W&AR-06

Consultation Workshop No. 2

August 6, 2013

From: Staples, Rose
Sent: Wednesday, March 20, 2013 6:03 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Postponement of Don Pedro March 27 TR Chinook Salmon Population Model Workshop

The W&AR-06 Chinook Salmon Population Model Workshop, initially scheduled for March 27th, is being postponed to a later date. A NEW Date and Time will be announced on April 2nd.

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From: Staples, Rose
Sent: Thursday, April 11, 2013 6:23 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: No Don Pedro Workshop Meetings Next Week--New Schedule Coming Soon

We are currently developing a revised schedule for the Project Operations Model Base Case rollout, the Integrated Model Training, and the W&AR-6 Salmon Population Model Workshop (previously scheduled for April 18th). The new schedule will be issued next week—and I will advise you at that time as well as update the relicensing website calendar. So, therefore, there will be NO meetings/workshops next week. Thank you.

ROSE STAPLES
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HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Friday, April 26, 2013 7:43 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Relicensing Workshop Schedule May-June 2013

The Districts have released the following schedule for upcoming Don Pedro Project relicensing workshops for the Tuolumne River Daily Operations Model Base Case presentation, River and Reservoir Temperature Models final calibration and validation presentation and additional training, Integrated Model Training, and the Chinook Population Model presentation and discussion.

MAY 30 – All-Day Operational Model Base Case Presentation Workshop
All-day workshop on the Operations Model Base Case, to be held at the MID Offices in Modesto. The workshop AGENDA and Advance Material will be forwarded (and posted on the relicensing website) circa May 20th.

JUNE 4 – All-Day River and Reservoir Temperature Models Workshop
All-day workshop on the River and Reservoir Temperature Models, to be held at the HDR Office in Sacramento. The workshop AGENDA and Advance Material will be forwarded (and posted on the relicensing website) circa May 23rd.

JUNE 5 – All-Day Workshop on Integrated Model Training
All-day workshop for those interested in using all three models in sequence (Operations Model, Reservoir Temperature Model, and River Temperature Model), to be held at the HDR Office in Sacramento.

JUNE 6 – All-Day Chinook Population Model
All-day workshop for the presentation and discussion of the Chinook Population Model, to be held at the HDR Office in Sacramento. The workshop AGENDA and Advance Material will be forwarded (and posted on the relicensing website) circa May 24.

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From: Staples, Rose
Sent: Wednesday, May 29, 2013 4:17 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro June 6 W-AR-06 Chinook Population Model Workshop Cancel--New Schedule to be Announced Next Week

The June 6, 2013 Workshop on Don Pedro W&AR-06 Chinook Population Model has been cancelled. The Districts will provide an updated schedule for the Workshop and the report by next week. Thank you.

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From: Staples, Rose
Sent: Tuesday, July 02, 2013 2:09 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; Wetzel, Jeff; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro W-AR-06 Chinook Salmon Pop Model Workshop No. 2 Scheduled for Aug 6 at HDR Offices Sacramento

Please note that the Don Pedro Chinook Salmon Population Model (W&AR-06) Workshop No 2 is being scheduled for August 6, 2013 from 9 am to 4 pm at HDR’s Sacramento offices (2379 Gateway Oaks Drive Suite 200). Agenda and meeting materials will be provided by July 24.

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From: Staples, Rose
Sent: Friday, July 26, 2013 1:28 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: AGENDA and ADVANCE MATERIALS for Aug 6 Don Pedro W&AR-06 Workshop
Attachments: DonPedroAug6ChinookWkshopAGENDA_130726.pdf

Attached is the agenda for the August 6, 2013 Don Pedro Relicensing W&AR-06 Chinook Salmon Population Model Workshop, to be held at the HDR Offices in Sacramento. The W&AR-06 STUDY REPORT has been uploaded to the www.donpedro-relicensing website, under the ANNOUNCEMENT tab. Please note the AGENDA includes the LIVE MEETING link and the audio conferencing number for those participants who are not able to attend in person.

Chinook salmon Population Model Workshop No. 2

Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994
....
Join online meeting
https://meet.hdrinc.com/carin.loy/HM5F42M3
First online meeting?
[!OC([1033])!]
....
Agenda
9:00 a.m. – 9:15 a.m. Introductions and Background
9:15 a.m. – 10:30 a.m. Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production
1. Relationship to W&AR-5 Synthesis Study
2. General assumptions and model structure
3. Key Sub Model Relationships by Life-Stage

10:30 a.m. – 11:00 a.m. Model Calibration and Validation Results
11:00 a.m. – 12:00 p.m. Modeling Sensitivity Testing
12:00 p.m. – 1:00 p.m. Lunch (on your own)
1:00 p.m. – 2:00 p.m. Discussion of Base Case (1971–2009) Scenario Results
2:00 p.m. – 3:00 p.m. Discussion of Factors Affecting Chinook Production
3:00 p.m. – 3:45 p.m. Discussion of Modeling Scenarios
- 300 cfs Test Case Run
- Requests for Additional Scenarios

3:45 p.m. – 4:00 p.m. Next Steps

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Chinook salmon Population Model Workshop No. 2
Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994

Join online meeting
https://meet.hdrinc.com/carin.loy/HM5F42M3

First online meeting?

Agenda

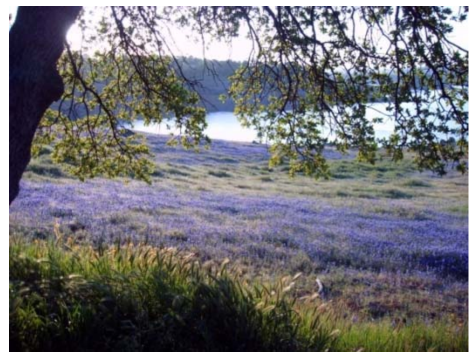
9:00 a.m. – 9:15 a.m.	**Introductions and Background**
9:15 a.m. – 10:30 a.m.	**Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production** **1. Relationship to W&AR-5 Synthesis Study** **2. General assumptions and model structure** **3. Key Sub Model Relationships by Life-Stage**
10:30 a.m. – 11:00 a.m.	**Model Calibration and Validation Results**
11:00 a.m. – 12:00 p.m.	**Modeling Sensitivity Testing**
12:00 p.m. – 1:00 p.m.	**Lunch (on your own)**
1:00 p.m. – 2:00 p.m.	**Discussion of Base Case (1971–2009) Scenario Results**
2:00 p.m. – 3:00 p.m.	**Discussion of Factors Affecting Chinook Production**
3:00 p.m. – 3:45 p.m.	**Discussion of Modeling Scenarios** - **300 cfs Test Case Run** - **Requests for Additional Scenarios**
3:45 p.m. – 4:00 p.m.	**Next Steps**

CHINOOK SALMON POPULATION MODEL STUDY

DRAFT REPORT

DON PEDRO PROJECT
FERC NO. 2299





TID WATER & POWER
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MID
Modesto Irrigation District

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
Stillwater Sciences

July 2013

Study Report W&AR-6
Chinook Salmon Population Model Study
In-Progress Draft – May 1, 2013

