ASCE Journal of Water Resource Planning and Management

Water management adaptations to prevent loss of spring-run Chinook salmon in California under climate change

Lisa C. Thompson, Marisa I. Escobar, Christopher M. Mosser, David R. Purkey, D. Yates, and Peter B. Moyle

DOI: 10.1061/(ASCE)WR.1943-5452.0000194

Supplemental Data

Relation.dat

Chinook Salmon ; FRESHET MOVEMENT PARAMETERS ----------

Fry

F25-40

15000 .5 .3 ; Distance Moved (m), Prop. Moved, Prop. Dying

F40-60

15000 .5 .30

0+Parr

P60-80

15000 .50 .20

P80-100

15000 .50 .15

1+Parr

P100-125

15000 .50 .05

P125-150

15000 .50 .03

P150-200

15000 .50 .01

SUPPLEMENTAL DATA

Chinook Salmon ; SEASONAL MOVEMENT PARAMETERS ----------

Fry

F25-40

27 1500 .6 .010

28 1500 .6 .010

29 1500 .6 .010

30 1500 .6 .010

31 1500 .6 .010

32 1500 .6 .010

33 1500 .6 .010

34 1500 .6 .010

35 1500 .6 .010

36 1500 .6 .010

37 1500 .6 .010

38 1500 .6 .010

39 1500 .6 .010

40 1500 .6 .010

41 1500 .6 .010

42 1500 .6 .010

43 1500 .6 .010

44 1500 .6 .010

45 1500 .6 .010

46 1500 .6 .010

47 1500 .6 .010

48 1500 .6 .010

49 1500 .6 .010

50 1500 .6 .010

51 1500 .6 .010

52 1500 .6 .010

1 1500 .6 .010

2 1500 .6 .010

F40-60

10 1500 .6 .010

11 1500 .6 .010

12 1500 .6 .010

13 1500 .6 .010

14 1500 .6 .010

15 1500 .6 .010

16 1500 .6 .010

17 1500 .6 .010

18 1500 .6 .010

18 1500 .6 .010

20 1500 .6 .010

21 1500 .6 .010

22 1500 .6 .010

23 1500 .6 .010

24 1500 .6 .010

25 1500 .6 .010

26 1500 .6 .010

27 1500 .6 .010

28 1500 .6 .010

29 1500 .6 .010

30 1500 .6 .010

31 1500 .6 .010

32 1500 .6 .010

33 1500 .6 .010

34 1500 .6 .010

35 1500 .6 .010

36 1500 .6 .010

37 1500 .6 .010

38 1500 .6 .010

39 1500 .6 .010

0+Parr

P60-80

12 1500 .2 .00 ; Time, Distance (m), Proportion, Mortality

13 1500 .2 .010

14 1500 .2 .010

15 1500 .2 .010

16 1500 .2 .010

17 1500 .2 .010

18 1500 .2 .010

18 1500 .2 .010

20 1500 .2 .010

21 1500 .2 .010

22 1500 .2 .010

23 1500 .2 .010

24 1500 .2 .010

25 1500 .2 .010

26 1500 .2 .010

27 1500 .2 .010

28 1500 .2 .010

29 1500 .2 .010

30 1500 .2 .010

31 1500 .2 .010

32 1500 .2 .010

33 1500 .2 .010

34 1500 .2 .010

35 1500 .2 .010

36 1500 .2 .010

37 1500 .2 .010

38 1500 .2 .010

39 1500 .2 .010

40 1500 .2 .010

41 1500 .2 .010

P80-100

52 00000 .00 .00 ; time, distance, proportion, mortality

7 1500 .2 .010

8 1500 .2 .010

9 1500 .2 .010

10 1500 .2 .010

11 1500 .2 .010

12 1500 .2 .010

13 1500 .2 .010

14 1500 .2 .010

15 1500 .2 .010

16 1500 .2 .010

17 1500 .2 .010

18 1500 .2 .010

18 1500 .2 .010

20 1500 .2 .010

21 1500 .2 .010

22 1500 .2 .010

23 1500 .2 .010

24 1500 .2 .010

25 1500 .2 .010

26 1500 .2 .010

27 1500 .2 .010

28 1500 .2 .010

