primarily upstream of Watt Ave. area	Year-round	Water temperatures warmer than life stage requirements	Physiological effects - increased susceptibility to disease (e.g., anal vent inflammation) and predation	Reduced growth; Reduced survival

June

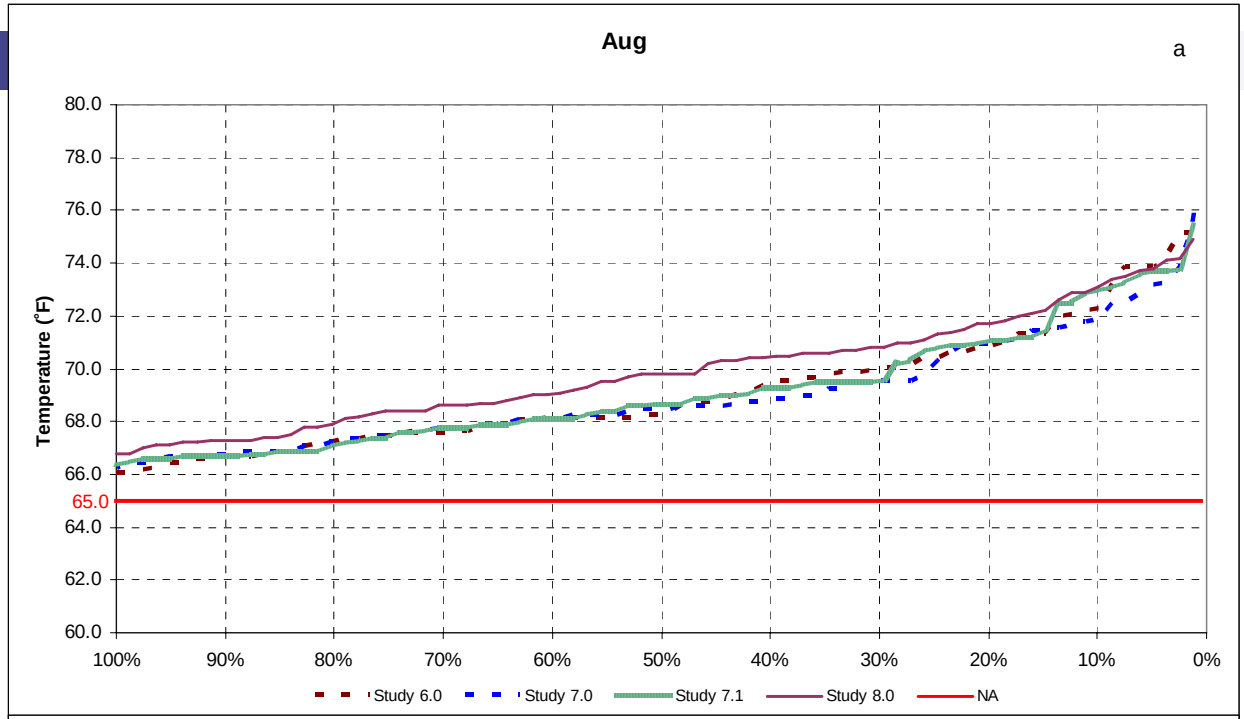


July

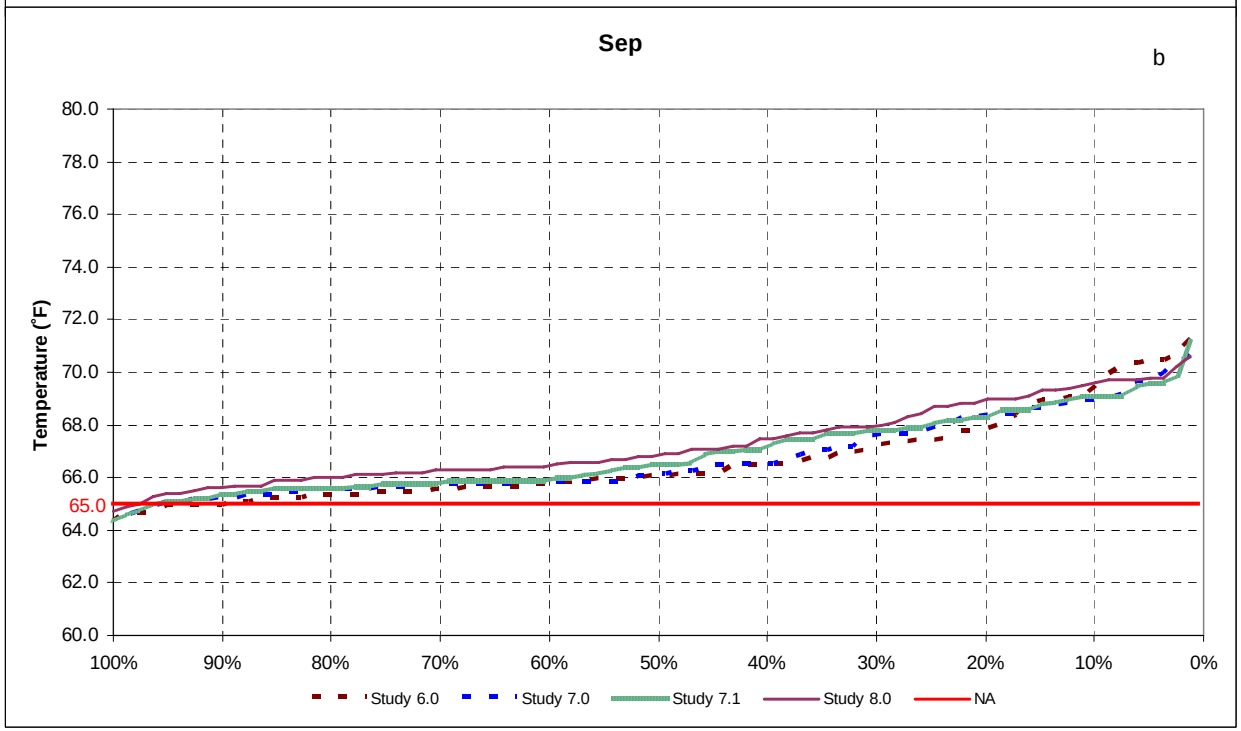


Exposure to daily mean water temps. above 65°F are associated with anal vent inflammation in juvenile steelhead in the LAR