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List of Attachments

List of Acronyms

ACEC.........................Area of Critical Environmental Concern
AF ....acre-feet
ACOE.........................U.S. Army Corps of Engineers
ADA...........................Americans with Disabilities Act
ALJ............................Administrative Law Judge
APE............................Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA..............................Biological Assessment
Basin Plan ....Water Quality Control Plan for the Sacramento and San Joaquin Rivers
BDCP.........................Bay-Delta Conservation Plan
BLM...........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI............................Benthic macroinvertebrates
BMP...........................Best Management Practices
BO..............................Biological Opinion
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CAS............................California Academy of Sciences
CCC............................Criterion Continuous Concentrations
CCIC..........................Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV....................California Central Valley Habitat Joint Venture
CD..............................Compact Disc
CDBW........................California Department of Boating and Waterways
CDEC.........................California Data Exchange Center
CDFA.........................California Department of Food and Agriculture
CDFG.........................California Department of Fish and Game
CDMG........................California Division of Mines and Geology
CDOF.........................California Department of Finance
CDPH.........................California Department of Public Health
CDPR.........................California Department of Parks and Recreation

CDSOD......................California Division of Safety of Dams
CDWR........................California Department of Water Resources
CE ....California Endangered Species
CEII............................Critical Energy Infrastructure Information
CEQA.........................California Environmental Quality Act
CESA ....California Endangered Species Act
CFR ....Code of Federal Regulations
cfs...............................cubic feet per second
CGS............................California Geological Survey
CMAP ....California Monitoring and Assessment Program
CMARP......................Comprehensive Monitoring, Assessment, and Research Program
CMC...........................Criterion Maximum Concentrations
CNDDB......................California Natural Diversity Database
CNPS..........................California Native Plant Society
CORP ....California Outdoor Recreation Plan
CPUE ....Catch Per Unit Effort
CRAM........................California Rapid Assessment Method
CRLF..........................California Red-Legged Frog
CRRF ....California Rivers Restoration Fund
CSAS..........................Central Sierra Audubon Society
CSBP..........................California Stream Bioassessment Procedure
CT ....California Threatened Species
CTR............................California Toxics Rule
CTS ....California Tiger Salamander
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWHR........................California Wildlife Habitat Relationship
Districts......................Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity

EES ....EES Consulting, Inc.
EFH ....Essential Fish Habitat
EIR ....Environmental Impact Report
EIS..............................Environmental Impact Statement
EPA ............................U.S. Environmental Protection Agency
ESA ....Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU ....Evolutionary Significant Unit
EWUA........................Effective Weighted Useable Area
FC...............................Candidate for listing under ESA
FE ....Federally listed Endangered Species under ESA
FERC..........................Federal Energy Regulatory Commission
FFS ....Foothills Fault System
FL ....Fork length
FLA ....Final License Application
FMU ....Fire Management Unit
FOT ....Friends of the Tuolumne
FPC ....Federal Power Commission
FPD ....Species Proposed for Delisting under ESA
FPE.............................Proposed for listing as Endangered under ESA
FPT.............................Species Proposed to be listed as Threatened under ESA
FT ....Federally listed Threatened Species under ESA
ft/mi............................feet per mile
FWCA ....Fish and Wildlife Coordination Act
FYLF..........................Foothill Yellow-Legged Frog
GIS ....Geographic Information System
GLO ....General Land Office
GORP ....Great Outdoor Recreation Pages
GPS ....Global Positioning System
HCP............................Habitat Conservation Plan
HHWP........................Hetch Hetchy Water and Power
HORB ....Head of Old River Barrier
HPMP.........................Historic Properties Management Plan

ILP..............................Integrated Licensing Process
ISR ....Initial Study Report
ITA ....Indian Trust Assets
kV...............................kilovolt
m ....meters
M&I............................Municipal and Industrial
MCL...........................Maximum Contaminant Level
mg/kg ....milligrams/kilogram
mg/L...........................milligrams per liter
mgd ....million gallons per day
MID............................Modesto Irrigation District
MOU ....Memorandum of Understanding
MSCS.........................Multi-Species Conservation Strategy
msl..............................mean sea level
MVA ....Megavolt Ampere
MVZ...........................Museum of Vertebrate Zoology
MW ....megawatt
MWh ....megawatt hour
mya.............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAS............................National Academy of Sciences
NAWQA ....National Water Quality Assessment
NCCP ....Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent

NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP ....National Register of Historic Places
NRI.............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI............................National Wetland Inventory
NWIS ....National Water Information System
NWR ....National Wildlife Refuge
O&M ....operation and maintenance
OEHHA......................Office of Environmental Health Hazard Assessment
ORV ....Outstanding Remarkable Value
PAD............................Pre-Application Document
PDO............................Pacific Decadal Oscillation
PEIR...........................Program Environmental Impact Report
PGA............................Peak Ground Acceleration
PHG............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF............................Probable Maximum Flood
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb.............................parts per billion
ppm ....parts per million
PSP.............................Proposed Study Plan
PTL ....Project Tracking List
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP...............................Relicensing Participant
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF ....Resource-Specific Work Groups
RWG ....Resource Work Group

RWQCB.....................Regional Water Quality Control Board
SC...............................State candidate for listing under CESA
SCD............................State candidate for delisting under CESA
SCE ....State candidate for listing as endangered under CESA
SCT ....State candidate for listing as threatened under CESA
SD1 ....Scoping Document 1
SD2 ....Scoping Document 2
SE...............................State Endangered Species under CESA
SFP.............................State Fully Protected Species under CESA
SFPUC ....San Francisco Public Utilities Commission
SHPO ....State Historic Preservation Office
SJRA ....San Joaquin River Agreement
SJRGA ....San Joaquin River Group Authority
SNTEMP....................stream network temperature
SR...............................California Rare Species
SRA............................State Recreation Area
SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)
SRMP.........................Sierra Resource Management Plan
SRP ....Special Run Pools
SSC ....State species of special concern
ST...............................California Threatened Species
STORET ....Storage and Retrieval
SWAMP.....................Surface Water Ambient Monitoring Program
SWE ....Snow-Water Equivalent
SWRCB......................State Water Resources Control Board
TAF ....thousand acre-feet
TAC............................Technical Advisory Committee
TCP ....Traditional Cultural Properties
TDS ....Total Dissolved Solids
TID.............................Turlock Irrigation District
TMDL ....Total Maximum Daily Load
TOC............................Total Organic Carbon

TRT............................Tuolumne River Trust
TRTAC.......................Tuolumne River Technical Advisory Committee
UC..............................University of California
UUILT........................Ultimate upper incipient lethal temperature
USDA.........................U.S. Department of Agriculture
USDOC......................U.S. Department of Commerce
USDOI.......................U.S. Department of the Interior
USFS..........................U.S. Forest Service
USFWS......................U.S. Department of the Interior, Fish and Wildlife Service
USGS.........................U.S. Geological Survey
USR............................Updated Study Report
VAMP........................Vernalis Adaptive Management Plan
VELB.........................Valley Elderberry Longhorn Beetle
VRM..........................Visual Resource Management
WPT...........................Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP..........................Water System Improvement Program
WWTP.......................Wastewater Treatment Plant
WY.............................water year
µS/cm.........................microSeimens per centimeter