29 1500 .2 .010

30 1500 .2 .010

31 1500 .2 .010

32 1500 .2 .010

33 1500 .2 .010

34 1500 .2 .010

35 1500 .2 .010

1+Parr

P100-125

30 1500 .01 .10 ; time, distance, proportion, mortality

31 1500 .01 .10

32 1500 .01 .10

33 1500 .01 .10

34 1500 .01 .10

35 1500 .01 .10

P125-150

30 1500 .10 .10 ; time, distance, proportion, mortality

31 1500 .10 .10

32 1500 .10 .10

33 1500 .10 .10

34 1500 .10 .10

35 1500 .10 .10

P150-200

30 1500 .60 .10 ; time, distance, proportion, mortality

31 1500 .60 .10

32 1500 .60 .10

33 1500 .60 .10

34 1500 .60 .10

35 1500 1.0 .10

Chinook Salmon ;TEMPERATURE:GROWTH RELATIONSHIP

Eggs/Embryos ; temp(C), growth rate-per/day (additive CM)

1 0.0025 ; Derived from eq. 3b per Crisp (1981) CM

2 0.0031 ; Crisp equations only until hatch, not emergence CM

3 0.0038 ; Multiplied by 0.6 as per Sacramento Salmod final report to account for emergence time CM

4 0.0046

5 0.0055

6 0.0065

7 0.0076

8 0.0088

9 0.0101

10 0.0114

11 0.0127

12 0.0140

13 0.0153

14 0.0165

15 0.0176

22 0.0202

25 0.0180

28 0.0145

30 0.0119

35 0.0059

40 0.0022 ; just for upper limit

Fry ; temp (C), growth rate- per day (multiplicative)

0 0 ; derived and estimated from Clark and Shelbourne 1985 Fig 1 CM

6 .018

8 .023

10 .030

12 .036

14 .043

16 .051

18 .056

24 -0.02

40 -0.02

SUPPLEMENTAL DATA

0+Parr ; temp (C), growth rate- per day (multiplicative)

0 0 ; derived and estimated from Clark and Shelbourne 1985 Fig 1 CM

6 .018

8 .024

10 .030

12 .038

14 .042

16 .047

18 .051

24 -0.02

40 -0.02

1+Parr ; temp (C), growth rate- per day (multiplicative)

0 0 ;

8 .023 ; derived and estimated from Clark and Shelbourne 1985 Fig 1 CM

10 .027 ; estimates based on fish growth up to ~ 100mm in length CM

12 .031

14 .034

16 .038

18 .041

24 -0.02

40 -0.02

Adult Females=1+Parr

Spawning Females=Adult Females

Adult Males=Adult Females

Spawning Males=Adult Females

Chinook Salmon ; BASE MORTALITY RATES (weekly)

Eggs/Embryos ; All values from Sacramento SalMod final report CM

0.035

Fry

0.025

0+Parr

0.025

1+Parr

0.025

Adult Females

.0030 ;Calibrate baseline mortality rate:0.0015

Spawning Females=Adult Females

Adult Males=Adult Females

Spawning Males=Adult Females

Chinook Salmon ; TEMPERATURE:MORTALITY RELATION - WEEKLY (MULT)

Eggs/Embryos ;

2.00 0.0426; Murray and McPhail 1988 0.00 1.00 ; temp (C), mort rate

5.00 0.0068;

8.00 0.0064;

11.00 0.0115

14.00 0.0827

40.00 1.00

Fry

0.00 0.00

15.50 0.00

20.00 0.175

25.00 0.80

30.00 1.00

40.00 1.00

0+Parr = Fry

1+Parr = Fry

Adult Females

0.00 0.00 ; Shifted to the right 2.5 degrees as per Quinn corespondence in Sacramento salmod final report and Berman and Quinn 1991 CM