August



September

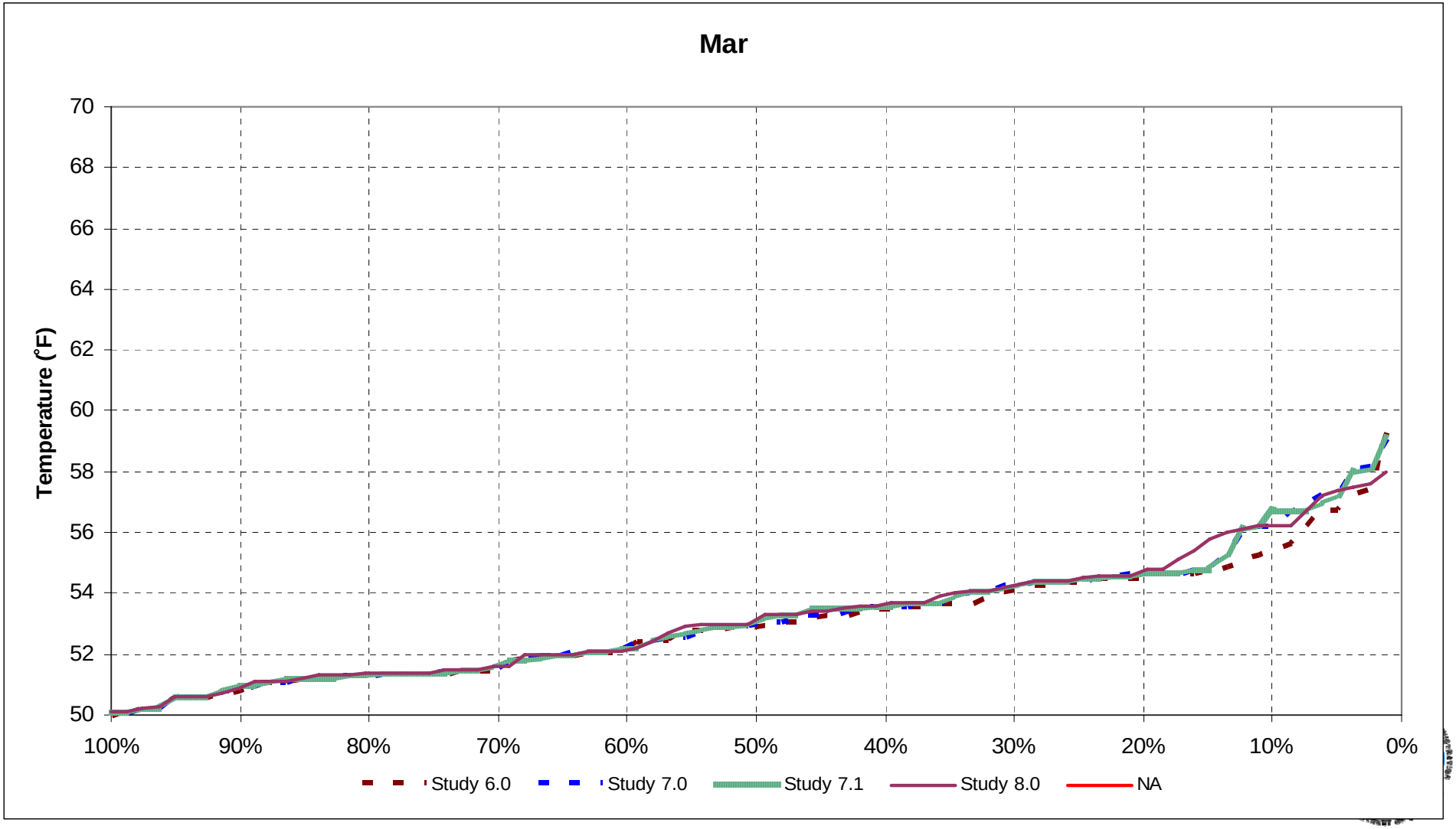


Project Effects on LAR Steelhead

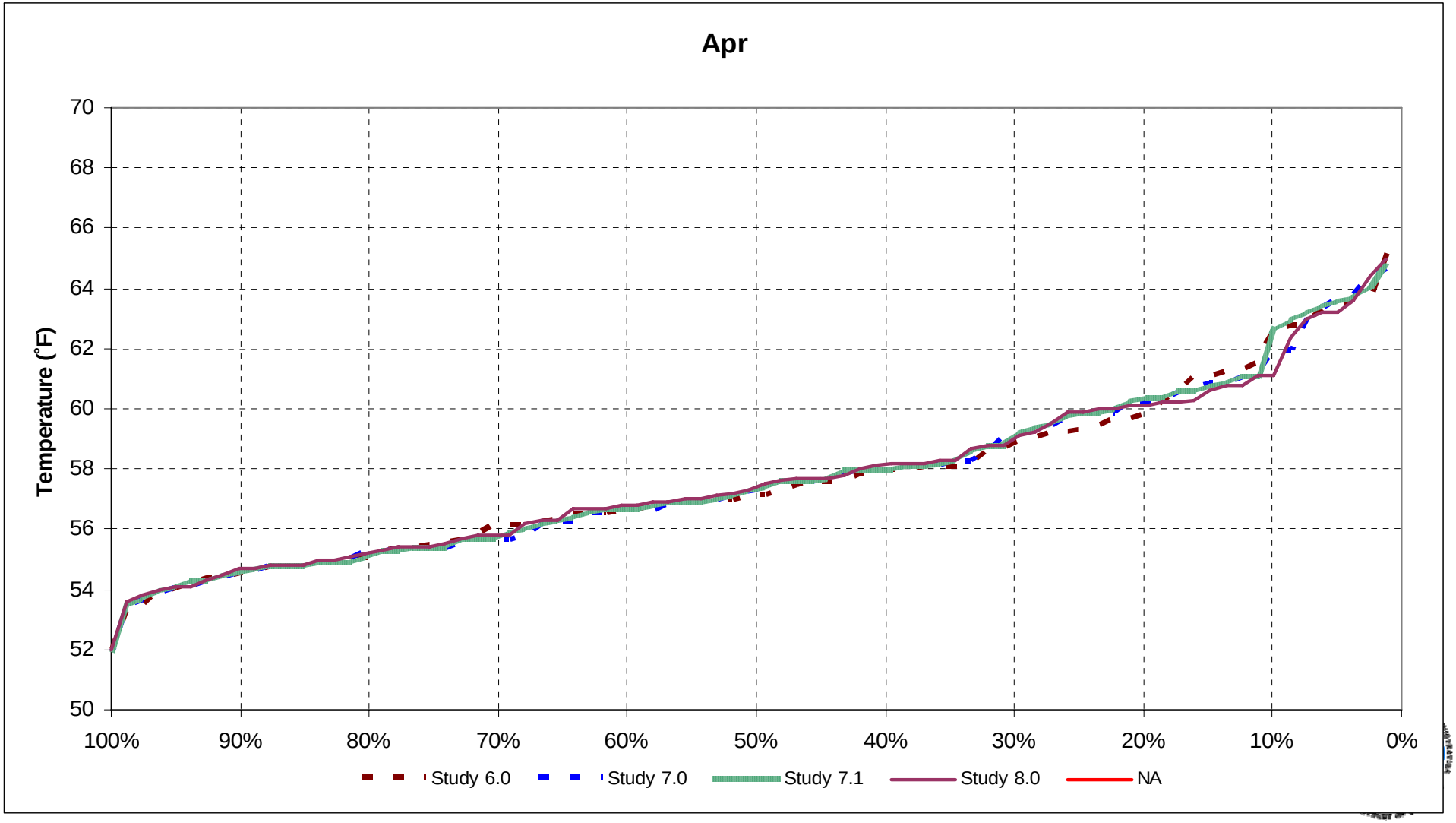
Life Stage/ Location	Life Stage Timing	Stressor	Response	Probable Fitness Reduction
Smolt emigration Throughout entire river	January through June	Water temperatures warmer than life stage requirements	Physiological effects – reduced ability to successfully complete the smoltification process, increased susceptibility to predation	Reduced growth; Reduced survival

- Successful smolt transformation occurs at water temperatures:
  - below 52.3°F (Adams et al. 1975; Myrick and Cech 2001)
  - below 54° F (Zaugg and Wagner 1973, Wedemeyer *et al*. 1980, EPA 2001)