Glossary of Terms and Definitions

Adipose fin	A small fleshy fin with no rays, located between the dorsal and caudal fins. Clipping of adipose fins is used to identify hatchery-raised salmonids.
Age	The number of years of life completed, here indicated by an Arabic numeral, followed by a plus sign if there is any possibility of ambiguity (e.g., age 1, age 1+).
Age composition	Proportion of individuals of different ages in a stock or in the catches.
Age-class	A group of individuals of a certain species that have the same age.
Alevin	The developmental life stage of young salmonids and trout that are between the egg and fry stage. The alevin has not absorbed its yolk sac and has not emerged from the spawning gravels.
Anadromous	Fish that migrate from the sea to spawn in fresh water.
Coded-wire tag (CWT)	A small (0.25mm diameter x 1 mm length) wire etched with a distinctive binary code and implanted in the snout of salmon or steelhead, which, when retrieved, allows for the identification of the origin of the fish bearing the tag.
Cohort	Members of a life-stage that were spawned in the same year.
Density-dependent	Density-dependence in stock-production relationships occurs whenever food or space limitations cause the life-stage specific survival or growth to be related to the numbers of individuals present. Density dependent factors may include spawning habitat area or juvenile rearing area at higher population sizes.
Density Independence	Factors affecting the population regardless of population size, such as temperature, disease, or stranding.
Delta	An alluvial landform composed of sediment at a river mouth that is shaped by river discharge, sediment load, tidal energy, land subsidence, and sea-level changes. The Sacramento and San Joaquin River Delta refers to a complex network of channels east of Suisun Bay (an upper arm of the San Francisco Bay estuary).
Dispersal	A process by which animals move away from their natal population
Escapement	The number of sexually mature adult salmon or steelhead that successfully pass through an ocean fishery to reach the spawning grounds. The total amount of escapement reflects losses resulting from harvest, and does not reflect natural mortality during upmigration such as pre-spawn mortality.
El Niño	A climactic event that begins as a warming episode in the tropical Pacific zone that can result in large scale intrusions of anomalously

	warm marine water northward along the Pacific coastline of North America (also see La Niña).
Estuary	A region where salt water from the ocean is mixed with fresh water from a river or stream (also see Delta). The greater San Francisco Bay estuary includes brackish and salt water habitats from the Golden Gate Bridge in San Francisco Bay and includes Suisun, San Pablo, Honker, Richardson, San Rafael, San Leandro, and Grizzly bays.
Floodplain	The part of a river valley composed of unconsolidated river deposits that periodically floods. Sediment is deposited on the floodplain during floods and through the lateral migration of the river channel across the floodplain.
Fry	Salmonid life stage between the alevin and parr stages. Functionally defined as a size <50–69 mm, fry generally occupy stream margin habitats, feeding on available insect larvae.
Homing	The ability of a salmon or steelhead to correctly identify and return to their natal stream, following maturation at sea.
Hydroelectric	Generation of electricity by conversion of the energy of running water into electric power.
Irrigation	The application of water to land for agricultural crops by means of pumps, pipes, and ditches in order to provide water required by the crops for growth.
Kelts	A spent or exhausted salmon or steelhead after spawning. All species of Pacific salmon, except some steelhead and sea-run cutthroat, die after spawning.
La Niña	A cooling of the surface water of the eastern and central Pacific Ocean, occurring somewhat less frequently than El Niño events but causing similar, generally opposite disruptions to global weather patterns.
Life history	The events that make up the life cycle of an animal, with events for fish including migration, spawning, incubation, and rearing. There is typically a diversity of life history patterns both within and between populations. Life history can refer to one such pattern, or collectively refer to a stylized description of the 'typical' life history of a population.
Life-stage	Temporal stages (or intervals) of an animal’s life history that have distinct anatomical, physiological, and/or functional characteristics that contribute to potential differences in use of available habitats.
Macroinvertebrate	Invertebrates visible to the naked eye, such as insect larvae and crayfish generally found in streams and become food for fish.

Osmoregulation	Refers to the physical changes that take place in salmonids as their gills and kidneys adjust from fresh water to salt water as they enter the ocean, and from salt water to fresh water upon their return.
Pacific Decadal Oscillation	A pattern of Pacific climate variability associated with sea surface warming and changes in ocean circulation that shifts phases on at least inter-decadal time scale, usually about 20 to 30 years.
Parr	Life stage of salmon or *O. mykiss* between the fry and smolt stages. Functionally defined as a size of 50–69 mm at this stage, juvenile fish have distinctive vertical parr marks and are actively feeding in fresh water.
Predator	An animal which feeds on other living animals.
Production	Output from a stock-production model at a particular life-step.
Proximate factor	Stimuli or conditions responsible for animal behavior at ecological time scales (i.e., immediate or short-term responses).
Recruitment	Addition of new fish to a defined life history stage by growth from among smaller size categories. Often used in context of management, where the stage is the point where individuals become vulnerable to fishing gear.
Redd	A nest of fish eggs within the gravel of a stream, typically formed by digging motion performed by an adult female salmon or *O. mykiss*.
Riffle	A shallow gravel area of a stream that is characterized by increased velocities and gradients, and is the predominant stream area used by salmonids for spawning.
Riparian	Referring to the transition area between aquatic and terrestrial ecosystems. The riparian zone includes the channel migration zone and the vegetation directly adjacent to the water body that influence channel habitat through alteration of microclimate or input of LWD.
River mile	A statute mile measured along the center line of a river. River mile measurements start at the stream mouth (RM 0.0).
Riverine	Referring to the entire river network, including tributaries, side channels, sloughs, intermittent streams, etc.
Rotary Screw Trap	Rotary screw traps (RST) consist of a large perforated cone and live-box that are mounted on a floating patform and facing upstream at a fixed location in the river. Rotary screw traps are used to sample a portion of emigrating juvenile salmonids and other fish as they move downstream to allow estimation of total passage.
Semelperous	A reproductive strategy characterized by a single reproductive episode before death.
Smolt	Salmonid life stage between the parr and adult stages. Functionally defined as a size ≥70 mm at this stage, juvenile salmon and steelhead

	actively outmigrate from freshwater habitats and take on the appearance of silver adult fish.
Smoltification	Refers to the physiological changes to allow tolerance to saltwater conditions in the ocean.
Spawn	The act of producing a new generation of fish. The female digs a redd in the river bottom and deposits her eggs into it. The male then covers the eggs with milt to fertilize them.
Spawning grounds	Areas where fish spawn.
Straying	A natural phenomena of adult spawners not returning to their natal stream, but entering and spawning in some other stream.
Stock	Input value required by the stock-production models. It is the first required value entered into the population dynamics model spreadsheets; for example, stock would be the number of fry, for a fry-to-juvenile step.
Superimposition	Superimposition occurs when a redd site is reused by subsequent female spawners before the embryos (see Alevin) of the earlier arriving spawners have had sufficient time to develop and emerge fromn the spawning gravels.
Wild	Salmon or *O. mykiss* produced by natural spawning in fish habitat from parents that were spawned and reared in fish habitat.
Woody debris	Logs, branches, or sticks that fall or hang into rivers that may become submerged at changing river discharge. This debris gives salmonids places to hide and provides food for insects and plants which fish feed upon.
Yolk sac	A small sac connected to alevin which provides them with protein, sugar, minerals, and vitamins. Alevin live on the yolk sac for a month or so before emerging from the gravel and beginning to forage food for themselves.