14.0 0

15.0 0.00000

15.5 0.00000

16.0 5.0E-13

16.5 7.4E-12

17.0 .11E-9

17.5 1.7E-9

18.0 2.5E-8

18.5 3.8E-7

19.0 5.7E-6

19.5 8.5E-5

20.0 .00128

20.5 .01890

21.0 .22461

21.5 .813285

22.0 .984962

22.5 .998986

23.0 .999932

23.5 .999996

24.0 1.00000

24.5 1.00000

25.0 1.00000

30.0 1.0;

Spawning Females=Adult Females

Adult Males=Adult Females

Spawning Males=Adult Females

Chinook Salmon

0.00 1.00 ; temp (C), mort rate

5.60 .00

15.80 .00; 12.80 .00

18.00 1.00; 16.00 1.00 ; Reported as upper limit at which salmon will not spawn

40.00 1.00

Chinook Salmon ; WEIGHT(g):LENGTH(mm) RELATIONSHIP

0.08773202 20 ;20-200 Kimmerer et al. 2005 reporting Deer Creek relationship CM

0.294897435 30 ;250-1500 Jasper and Evanson 2006, Pilot Station, Alaska CM

0.697008088 40

1.35830955 50

2.342883437 60

3.714681502 70

5.537548011 80

7.875235445 90

10.79141622 100

14.34969175 110

18.61359967 120

23.6466197 130

29.51217858 140

36.27365416 150

43.99437898 160

52.73764329 170

62.56669776 180

73.54475581 190

85.73499572 200

197.7122239 250

349.2038385 300

856.8165903 400

1718.886132 500

3035.935883 600

4910.96206 700

7449.059676 800

10757.15245 900

14943.78787 1000

20118.97596 1100

26394.05892 1200

Chinook Salmon ; DISTANCE MOVED (m):MORTALITY RATE RELATION - PER STEP

Fry ; Last distance specified is the maximum distance

F25-40 ;

0 0.0 ;

16000 0.0 ;

17000 1.0

F40-60

0 0.0

16000 0.0

17000 1.0

0+Parr

P60-80

0 0.0

000 0.0

3000 1.0

P80-100

0 0.0

000 0.0

3000 1.0

1+Parr

P100-125

0 0.0

000 0.0

3000 1.0

P125-150

0 0.0

000 0.0

3000 1.0

P150-200

0 0.0

000 0.0

3000 1.0 ;

Chinook Salmon ; DENSITY/NUMBER:MORTALITY RELATION - WEEKLY

Eggs/Embryos ; Upper limit of density triggers habitat movement

0 0.0 ; Density-indep. relationship assumed here

1000 0.0 ; Upper bound not relevant for eggs

Fry

0 0.00

1.7 0.00 ; Numbers initially based on Grant and Kramer (1990)?????

0+Parr

0 0.00 ;

18.5 0.00 ;

1+Parr

0 0.00

21.6 0.00 ;