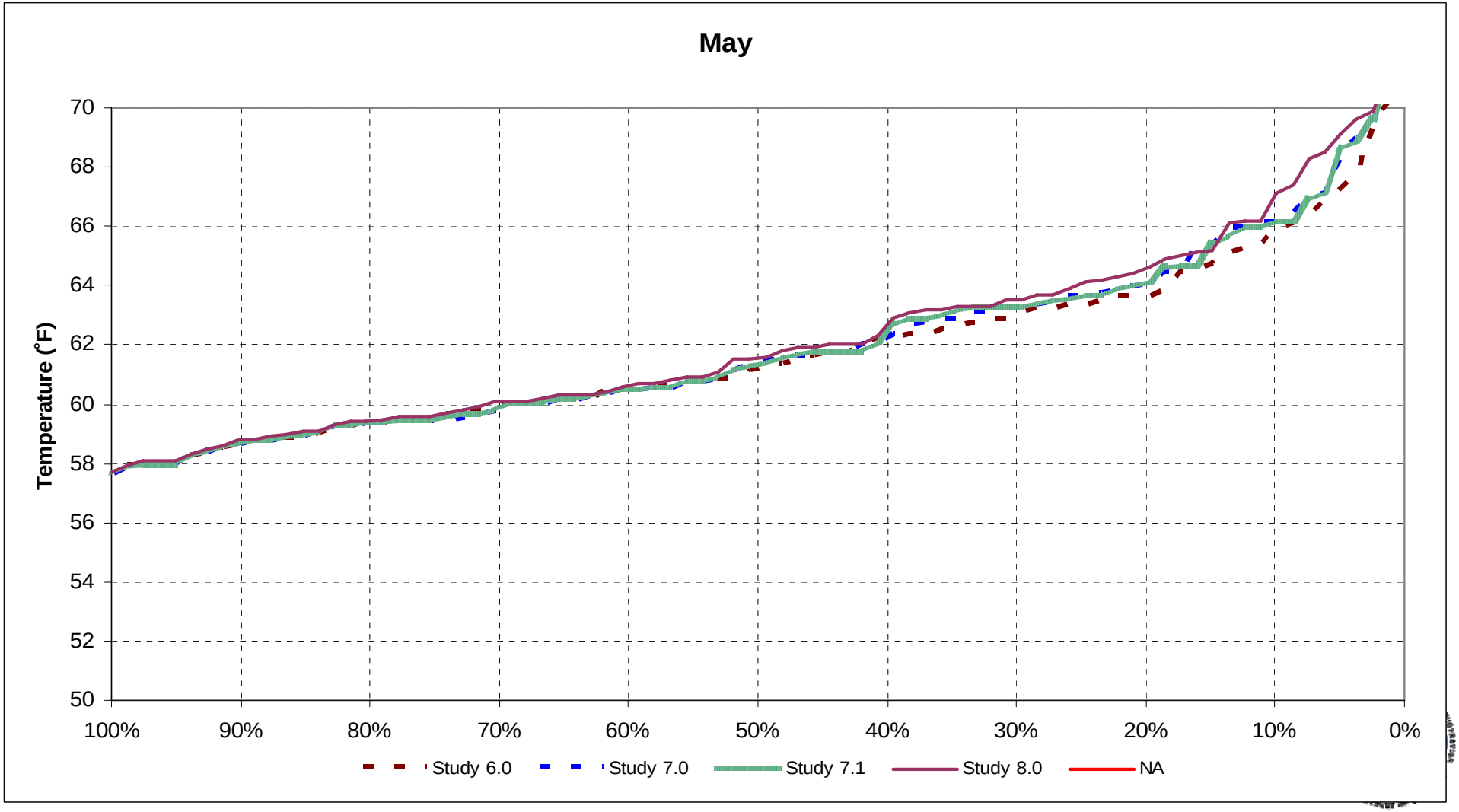
Water Temperature
March



Water Temperature
April



Water Temperature
May



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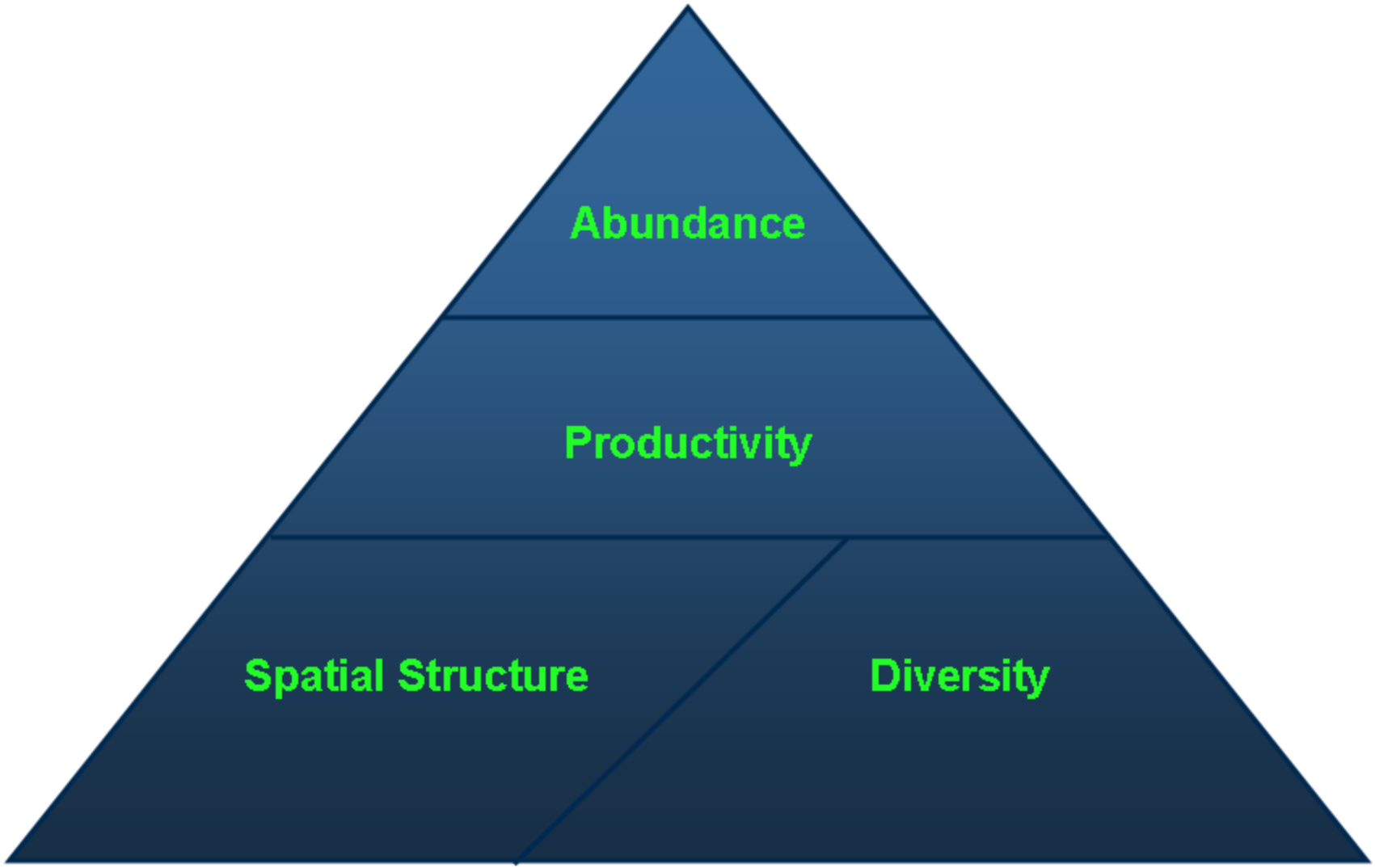
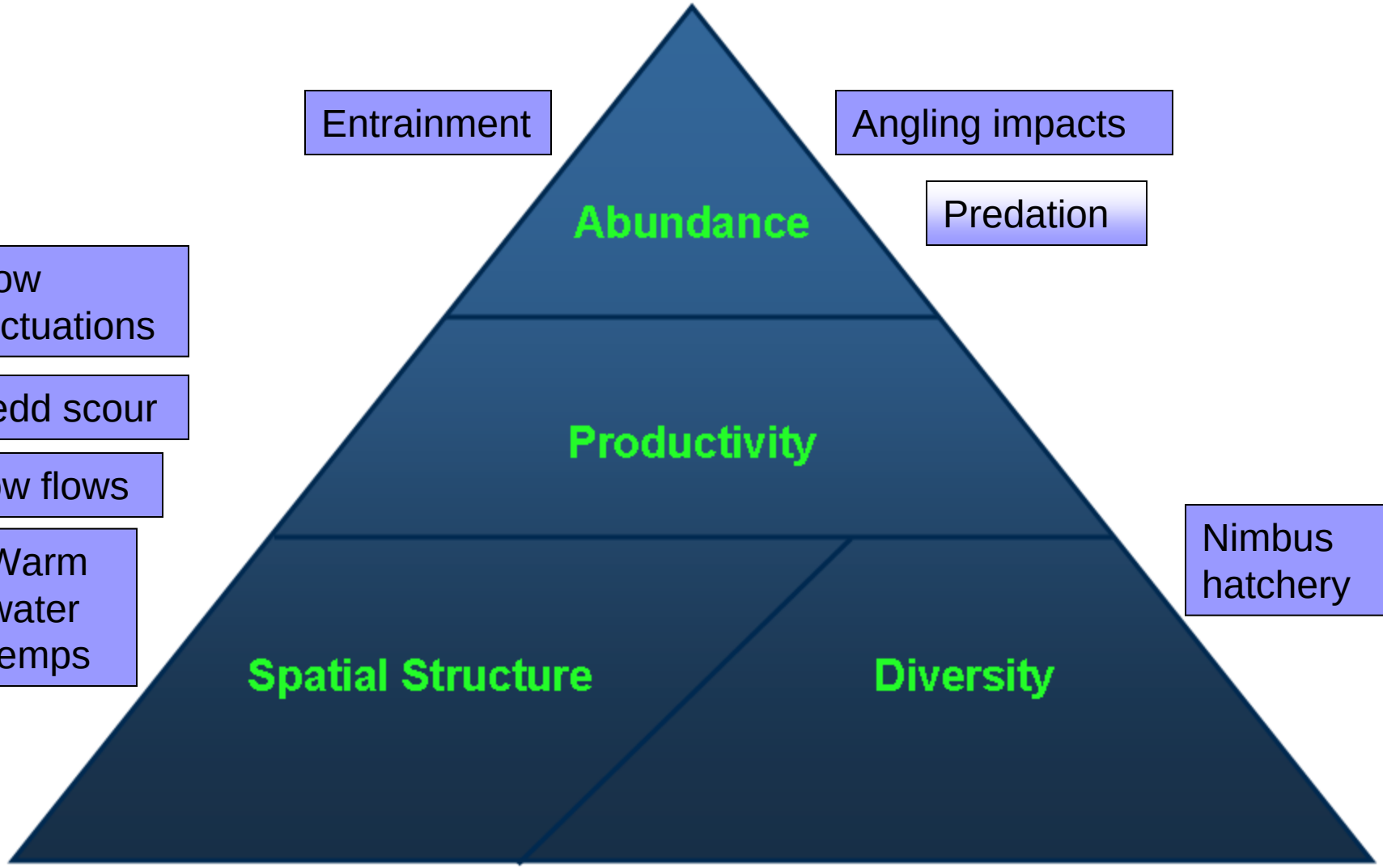
“VSP” = Viable Salmonid Population



"VSP" = Viable Salmonid Population



Entrainment

Angling impacts

Predation

Flow fluctuations

Redd scour

Low flows

Warm water temps

Nimbus hatchery

Loss of natural river function

Folsom and Nimbus Dams

Project Stressors

Baseline Stressors

Eastside Division

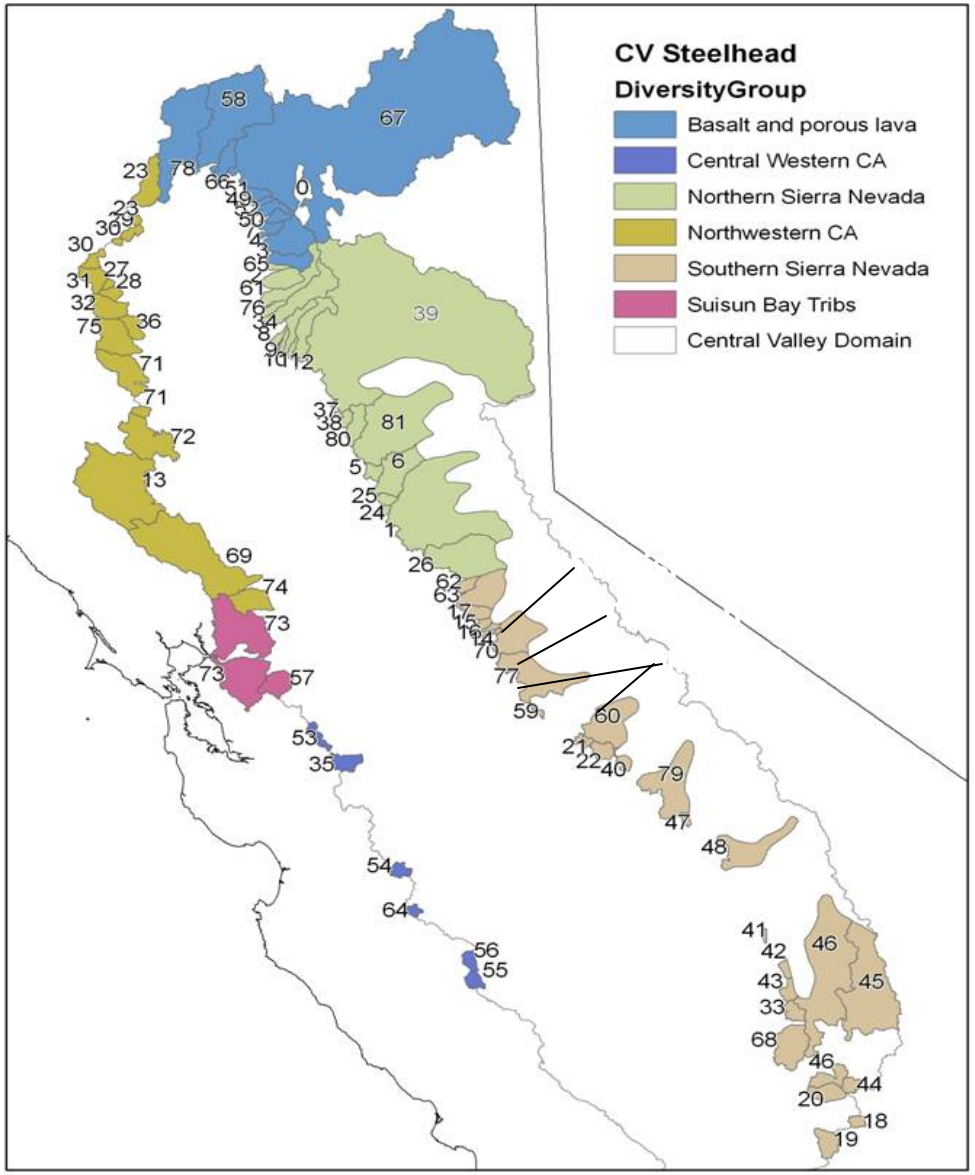
New Melones and Stanislaus River operations

Rhonda Reed

New Melones Dam
Tulloch Dam
Goodwin Dam
RM 59
TMB
Knights Ferry
KF
LL
HR
HB
BB
OB
VO
Hwy 120 Bridge
OR
Willms Pond
Orange Blossom Bridge
Oakdale
Stanislaus River
Hwy 99
Ripon
RP
MHA
JM
RB
Riverbank
MR
RE
Caswell Memorial State Park
San Joaquin River
Modesto
3.5 Miles
North
Stanislaus River Parks

Central Valley Steelhead Recovery

- Draft recovery plan status
- Draft Recovery goal: at least 2 viable steelhead populations within each diversity group
- San Joaquin Basin is the Southern Sierra Nevada diversity group
- Current population numbers very low



Steelhead: Key Stressors

- Temperature (Dams limit fish to unsuitable habitat)
- Flow (Spawning, Rearing, Migration)
- Habitat Quality
  - Ongoing degradation of spawning and rearing habitat; Freshwater migration corridors.

Key Water Uses

- Senior water rights
- D-1641 Water Quality needs for San Joaquin River
- Fish needs
- Contract obligations
- Modeling approach
  - Fish needs : Contract obligations

Basic Allocation Bands

- High Allocation Years (Projected New Melones Carryover Storage greater than 1.7MAF End of September)
- Mid-Allocation Years
- “Conference Year” conditions - New Melones Index is less than 1.0 MAF.

Unspecified Operational Conditions

- Flow
  - Operational rules not described; only look-up tables
  - VAMP ends 2011and future not defined for outmigrant pulse flows
  - b(2) and b(3) water assumed not reliable
  - Contracted deliveries equal to fishery needs

- Temperature
  - No definition to operations to ensure that model results are achieved for temperature
  - Fish related flows directed by external processes

Habitat Quality

Ongoing degradation of spawning and rearing habitat; Freshwater migration corridors.