Study Report W&AR-6
Chinook salmon Population Model Study
Draft Report – June 25, 2013

1.0 INTRODUCTION

1.1 General Description of the Don Pedro Project

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir formed by the dam extends 24-miles upstream at the normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2).

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with the requirements of the Raker Act passed by Congress in 1913 and agreements between the Districts and City and County of San Francisco (CCSF), the Project reservoir also includes a “water bank” of up to 570,000 AF of storage. CCSF may use the water bank to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. CCSF’s “water bank” within Don Pedro Reservoir provides significant benefits for its 2.6 million customers in the San Francisco Bay Area.

The Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Project are recreation, protection of the anadromous fisheries in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from approximately one mile downstream of the dam to approximately RM 79 upstream of the dam. Upstream of the dam, the Project Boundary runs generally along the 855 ft. contour interval which corresponds to the top of the Don Pedro Dam. The Project Boundary encompasses approximately 18,370 ac with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) are owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Project and its primary facilities are shown in Figure 1-1.

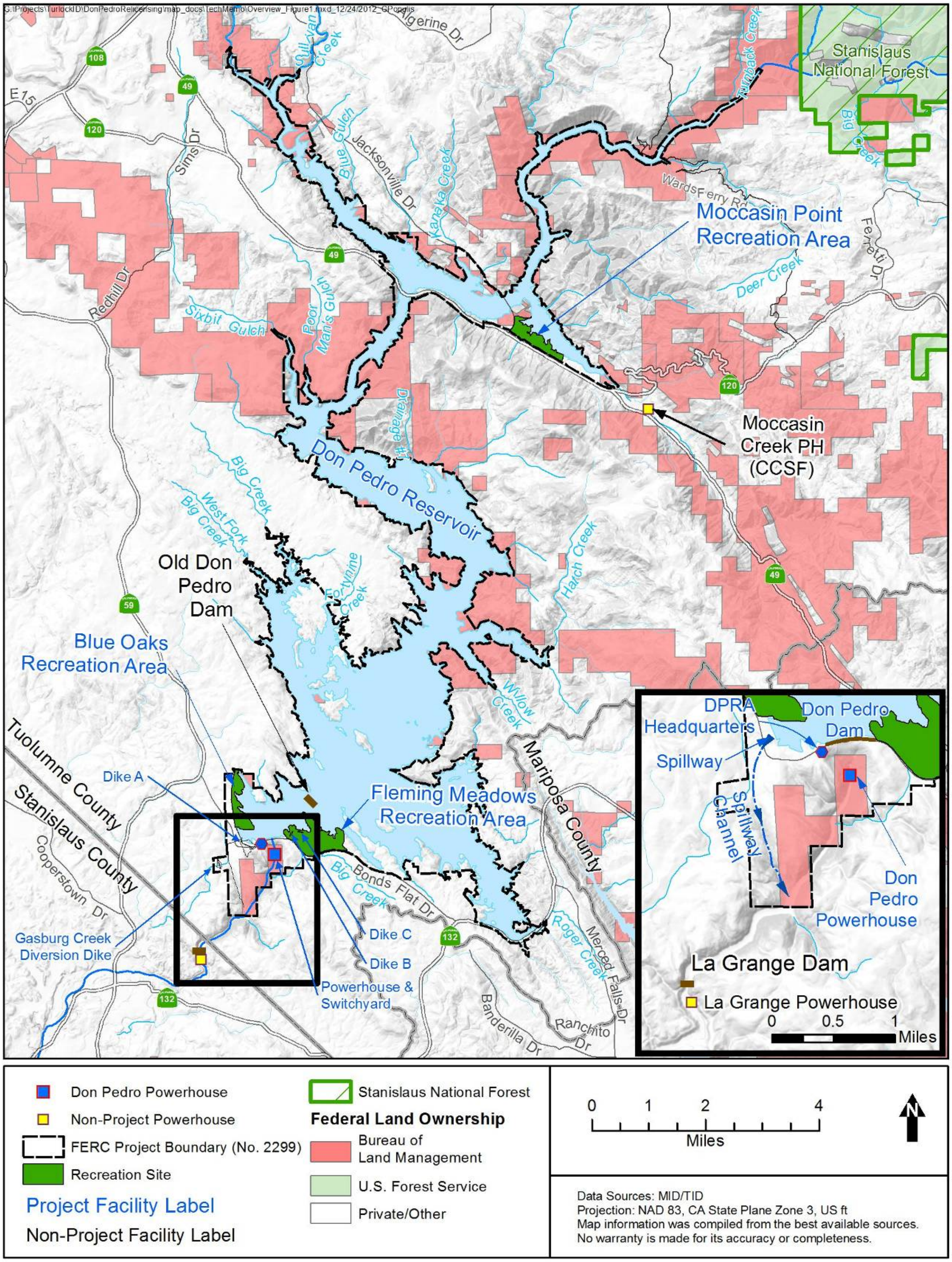

Figure 1-1. Don Pedro Project location.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts will apply for a new license no later than April 30, 2014. The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (ILP). The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012.

This study report describes the objectives, methods, and results of the Recreation Facility Condition and Public Accessibility Assessment, and Recreation Use Assessment Study (RR-01) as implemented by the Districts in accordance with FERC's SPD and subsequent study modifications and clarifications. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at: http://www.donpedro-relicensing.com/

1.3 Study Plan

FERC's Scoping Document 2 identified potential effects of the Project on aquatic resources including anadromous fish. The continued operation and maintenance (O&M) of the Project may contribute to cumulative effects on habitat availability and production of in-river life stages of Chinook salmon. The *Chinook Salmon Population Model Study Plan* (W&AR-5) was accepted by FERC in their December 22, 2011 Study Plan Determination (SPD) with the modifications discussed below.

As recommended by FERC Staff in Element No.1 of the SPD for the *Tuolumne River Chinook Salmon Population Model Study* (W&AR-6), the population model includes mechanisms and parameters "that address the association between flows, water temperature, changing habitat conditions, predation, and the population response for specific in-river life-stages including smolts for existing conditions and for potential future conditions." As recommended in Elements No. 2 through 6, a workshop consultation process was prepared and distributed to relicensing participants on March 20, 2012 that centers upon "Communication" recommendations in the June 2011 *Integrated Life Cycle Models Workshop Report* (Rose et al. 2011), including elements such as a standard glossary of terms and definitions, preparation of presentations and documentation that are tailored to the audience, methods for achieving consensus on key issues between interested participants and the Districts, and applicable conceptual clarifications.