Adult Females

4.000 0.00

Spawning Females=Adult Females

Adult Males=Adult Females

Spawning Males=Adult Females

Chinook Salmon ; WEIGHT (g):num EGGS RELATIONSHIP CM

856 0

1718 889

3035 2426.8

4910 3964.6 ;L=700

7449 5502.4 ;L=800

10757 7040.2 ;L=900

14943 8578 ;L=1000

20118 10115.8 ;L=1100

26394 11653.6 ;L=1200

33881 13191.4 ;L=1300

42695 14729.2 ;L=1400

52949 16267 ;L=1500

Suplement.dat

1

Chinook Salmon ; 2001

1 3 4761 0.5 7500 7500

4 9 2692 0.5 7500 7500

10 12 916 0.5 7500 7500

13 15 385 0.5 7500 7500

16 21 696 0.5 7500 7500

22 24 403 0.5 7500 7500

25 30 1062 0.5 7500 7500

31 36 787 0.5 7500 7500

37 42 421 0.5 7500 7500

43 45 494 0.5 7500 7500

55 57 1428 0.5 7500 7500

58 63 970 0.5 7500 7500

64 69 1172 0.5 7500 7500

70 75 513 0.5 7500 7500

76 84 568 0.5 7500 7500

85 93 659 0.5 7500 7500

94 102 385 0.5 7500 7500

112 120 18 0.5 7500 7500

53

Chinook Salmon ; 2002 spawners

1 3 6335 0.5 7500 7500

4 9 2139 0.5 7500 7500

10 12 816 0.5 7500 7500

13 15 555 0.5 7500 7500

16 21 735 0.5 7500 7500

22 24 294 0.5 7500 7500

25 30 457 0.5 7500 7500

31 36 441 0.5 7500 7500

37 42 261 0.5 7500 7500

43 45 376 0.5 7500 7500

55 57 1682 0.5 7500 7500

58 63 980 0.5 7500 7500

64 69 996 0.5 7500 7500

70 75 163 0.5 7500 7500

76 84 16 0.5 7500 7500

85 93 98 0.5 7500 7500

105

Chinook Salmon ; 2003 spawners

1 3 2681 0.5 7500 7500

4 9 865 0.5 7500 7500

10 12 1332 0.5 7500 7500

13 15 692 0.5 7500 7500

16 21 657 0.5 7500 7500

22 24 259 0.5 7500 7500

25 30 1055 0.5 7500 7500

31 36 484 0.5 7500 7500

37 42 311 0.5 7500 7500

43 45 190 0.5 7500 7500

46 54 0 0.5 7500 7500

55 57 5259 0.5 7500 7500

58 63 1505 0.5 7500 7500

64 69 1055 0.5 7500 7500

70 75 398 0.5 7500 7500

76 84 346 0.5 7500 7500

85 93 86 0.5 7500 7500

94 102 17 0.5 7500 7500

103 111 17 0.5 7500 7500

157

Chinook Salmon ; 2004 spawners

1 3 1117 0.5 7500 7500

4 9 1319 0.5 7500 7500

10 12 1436 0.5 7500 7500

13 15 564 0.5 7500 7500

16 21 394 0.5 7500 7500

22 24 96 0.5 7500 7500

25 30 840 0.5 7500 7500

31 36 585 0.5 7500 7500

37 42 404 0.5 7500 7500

43 45 287 0.5 7500 7500

46 54 170 0.5 7500 7500

55 57 1362 0.5 7500 7500

58 63 862 0.5 7500 7500

64 69 500 0.5 7500 7500

70 75 234 0.5 7500 7500

76 84 202 0.5 7500 7500

85 93 138 0.5 7500 7500

94 102 160 0.5 7500 7500

209

Chinook Salmon ; 2005 spawners

1 3 2535 0.5 7500 7500

4 9 1074 0.5 7500 7500

10 12 880 0.5 7500 7500

13 15 722 0.5 7500 7500

16 21 334 0.5 7500 7500

25 30 1144 0.5 7500 7500

31 36 1126 0.5 7500 7500

37 42 317 0.5 7500 7500

43 45 158 0.5 7500 7500

55 57 3855 0.5 7500 7500

58 63 2007 0.5 7500 7500

64 69 1267 0.5 7500 7500

70 75 827 0.5 7500 7500

76 84 898 0.5 7500 7500

85 93 299 0.5 7500 7500

94 102 141 0.5 7500 7500

261

Chinook Salmon ; 2006 spawners

1 3 517 0.5 7500 7500

4 9 288 0.5 7500 7500

10 12 353 0.5 7500 7500

13 15 39 0.5 7500 7500

16 21 157 0.5 7500 7500

22 24 13 0.5 7500 7500

25 30 366 0.5 7500 7500

31 36 484 0.5 7500 7500

37 42 177 0.5 7500 7500