- Transport of spawning gravel with limited replacement
- Fossilization of point bars
- Channel incision prevents floodplain inundation and limits rearing habitat
- No channel forming flows
- No winter variablility in flow to distribute YOY
- Reduced anadromy

Long Term Outlook

- Modeling and recent data suggest summer temperature criteria could be met at OBB
- Instream flows could meet IFIM
- Increase in egg mortality if future climate is warmer, drier or both
- Degradation of spawning and rearing habitat will continue at a rate faster than restoration

Delta Division Analysis

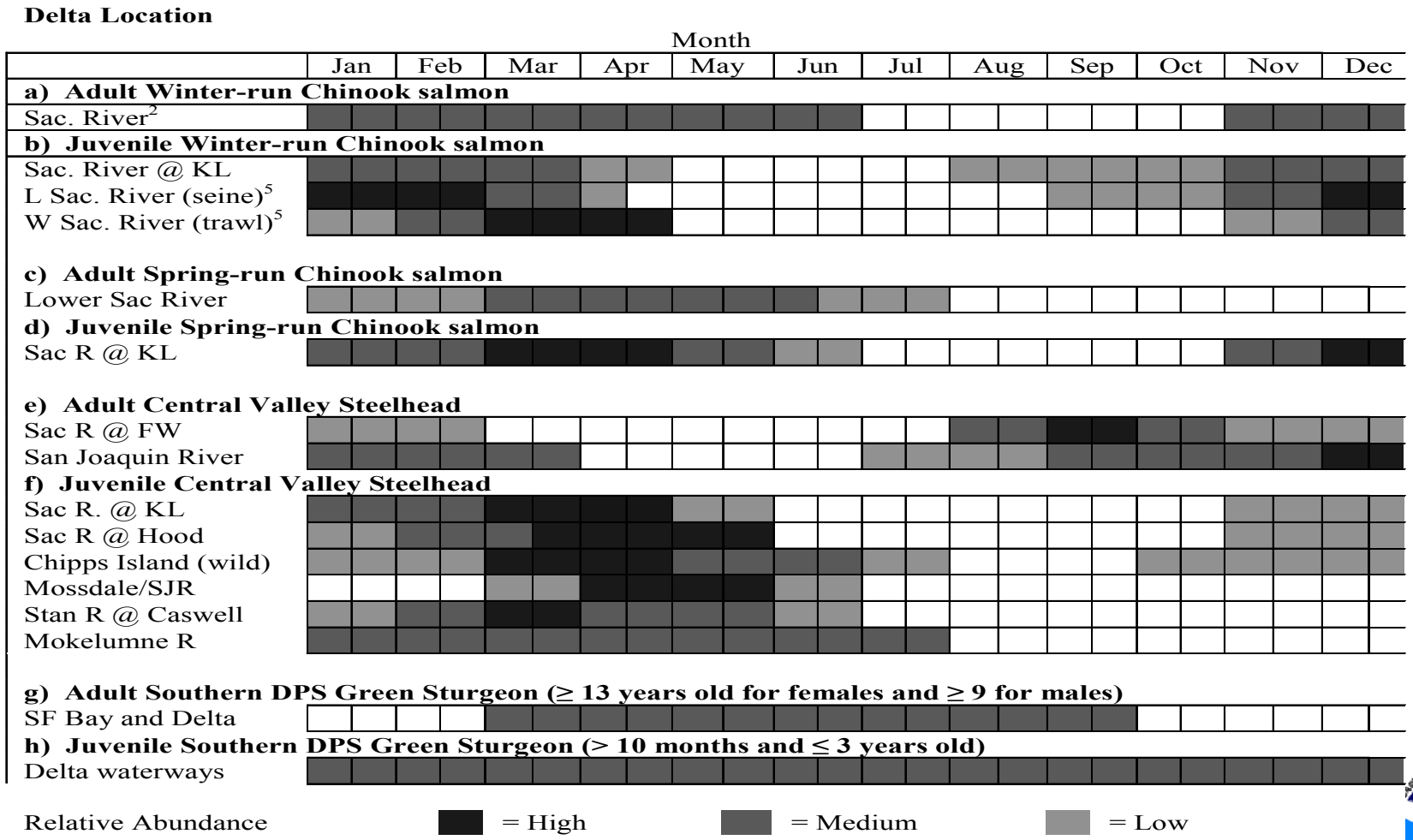
Jeff Stuart

NMFS

Elements of Delta Division Analyzed

- Exports From Proposed Project
- Direct Entrainment at Project Facilities
- Indirect Mortality within Delta
- Clifton Court Aquatic Weed Control Program
- South Delta Temporary Barriers
- SDIP Stage 1
- Delta Cross Channel
- Contra Costa Water District Diversions
- North Bay Aqueduct
- Climate Change
- Vernalis Adaptive Management Plan

Temporal Occurrence of Species in Delta



Project Related Changes to Delta Hydrology

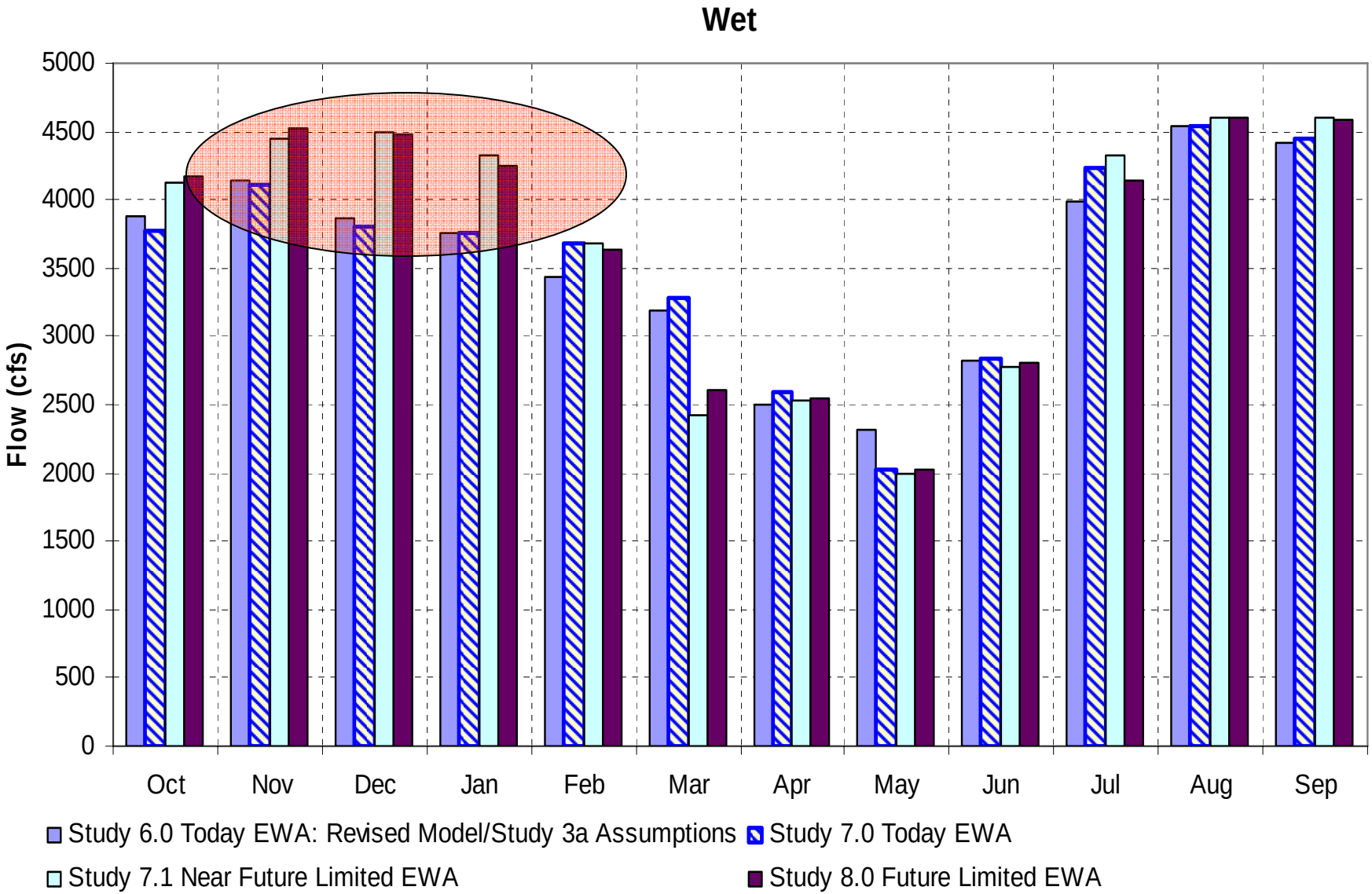
- Long term average Delta inflow will decrease as modeled under Studies 7.0, 7.1, and 8.0

Difference in Thousand acre feet (TAF)	Study 7.0 – Study 6.0	Study 7.1 – Study 7.0	Study 8.0 – Study 7.0	Study 8.0 – Study 7.1
Long-term annual average Total Delta Inflow	-69	-201	-270	-70
1929 -34 Annual average Total Delta Inflow	136	-272	-403	-130

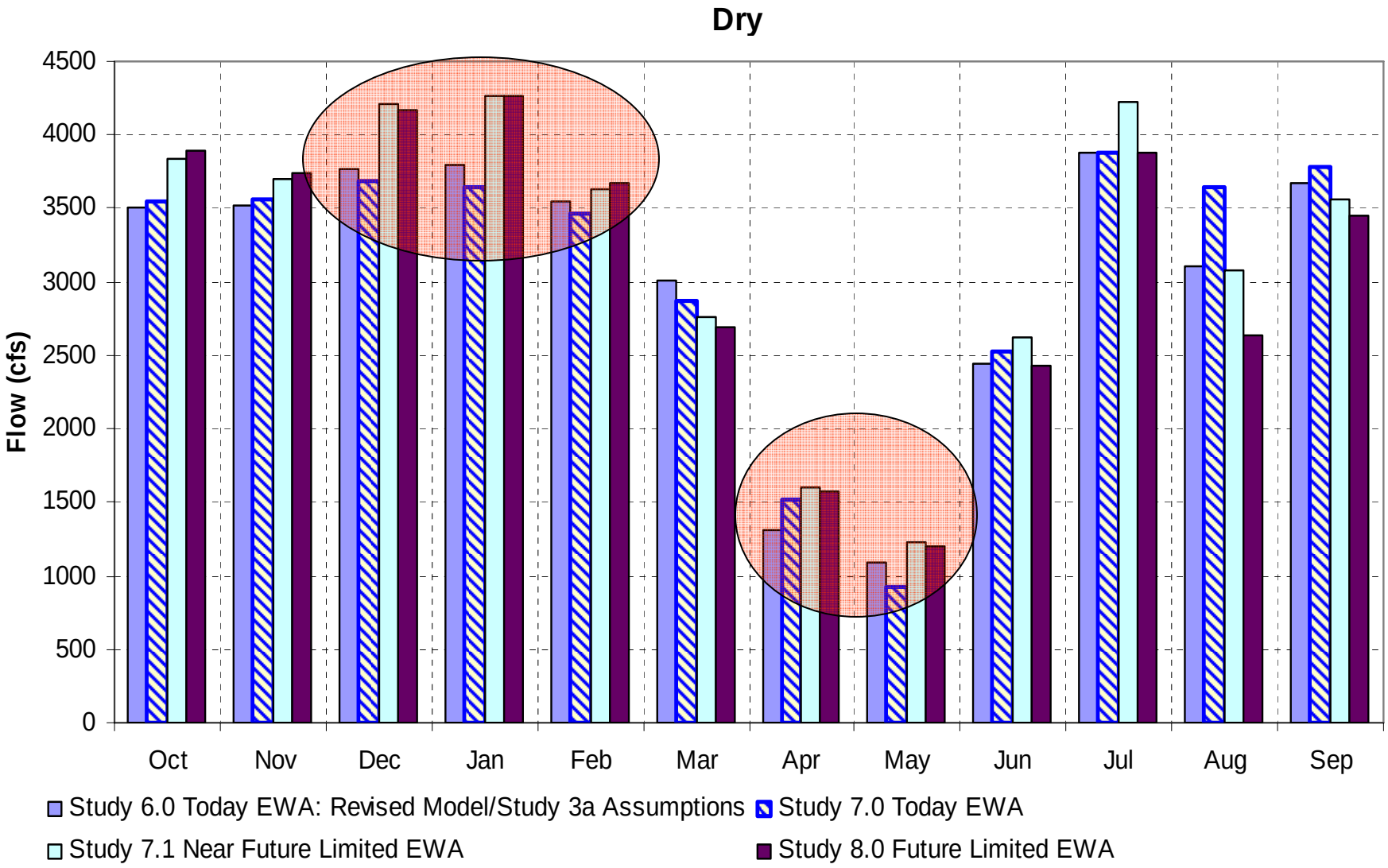
Modeled Changes in Export Levels

- CVP and SWP exports increase in both near future (Study 7.1) and future conditions (Study 8.0).
- Significant increases in exports during the late fall and winter time frames over current operations.
- SWP exports increase in April and May due to decrease in “fish water” available for export curtailment.