The Districts have held the first of two relicensing participant meetings on November 15, 2012. Workshop No. 1 was held to review preliminary conceptual models developed as part of the interrelated *Salmonid Information Integration and Synthesis Study* (W&AR-5) ("Synthesis Study") and to present the approaches and parameters to be used in the development of life-stage-specific population models in accordance with the *Tuolumne River Chinook Salmon Population Model Study Plan* (W&AR-6). A meeting agenda was provided to relicensing participants on November 5, 2012 and materials presented at the Workshop—preliminary conceptual models and an accompanying narrative—were provided to relicensing participants on November 15, 2012. At the workshop, relicensing participants and the Districts discussed the model framework and approach for investigating the relative influence of factors identified by the Synthesis Study (W&AR-5). Draft workshop notes were prepared and distributed to relicensing participants on December 13, 2012 and comments were received from CDFW on January 14, 2013. In their filing of the final notes for Workshop No. 1 on March 18, 2013, the Districts responded to comments and provided assurances that the effects of flow and water temperature upon individual life stages would be included in the model.

An additional workshop will be held on August 6, 2013 to review and discuss the selected modeling approach, model calibration and validation, parameter sensitivity testing, as well as the results of a baseline hydrology and water temperature scenario. In addition to juvenile production estimates provided under the baseline scenario, up to three additional scenarios will be developed with relicensing participants. For example, scenarios may be developed representing under various Project operations, habitat modifications, or to compare production across years or seasons with dissimilar hydrology and meteorology. The results of these scenarios will be provided with the Draft License Application.

2.0 STUDY GOALS AND OBJECTIVES

The goal of the *Tuolumne River Chinook Salmon Population Model Study* is to provide a quantitative salmon production model to investigate the influences of various factors on the life-stage specific production of Chinook salmon in the Tuolumne River, identify critical life-stages that may represent a life-history "bottleneck," and compare **relative** changes in population size between potential alternative management scenarios. Using historical information as well as results of interrelated relicensing studies, the results of this study will be used to assess the extent to which the abundance of juvenile Chinook salmon in the Tuolumne River may be affected by in-river factors.

3.0 STUDY AREA

Figure 3-1 provides an overview of the broad geographic range of fall-run Chinook salmon life stages occurring in the Tuolumne River, Delta, and ocean. The study area includes habitat used by in-river life stages (i.e., upmigration, spawning, egg incubation, fry/juvenile rearing, and smolt emigration) along the Tuolumne River from the La Grange Dam (River Mile [RM] 52) downstream to the location of the rotary screw trap at Grayson River Ranch (RM 5) near the San Joaquin River confluence. As discussed in the Synthesis Study (W&AR-5), the average age at return for Chinook salmon upmigrants arriving from the ocean is 2.7 years, with three-, two-, and four-year-old salmon making up the largest proportions of the annual spawning run. Following egg incubation for 2–3 months, juveniles rear for an additional 3–4 months prior to smoltification and emigration. Although Chinook salmon may potentially emigrate as yearlings (i.e., Year 1+ smolts), because the contribution of this life history strategy to juvenile production is very low under current conditions, juvenile Chinook salmon over-summering and yearling emigration is not represented in the current model implementation.

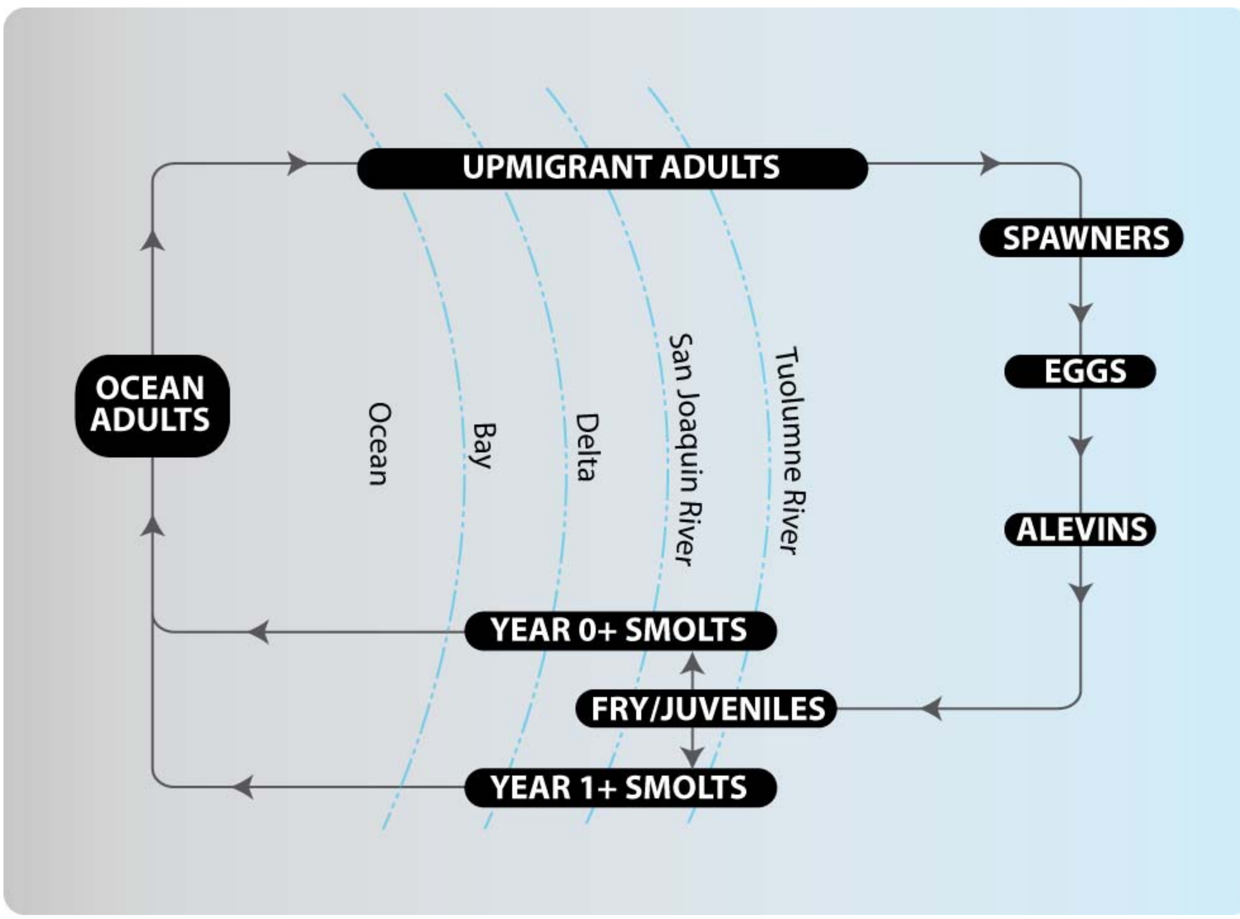

Figure 3-1. Generalized life stage distribution of Tuolumne River fall-run Chinook salmon.

4.0 METHODOLOGY

The *Tuolumne River Chinook salmon population modeling study* builds upon existing literature and information identified in the interrelated Synthesis Study (W&AR-5), including monitoring data collected as part of previously conducted Tuolumne River monitoring efforts, more recent data from interrelated relicensing studies, as well as previous population modeling efforts on the Tuolumne River. As detailed further below, the population model development was separated into four steps: (1) Conceptual Model Review and Refinement, (2) Quantitative Model Development, (3) Sensitivity Analyses, and (4) Evaluation of Relative Salmon Production under Current and Potential Future Project Operations.