43 45 118 0.5 7500 7500

46 54 7 0.5 7500 7500

55 57 1983 0.5 7500 7500

58 63 452 0.5 7500 7500

64 69 340 0.5 7500 7500

70 75 340 0.5 7500 7500

76 84 366 0.5 7500 7500

85 93 314 0.5 7500 7500

94 102 157 0.5 7500 7500

103 111 33 0.5 7500 7500

112 120 33 0.5 7500 7500

313

Chinook Salmon ; 2007 spawners

1 3 828 0.5 7500 7500

4 9 698 0.5 7500 7500

10 12 431 0.5 7500 7500

13 15 424 0.5 7500 7500

16 21 274 0.5 7500 7500

22 24 376 0.5 7500 7500

25 30 637 0.5 7500 7500

31 36 452 0.5 7500 7500

37 42 301 0.5 7500 7500

43 45 157 0.5 7500 7500

46 54 253 0.5 7500 7500

55 57 986 0.5 7500 7500

58 63 212 0.5 7500 7500

64 69 185 0.5 7500 7500

70 75 68 0.5 7500 7500

76 84 130 0.5 7500 7500

85 93 294 0.5 7500 7500

94 102 62 0.5 7500 7500

103 111 7 0.5 7500 7500

112 120 68 0.5 7500 7500

365

Chinook Salmon ; 2008 spawners

1 3 2272 0.5 7500 7500

4 9 1056 0.5 7500 7500

10 12 1800 0.5 7500 7500

13 15 441 0.5 7500 7500

16 21 444 0.5 7500 7500

22 24 164 0.5 7500 7500

25 30 631 0.5 7500 7500

31 36 532 0.5 7500 7500

37 42 467 0.5 7500 7500

43 45 340 0.5 7500 7500

46 54 272 0.5 7500 7500

55 57 1282 0.5 7500 7500

58 63 515 0.5 7500 7500

64 69 323 0.5 7500 7500

70 75 297 0.5 7500 7500

76 84 238 0.5 7500 7500

85 93 59 0.5 7500 7500

94 102 3 0.5 7500 7500

Control.dat

; Options for Chinook Salmon dataset CM

Timesteps=389; CM

Date=05/29/2001; CM

Capacity=Numbers ;Biomass; CM

Population=Multiyear; Anadromous; CM

; Processes

; Standard deviation of emergent fry from Power and Power (1994)

Graduate /Stage='Eggs/Embryos', Fry, 0+Parr, 1+Parr /InitDev=4;

Supplement;

Carry /Time=0,10; This may need to be changed if simulation start date is moved to Spring or Summer as I am considering doing CM

Spawn /Time=1,10 /SI=Random; This may need to be changed for same reason as above CM

; Don't let freshet and seasonal movement overlap in time

; Freshet Movement; not used

Seasonal Movement /Time=1,35 /Stage=Fry,0+Parr,1+Parr; This may need to be changed for same reason as above CM

Biomass computation;

;Move smallest fish first if necessary - let larger fish defend territories (Bley 1987)

;Some fry move upstream per citation in Kocik and Ferrero (1998)

;Habitat Movement /Stage=Adult Females /Move=Down080

;Habitat Movement /Stage=Fry /Class=F25-40 /Move=Down080; Changed to reflect info from G&M p 336 CM

;Habitat Movement /Stage=Fry /Class=F40-60 /Move=Down070; "" CM

;Habitat Movement /Stage=0+Parr /Class=P60-80 /Move=Down060; "" CM

;Habitat Movement /Stage=0+Parr /Class=P80-100 /Move=Down050;

;Habitat Movement /Stage=1+Parr /Class=P100-125 /Move=Down080;

;Habitat Movement /Stage=1+Parr /Class=P125-150 /Move=Down080;

;Habitat Movement /Stage=1+Parr /Class=P150-200 /Move=Down080;

Mortality /InVivo=2,17; Applies to in-stream fish only

Growth /Stage='Eggs/Embryos',Fry, 0+Parr; Moving fry and parr do not grow ??Is this appropriate, I let them for now CM

Immigration /Stage=Fry,0+Parr,1+Parr;

Growth /Stage= 1+Parr; but all smolts grow [per Bley (1987)]