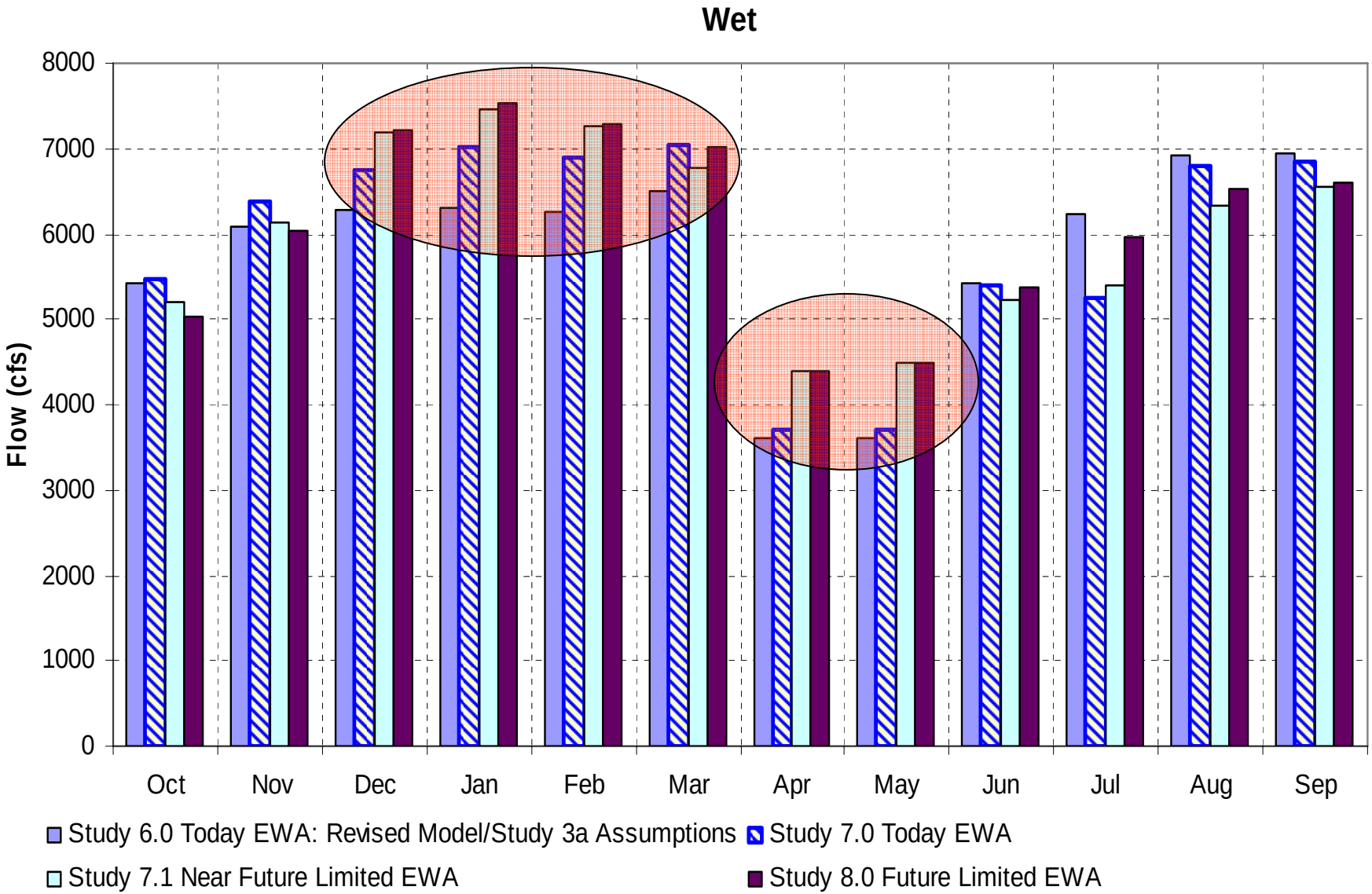
Average wet year (40-30-30) monthly CVP export rate



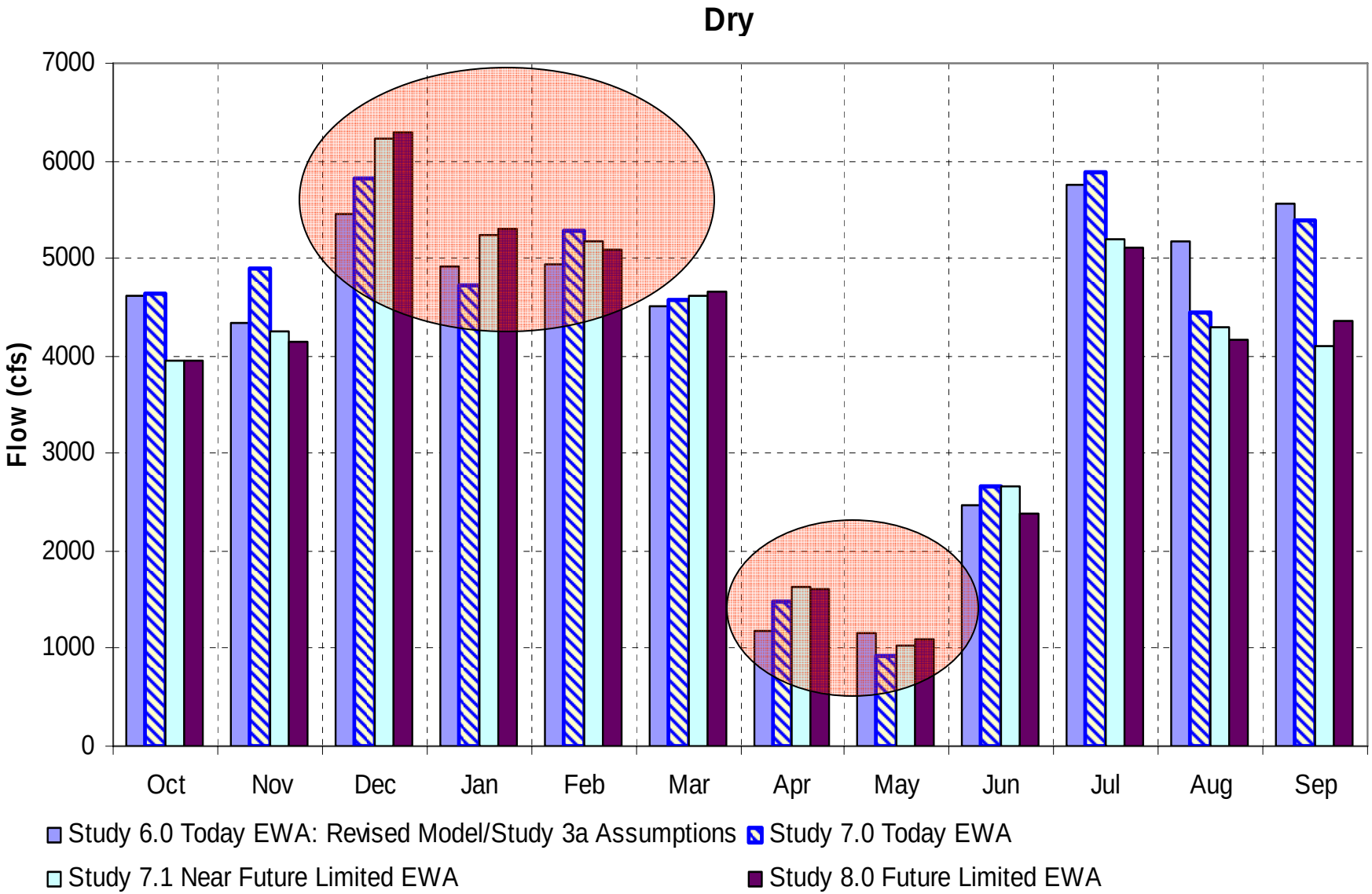
Average dry year (40-30-30) monthly CVP exports



Average wet year (40-30-30) monthly SWP export rate



Average dry year (40-30-30) monthly SWP export rate



Effects to Listed Salmonids

- Elevated exports during the late fall and early winter increase the potential for both entrainment by the export facilities, as well as migrational delays for fish entering the Delta interior.

- Diversion of listed fish into the interior of the Delta increases the risk of mortality (*i.e*., predation) as well as exposure to contaminants in the Delta interior.

- Increases in exports in April and May under proposed future operating conditions increase the risk of entrainment, particularly for San Joaquin River Basin fish.

Old and Middle River Flows

Projected Old and Middle River Net Flows (in cfs) in Wet and Above Normal Water Years for the Months of December through March (from Appendix G in 2008 Biological Assessment)

Study	December	January	February	March	Average
Study 7.0	-8099	-5552	-1847	-1052	-4138
Study 7.1	-9618	-5999	-2063	-311	-4498
Study 8.0	-9649	-6664	-2795	-1051	-5040

Study	April	May	June	July	Average
Study 7.0	609	-286	-4319	-7706	-2926
Study 7.1	-1865	-2616	-3487	-7803	-3943
Study 8.0	-1805	-2632	-3542	-7975	-3989

Projected Old and Middle River Net Flows (in cfs) in Below Normal and Dry Water Years for the months of December through March.