4.1 Conceptual Model Refinement and Functional Relationships

Potential density-dependent and density-independent factors affecting in-river life-stages of Chinook salmon in the Tuolumne River were identified as part of the initial conceptual model development in the Synthesis Study (W&AR-5). Attachment A provides graphical depictions of primary factors for modeling of in-river Chinook salmon life stages. A workshop was held with relicensing participants on November 15, 2012 to review and discuss conceptual models and to determine the relevant factors and preliminary parameters to be included in the model. The following sections draw upon these sources of information in developing functional relationships to represent the effects of flow upon physical habitat (e.g., areas of suitable depth and velocity) as well as indirect effects of flow and seasonal air temperatures during upmigration and spawning; egg incubation and fry emergence, in-river rearing and emigration.

4.1.1 **Adult Upmigration and Spawning**

4.1.1.1 Migration Timing and Spawner Movement

Information reviewed as part of the Synthesis Study (W&AR-5) suggests variations in arrival timing of Chinook salmon spawners near La Grange are unrelated to flow conditions in the lower Tuolumne River. Since water temperatures near the San Joaquin River confluence (RM 0) are only weakly related to variations in instream flows during September and October, other factors such as day-length effects or regional meteorology are more likely to affect upmigration timing into the lower Tuolumne River. Based upon this information, a decision was made to represent arrival timing based upon either the empirical distribution of weir passage data at RM 24.5 from 2009–2012 (Figure 4-1) or as a fixed spawner population size arriving according to the seasonal distribution of peak live count information collected by CDFW in historical spawner surveys. Comparisons of distribution of weir passage date (Figure 4-1) with the distribution of spawning activity based upon CDFW redd count data (Figure 4-2) indicates that redd construction typically lags weir passage by approximately two weeks. This is equivalent to 1–2 mi/day assuming no holding prior to spawning, or a faster upmigration in combination with some period of holding prior to spawning. Although little additional information is available to estimate upmigration rates in the Tuolumne River, rates of 4–46 km/d (2–29 mi/d) have been reported in tracking studies on the Klamath River (Strange 2010) as well as Columbia River (Goniea et al 2006).

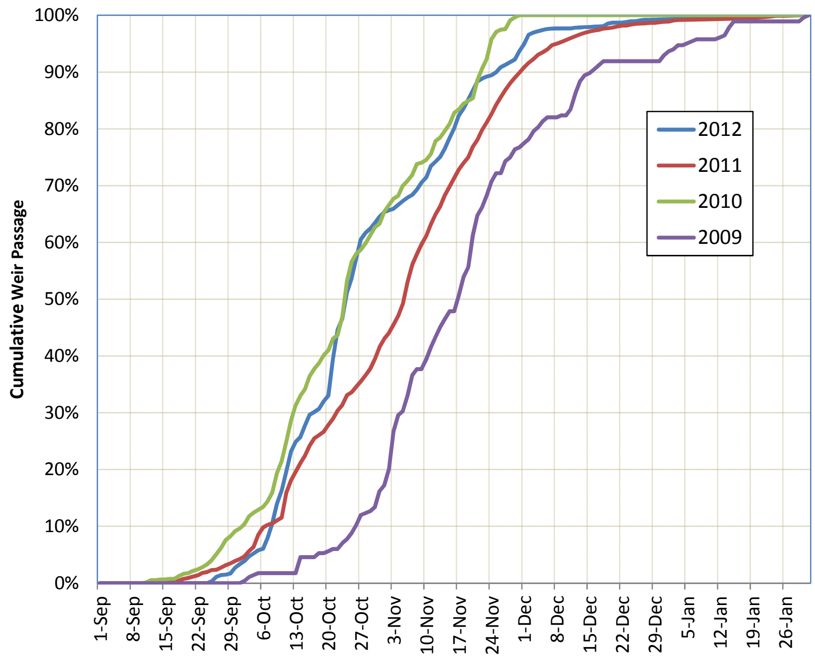

Figure 4-1. Distribution of Chinook salmon passage timing at the Tuolumne River weir (RM 24.5) from 2009–2012.

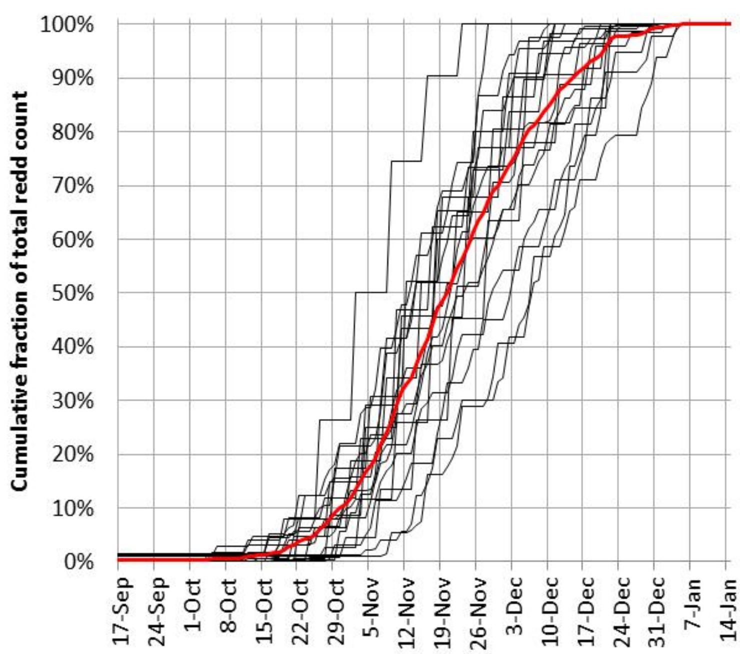

Figure 4-2. Distribution of redd construction timing in the Tuolumne River (1992–2010).

4.1.1.2 Spawning Habitat Use

Selection of suitable habitat by spawning female salmon is affected by (1) the availability of suitably-sized spawning gravels, (2) site-specific hydraulic conditions (i.e., depth, velocity, hyporheic flows), and (3) limitations on spawning at locations with suitable water temperatures. Use of PHABSIM modeling for predicting spawning habitat use is based upon studies in the Merced and American Rivers by Gallagher and Gard (1999) who found a significant correlation between weighted usable area (WUA) predictions and the observed density of Chinook salmon redds. On this basis, spawning habitat availability for the model is estimated from mapped areas of suitable gravels in riffle habitats from the *Spawning Gravel Study* (W&AR-4). Using PHABSIM modeling from the *Lower Tuolumne River Instream Flow Study* (Stillwater Sciences 2013), mapped areas of suitable gravels are re-scaled to areas at other flows based upon the relative amounts of WUA occurring within individual reaches of the lower Tuolumne River. Figure 4-3 shows the variation of total useable area with discharge as estimated within riffle habitats of various sub-reaches of the lower Tuolumne River.