Study	December	January	February	March	Average
Study 7.0	-6691	-7349	-7439	-6667	-7037
Study 7.1	-8535	-8594	-6574	-6426	-7532
Study 8.0	-7873	-8910	-7012	-6359	-7538

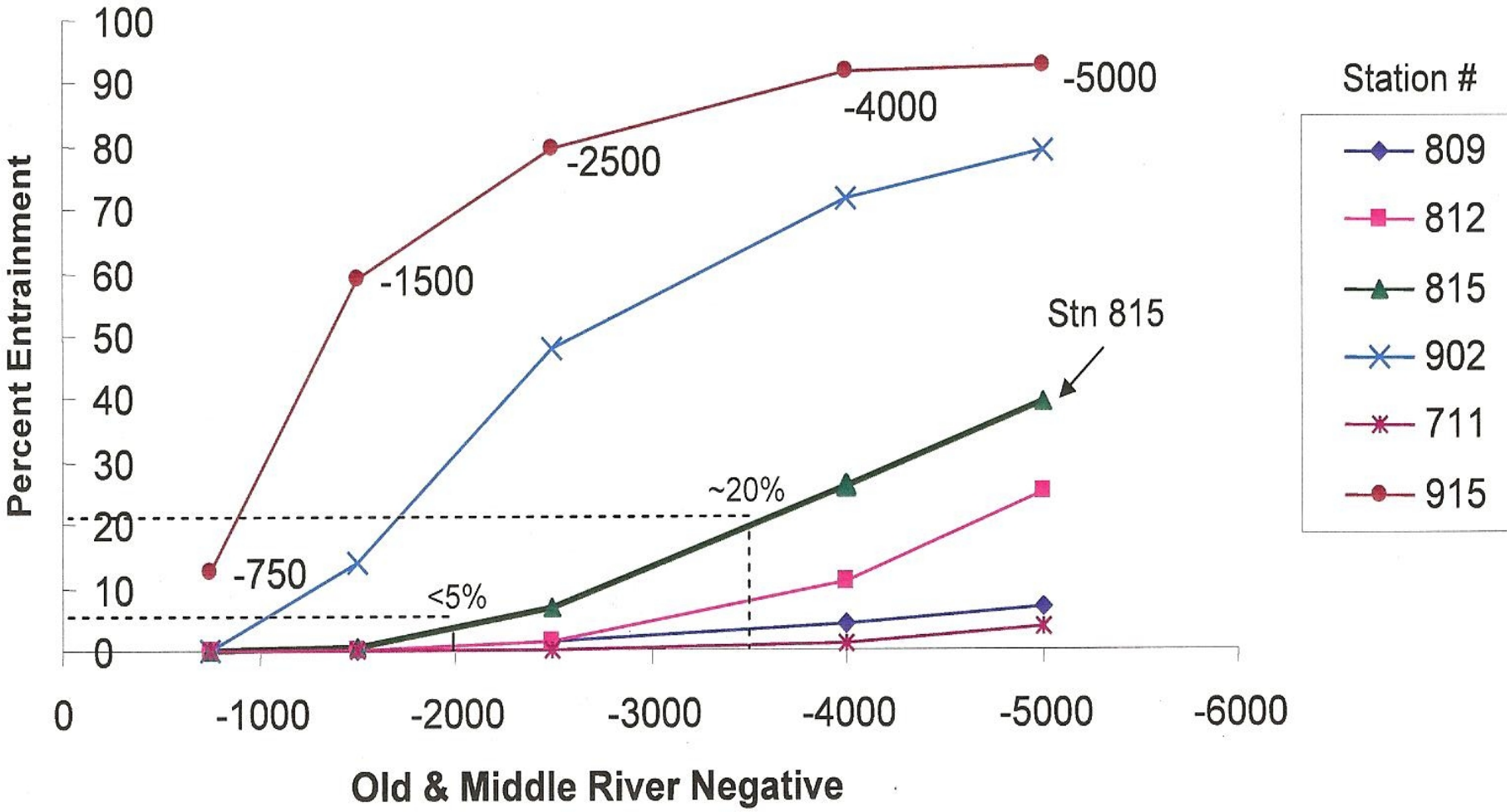
Study	April	May	June	July	Average
Study 7.0	-1530	-1856	-6527	-9957	-4976
Study 7.1	-2473	-2489	-6721	-10195	-5469
Study 8.0	-2495	-2783	-6837	-10814	-5732

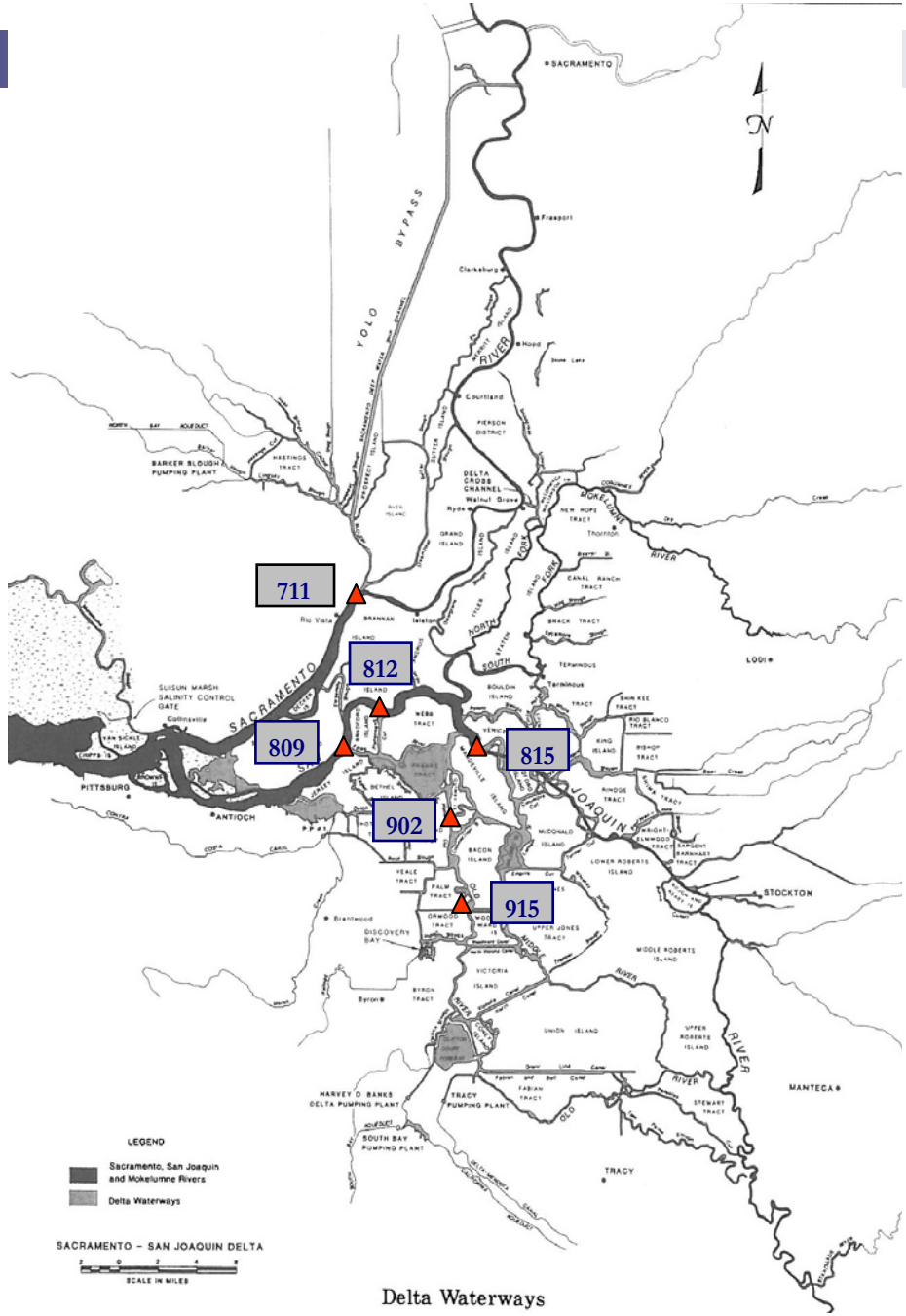
Projected Old and Middle River Net Flows (in cfs) in Critically Dry Water Years for the months of December through March.

Study	December	January	February	March	Average
Study 7.0	-7249	-5199	-2515	-3086	-4512
Study 7.1	-6763	-5852	-3054	-4236	-4976
Study 8.0	-7492	-5727	-2304	-4379	-4975

Study	April	May	June	July	Average
Study 7.0	-1566	-1573	-3748	-6093	-3245
Study 7.1	-2199	-1920	-2910	-5267	-3074
Study 8.0	-2246	-1898	-2616	-3676	-2609

Export Entrainment at Various Levels of Negative Flow for Old and Middle River Monitoring





Delta Waterways

Direct Entrainment at the Tracy Fish Collection Facility and the Skinner Fish Protection Facility

- Screening Efficiency
- Predation issues
- CHTR operations (Collection, Handling, Trucking and Release)

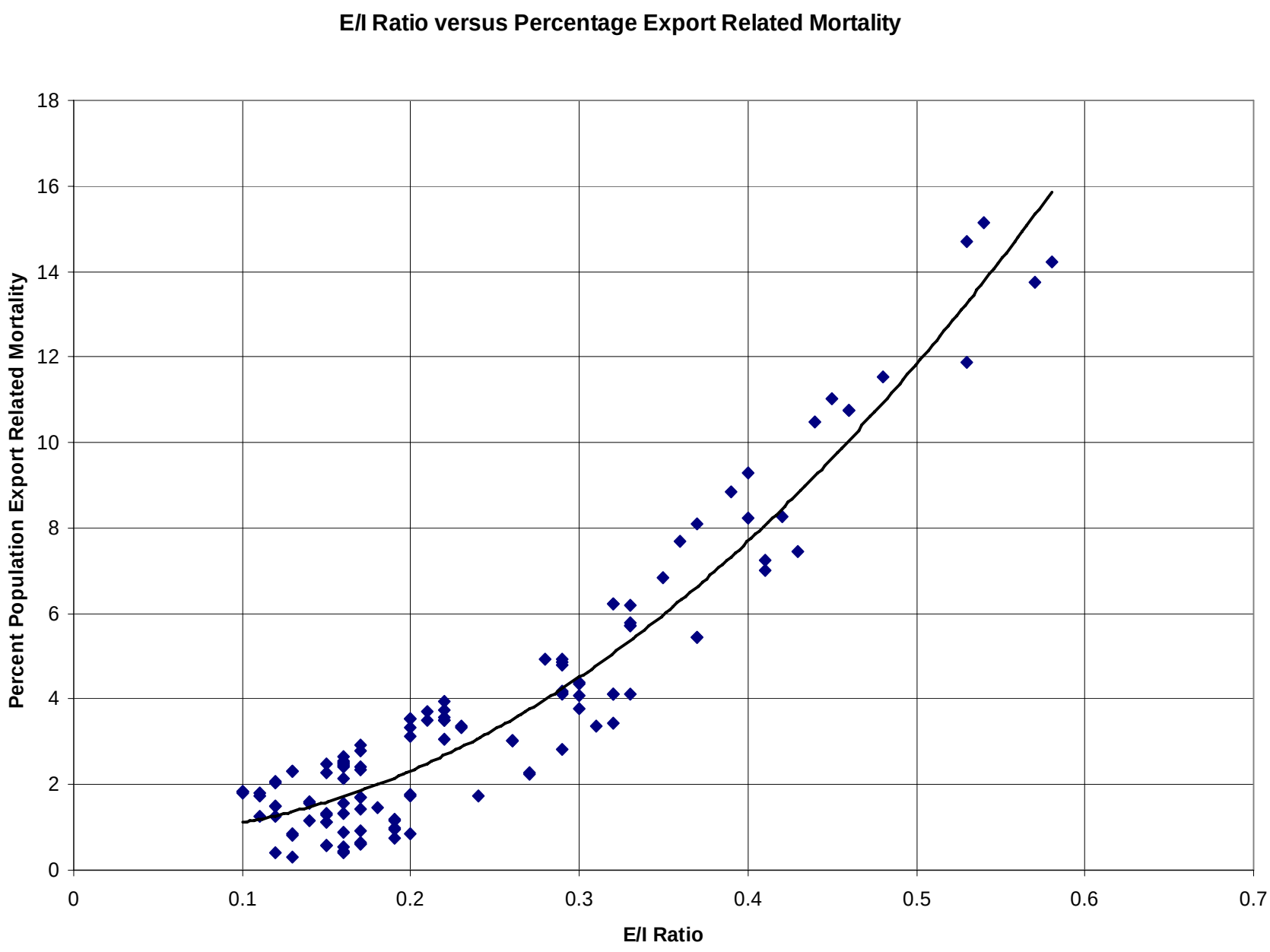
Overall survival estimates of fish collection actions

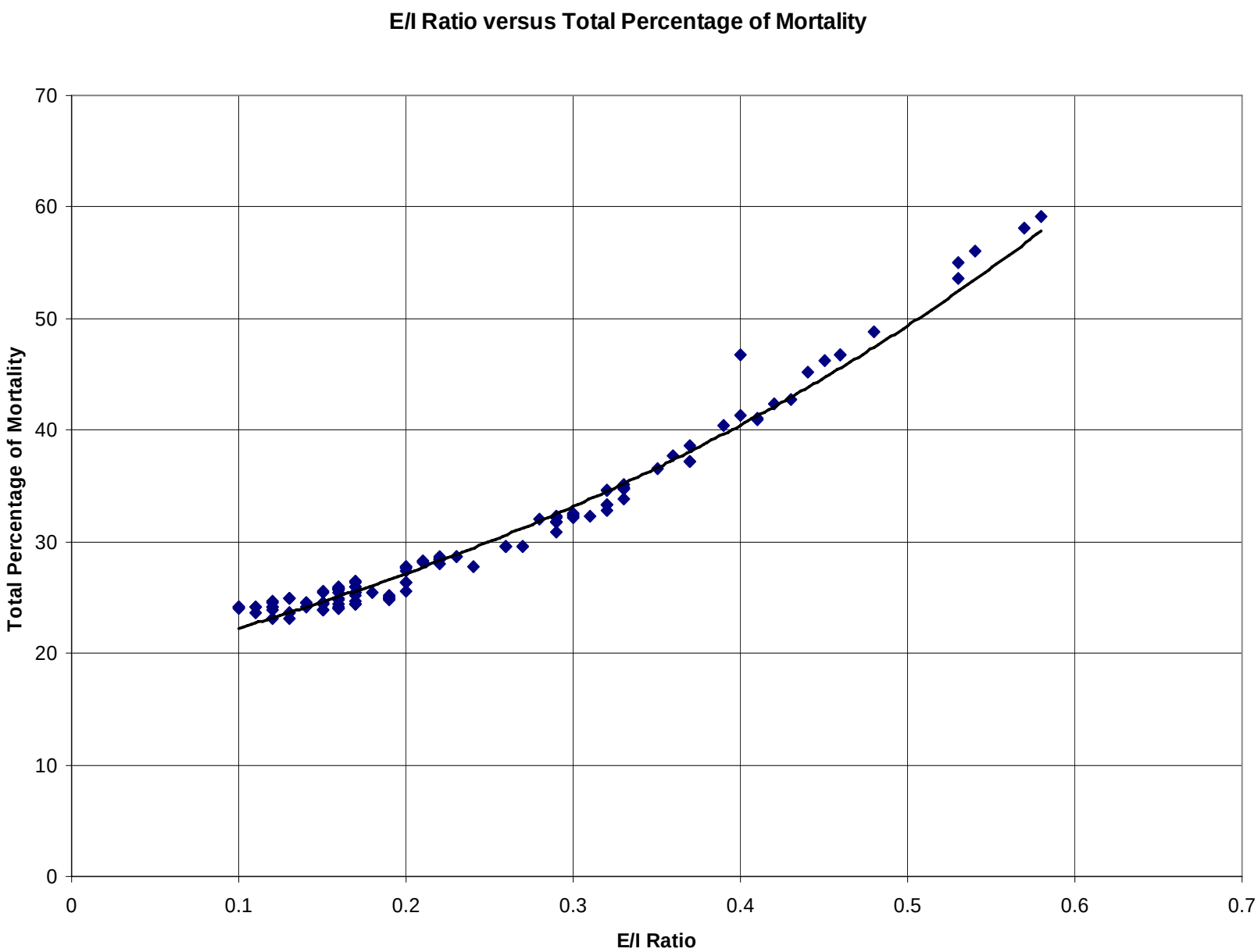
Estimate of Survival for Screening Process at the SWP and CVP[1]		
SWP	Percent survival	Running Percent
Pre-screen Survival[2]	25 percent[3] (75 percent loss)	25
Louver Efficiency	75 percent (25 percent loss)	18.75
CHTR Survival	98 percent (2 percent loss)	18.375
Post Release Survival (predation only)	90 percent (10 percent loss)	16.54
CVP[4]	Percent survival	Running Percent
Pre-screen Survival[5]	85 percent (15 percent loss)	85
Louver Efficiency[6]	46.8 (53.2 percent loss)	39.78
CHTR Survival	98 percent (2 percent loss)	38.98
Post Release Survival (predation only)	90 percent (10 percent loss)	35.08