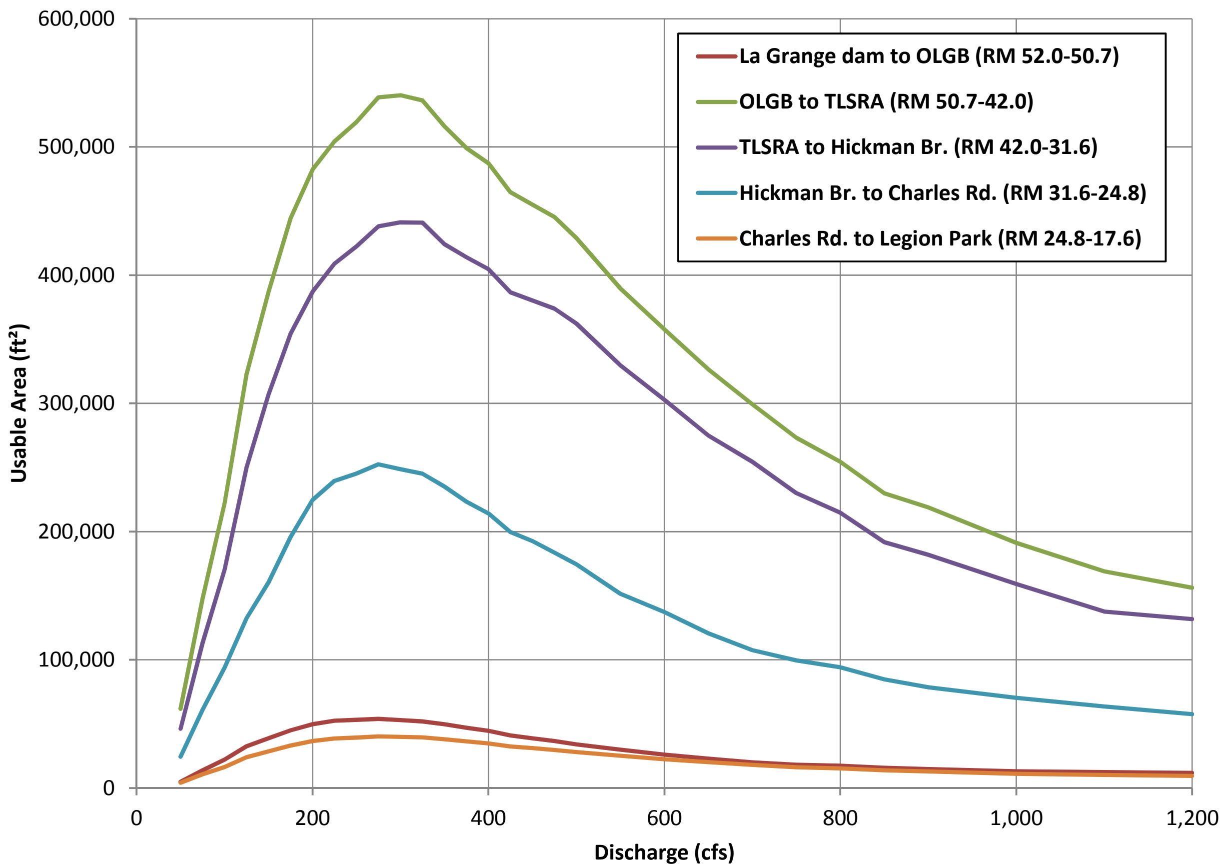

Figure 4-3. Variation of usable spawning area estimates with discharge for Chinook salmon in sub-reaches of the lower Tuolumne River.

In order to address potential temperature limits for spawning habitat selection, area estimates provided in Figure 4-3 are truncated to exclude sub-reach area contributions occurring downstream of locations exceeding the water temperature threshold for spawning, as determined by historical thermograph records as well as the *Lower Tuolumne River Temperature Model Study* (W&AR-16). Although literature reviews by McCullough (1999) found a maximum temperature of 18.9°C (66°F) for Chinook salmon upmigration and holding, an initial estimate of 16°C (60.4°F) was established as the upper limit for initiation of spawning (Groves and Chandler 1999). Spawners are assumed to avoid locations with water temperature above this threshold with spawning habitat selection limited to upstream (i.e., cooler) locations.

In addition to the effects of hydraulic and water temperature conditions upon spawning habitat selection, historical spawning surveys have long documented that Chinook salmon spawning habitat use is more heavily weighted towards upstream locations nearer to La Grange Dam (RM 52.2). Figure 4-4 shows the apparent habitat "preference" on the basis of cumulative gravel availability occurring downstream of mapped redd locations, with approximate locations shown as a secondary (upper) axis. For example, approximately 50% of redds observed between 2010–2012 and mapped as part of the *Salmonid Redd Mapping Study* (W&AR-8) were located within the 85% of the spawning gravels mapped downstream of approximately RM 49, with the other 50% of spawning occurring within the remaining 15% of the spawning gravels occuring between RM 49 and La Grange Dam (RM 52.2). The fitted line in Figure 4-4 represents this apparent preference based on the model in Equation 1 below.

$$\Phi^{-1}(G(i)) = b_0 + b_1\Phi^{-1}(F(i)),$$
$$\Phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} e^{-t^2/2}\,dt \qquad \text{Equation 1}$$

Equation 1 represents the fitted preference line in Figure 4-4, where $\Phi^{-1}$is the inverse of the probit transform Φ(z) above and *F(i)* is the cumulative fraction of gravel area within and downstream of a mapped riffle number *(i)* and *G(i)* is the cumulative fraction of the female spawners expected to spawn within and downstream of riffle number i.