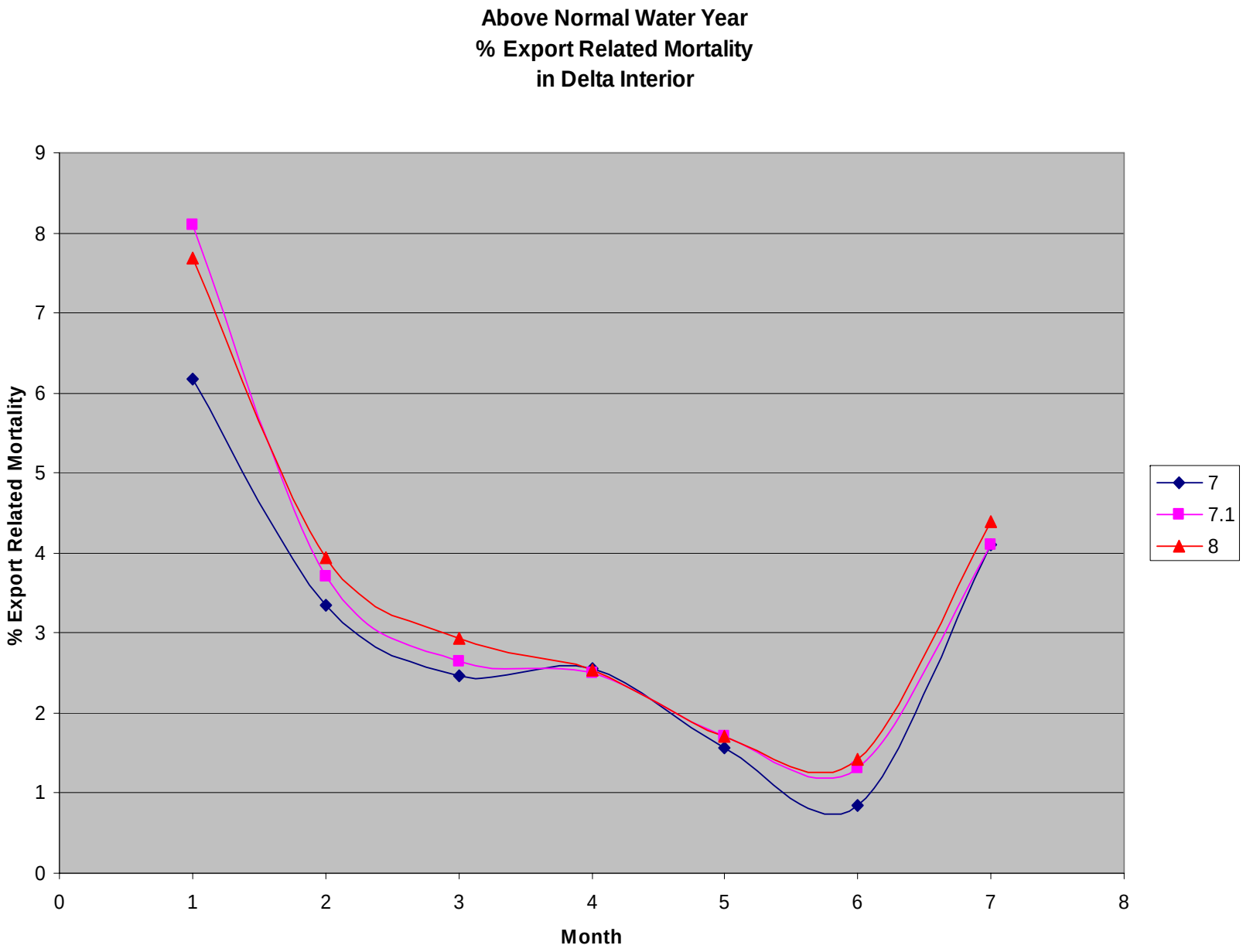
Indirect mortality in Delta Interior

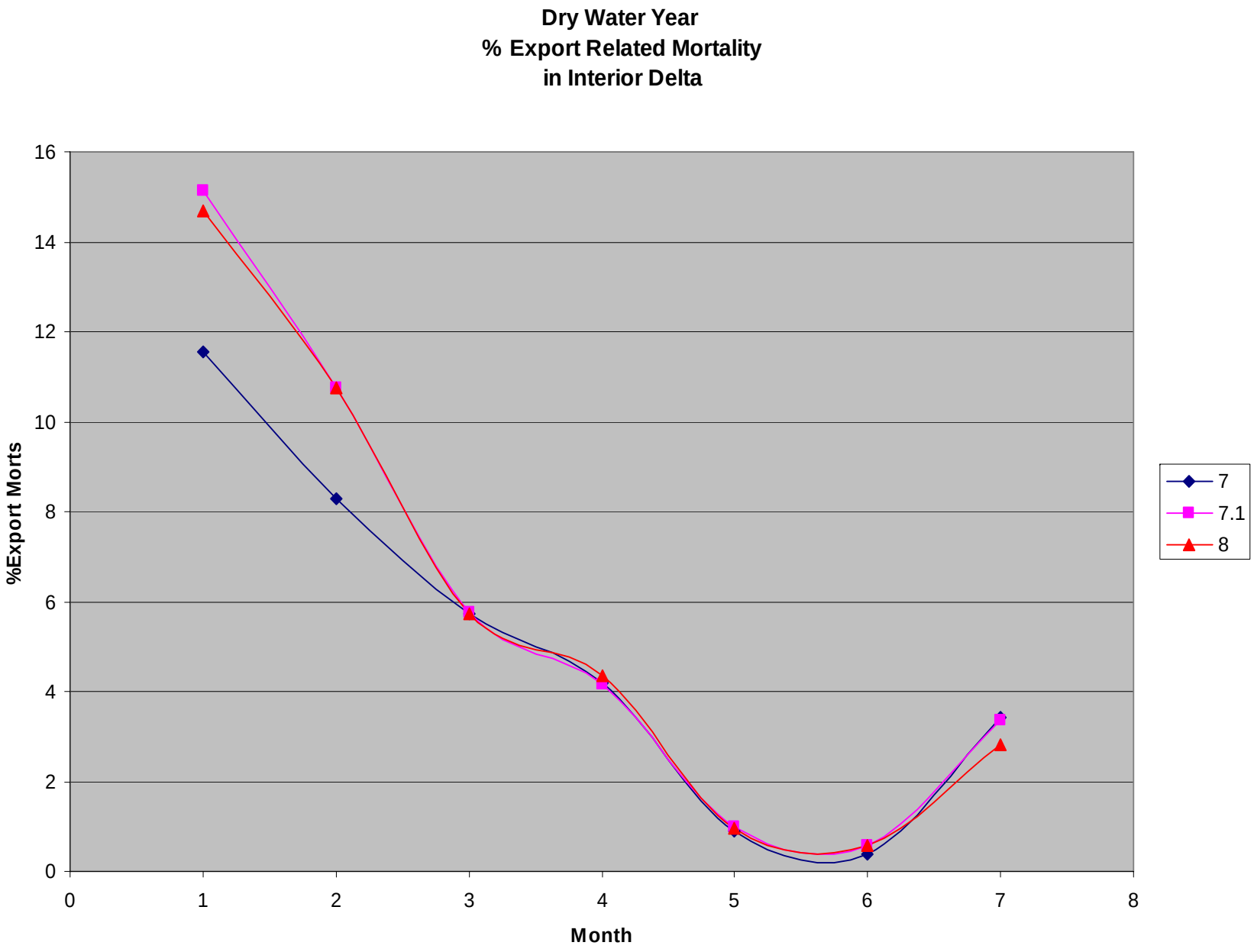
- Assessed indirect mortality within delta interior utilizing applicable studies and literature.
- Compared export and non-export related mortality within the interior delta utilizing DWR's Delta Survival model and CalSim II output from Studies 7.0, 7.1, and 8.0.

- Export related mortality ranged from 0.3% to 15.14% combining all studies and water year types for the period between December and June.
- Total Population Mortality ranged from 23.1% to 59.1% under same conditions as above.
- Indirect mortality (non-export) ranged from 3.3% to 31.53% combining all studies and water year types for the period between December and June.
- Higher E/I ratios had higher mortality levels.
- Higher E/I ratios typically occurred in December and January in drier hydrological conditions.


E/I Ratio versus Percentage Export Related Mortality
Percent Population Export Related Mortality
E/I Ratio
0
2
4
6
8
10
12
14
16
18
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


E/I Ratio versus Total Percentage of Mortality
Total Percentage of Mortality
E/I Ratio
0
10
20
30
40
50
60
70
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Above Normal Water Year
% Export Related Mortality
in Delta Interior
% Export Related Mortality
Month
0
1
2
3
4
5
6
7
8
9
7
7.1
8


Dry Water Year
% Export Related Mortality
in Interior Delta
%Export Morts
Month
0
2
4
6
8
10
12
14
16
0
1
2
3
4
5
6
7
8
7
7.1
8

Route specific survival through the Sacramento – San Joaquin Delta (Perry and Skalski 2008)

Migration Route	Survival $\hat{S}_h$ (SE)	95 %Profile Likelihood Interval	Probability of Migratory Route Ψ_h (SE)	95 %Profile Likelihood Interval
R_1 ; December 2006				
A) Steamboat & Sutter Sl	0.263 (0.112)	0.102, 0.607	0.296 (0.062)	0.186, 0.426
B) Sacramento River	0.443 (0.146)	0.222, 0.910	0.352 (0.066)	0.231, 0.487
C) Georgiana Sl	0.332 (0.179)	0.087, 0.848	0.117 (0.045)	0.048, 0.223
D) Delta Cross Channel	0.332 (0.152)	0.116, 0.783	0.235 (0.059)	0.133, 0.361
S_{Delta} (All Routes)	0.351 (0.101)	0.200, 0.692		
R_2: January 2007				
A) Steamboat & Sutter Sl	0.561 (0.092)	0.388, 0.747	0.414 (0.059)	0.303, 0.531
B) Sacramento River	0.564 (0.086)	0.403, 0.741	0.498 (0.060)	0.383, 0.614
C) Georgiana Sl	0.344 (0.200)	0.067, 0.753	0.088 (0.034)	0.036, 0.170
D) Delta Cross Channel	NA		0.0	NA
S_{Delta} (All Routes)	0.543 (0.070)	0.416, 0.691		

Clifton Court Aquatic Weed Control Program

- Assessed toxicity of Komeen herbicide to salmonids and sturgeon.
- Assessed risk of exposure to listed fish based on timing of presence in the Delta.

Komeen Toxicity Studies

CDFG toxicity Studies - OSPR

- Larval Fathead Minnow LC_{50} = 310 ppb
- Larval Splittail LC_{50} = 510 ppb
- Larval Delta Smelt LC_{50} = 1400 ppb
  - UCD studies indicate higher copper sensitivity for larval Delta smelt LC_{50} = 33.5 ppb (96 hr) for ionic copper
- Salmonids approximately 3x more sensitive to copper than fathead minnows thus LC_{50} should be approximately 100 ppb Komeen

Sturgeon Sensitivities to copper toxicity

- Recent studies indicated that three different sturgeon species had approximately equivalent sensitivities to contaminants as did *O. mykiss* exposed to the same compounds.

  Dwyer *et al.,* (2005) Assessing Contaminant Sensitivity of Endangered and Threatened Aquatic Species: Part I. Acute Toxicity of Five Chemicals. *Archives of Environmental Contamination and Toxicology* 48: 143-154.

- The studies exposed Atlantic sturgeon, shovelnose sturgeon, and shortnose sturgeon to copper sulfate. All three had similar LC_{50} values to *O. mykiss*.

Exposure to Salmonids & Green Sturgeon

- Majority of salmonid migrations occur between October and June in the Delta
- Winter run (E): November – April
- Spring run (T): January – May
- Steelhead (T): December – June
- Fall run: March – June
- Green Sturgeon (southern DPS) (T)– present all year in Delta – Only species present during the proposed Komeen treatment of July and August

Temporary and Permanent Barrier Programs in the South Delta

- Assessed farfield and near field changes in hydrodynamics as related to fish.
- Assessed changes in predation risks to listed fish.
- Assessed changes to critical habitat for listed fish (Central Valley steelhead and proposed Southern DPS green sturgeon).
- Assessed exposure risk to listed fish based on presence in the South Delta region.

Operation of barriers will:

- Increase risk of predation for salmonids in region of barriers – delay, increased structure, and turbulence at structures.
- Delay and impede migration of fish within the region of the barriers.
- Increase risk of entrainment into South Delta from north if HORB installed without concurrent reductions in exports and/or increases in San Joaquin River flows.
- Alter habitat function due to altered tidal and water elevation regimes within the region affected by the barriers.

Delta Cross Channel Operations:

- Open DCC allows greater proportion of downstream emigrating salmonids and sturgeon to enter the Delta interior.
- Delta interior has significantly higher risk of mortality for emigrating salmonid smolts (presumed to be predation).
- Open DCC allows more Sacramento River basin fish to fall under the influence of export actions in the central and southern Delta.

Delta Cross Channel Operations:

- Closed DCC redirects fish into Sutter and Steamboat Sloughs and increases apparent flow in Sacramento River – see an approximately 50 percent increase in through-Delta survival rates when DCC is closed versus opened (Perry and Skalski 2008).

- Open DCC configuration exposes early emigrating spring-run Chinook salmon yearlings and winter-run Chinook salmon to entrainment into the Delta interior with concurrent increase in mortality risk.

- Winter-run Juveniles and spring-run yearlings at greatest risk due to earlier migrational timing

Route specific survival through the Sacramento – San Joaquin Delta (Perry and Skalski 2008)

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D) Delta Cross Channel	NA		0.0	NA
S_{Delta} (All Routes)	0.543 (0.070)	0.416, 0.691		

CCWD Diversions:

- Three main facilities currently in operation, one future facility in construction.
- Mallard Slough, Old River, and the new intake on Victoria Canal are/will be screened in compliance with NMFS guidelines.
- Old River with positive screens is primary diversion point (approximately 80%). Screen is very effective at preventing listed salmonids and sturgeon from entering diversion.
- Rock Slough is secondary point of diversion and is currently unscreened. Few listed fish have been entrained since Old River became primary diversion point.
- Rock Slough usage is expected to decrease to only 10% of water diverted once the Victoria Canal facility comes online, further reducing the potential for fish entrainment.
- Low rate of loss associated with CCWD due to screening of three of four intakes, reductions in exports during critical spring periods and reduction in the use of the unscreened Rock Slough Diversion

North Bay Aqueduct:

- Relatively small diversion with screened intake compliant with NMFS criteria.
- Located in Barker Slough, spatially isolated from primary salmonid migration corridors.
- Low probability of salmonid loss from diversion's operation.

Climate Change Impacts to Delta:

- Fall and winter seasons have greatest sensitivity to climate change according to OCAP modeling.

- Greater risk of entrainment in drier climate scenarios during the January through June period compared to current climate, particularly in below normal, dry, and critical water year types.

- Wetter climate scenarios present less entrainment risk in the wet and above normal water year types, but have elevated risks in the drier water year types compared to current climate.

Vernalis Adaptive Management Plan:

- OCAP assumes that a VAMP – like flow regime, providing VAMP-like flows at Vernalis on the San Joaquin River and that VAMP-like export curtailments will continue into the future.

- No defined description of this operation has been presented to date. Limited “fish water” available to offset VAMP water costs.

- Spring-time flows currently seen during the VAMP operations on the Tuolumne River and Merced River are likely decline since neither Reclamation or DWR control the dams on these rivers, leading to reductions in steelhead and fall-run populations on these rivers due to diminishments in spring outmigration conditions.