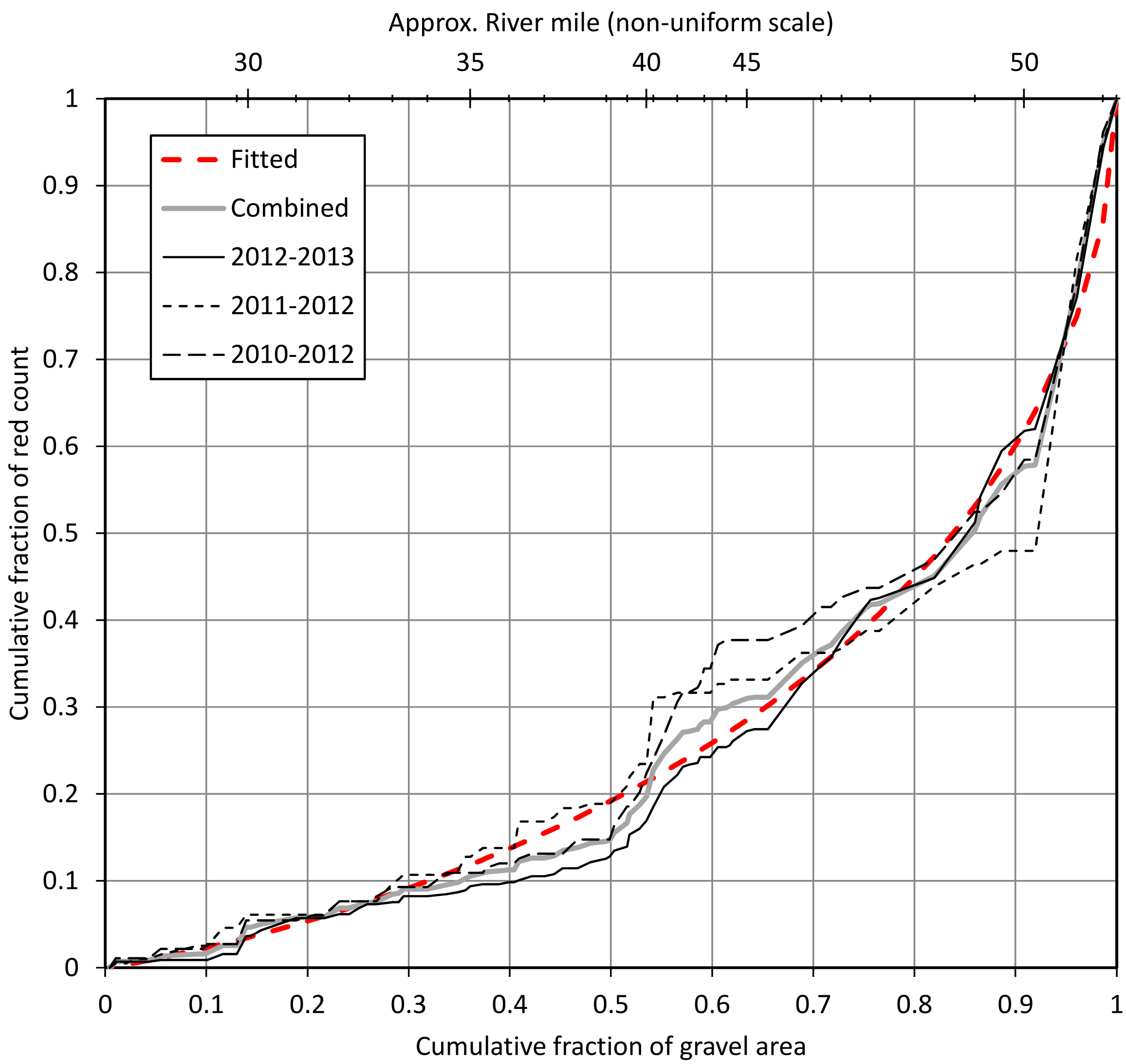

Figure 4-4. Cumulative proportion of total Chinook salmon spawning activity (2010–2012) as a function of total spawning gravel areas occurring downstream of mapped redds.

Depending upon the spawner preferences discussed above, adult female Chinook salmon arriving at a particular location will construct redds over a period of several days, with a median size of 4.8 m^2 (52 ft^2) reported for the Tuolumne River based upon detailed measurements (n=354) recorded in 1988–1989 (TID/MID 1992, Appendix 6). Spawner fecundity and egg deposition (Equation 2) is estimated based upon fish size and egg count information (n=48) collected by examining female spawners caught at the Los Banos Trap (Merced River) during fall 1988 by CDFW (Loudermilk et al 1990 as cited in TID/MID 1992, App 8) along with size information for various age classes (i.e., 2, 3, 4, or 5 yrs) estimated from weir monitoring or historical spawner surveys on the Tuolumne River (e.g., TID/MID 2012, Report 2011-2).

$$Eggs = 158.45 \times L - 6138.91 \qquad \text{Equation 2}$$

Based upon observations of redd superimposition summarized as part of the Synthesis Study (W&AR-5), spawning at locations previously occupied by spawning redds are assumed to potentially occur unless it is being actively defended. Typical redd defense times by the spawning female can range from 6–25 days (Neilson and Banford 1983), with a typical range of 7-days observed in the Tuolumne River based upon repeat redd surveys conducted in 1988 and 1989 (TID/MID 1992, App 6; TID/MID 1997, Report 96-6).

4.1.1.3 Mortality during Upmigration and Spawning

Potential sources of pre-spawn mortality during upmigration and arrival on the spawning gravels include exposure of spawning adults to elevated water temperatures with varying probabilities of direct or delayed mortality (e.g., Marine 1992). However, pre-spawn mortality has not been documented on the Tuolumne River and only low levels of pre-spawn mortality (1–4%) was identified on the neighboring Stanislaus River (Guignard 2006), mortality during upmigration and spawning due to elevated water temperature is assumed to be negligible and is not represented in the model. Chinook salmon are semelparous and generally die within a period of days to weeks following spawning due to cessation of feeding and related physiological changes (Dickhoff 1989). Based upon studies of senescence in sockeye salmon (*O. nerka*) by Morbey et al (2005), an upper estimate of 21-days survival for Chinook salmon spawners after arrival on the spawning gravels was selected for use in modeling.

4.1.2 **Egg Incubation**

4.1.2.1 Embryo Development

Normal Chinook salmon egg development times depend primarily upon water temperature as well as initial egg weight. Conventional degree-day models used in hatchery operations accumulate the exposure time of the eggs as the daily mean water temperature, predicting egg hatch and alevin "swim-up" when some thresholds are reached. After egg deposition, typical hatch times of 60–90 days have been observed, depending upon water temperature (Alderdice and Velson 1978, as cited in Healey 1991). Water temperature degree-day models have been used to successfully predict emergence timing of Chinook salmon fry (TID/MID 2007, Report 2006-7) and has been used in the formulation of a prior population model of the lower Tuolumne River (Jager and Rose 2003). Because incubation times have been shown to also depend upon initial egg weight (Beacham and Murray 1990), we employ a modified degree day model of Rombough (1985) for development time at a fixed temperature as well as initial egg weight. To account for time-varying water temperatures, Equation 3 accumulates "weighted thermal units" (WTU) based upon daily average water temperature, showing that fry hatching occurs *D* days after fertilization, where *D* is the smallest number for which:

$$\sum_{i=1}^{D} \mathrm{WTU}_i \geq 1, \text{ where}$$
$$WTU_i = e^{-5.88-0.000513W+0.152T_i} \qquad \text{Equation 3}$$

An estimate of initial egg weight (W) of 246 mg (Std. Dev.=35 mg) was used in Equation 3 based upon egg lot subsample measurements (n=125) recorded as part of the 2001 *Tuolumne River Survival to Emergence Study* (TID/MID 2007, Report 2006-7).

4.1.2.2 Embryo Mortality during Incubation

Chinook salmon egg mortality is assumed to occur through redd superimposition, exceedance of laboratory based estimates of water temperature mortality thresholds (e.g., UUILT), or impairment of intra-gravel flow conditions due to excess fines. Information reviewed as part of the Synthesis Study (W&AR-5) suggested that it is unlikely that intragravel water temperature conditions contribute to high rates of egg mortality of Chinook salmon on the Tuolumne River. Geist et al. (2006) suggest that early-stage embryos are more tolerant of warm water, so that Chinook spawning occurring at water column temperatures of 15–16°C may not result in high rates of egg mortality. Nevertheless, to allow evaluation of a broad range of flow and water temperature conditions using the completed model, an initial acute mortality threshold of 14.4°C (58°F) was included based upon a literature review by Rich (2007). This is within the range of 13.9–15.6°C (57–60°F) corresponding to a rapid increase in mortality documented in laboratory experiments by Seymour (1956), which was validated in further experiments by USFWS (1998) in the Sacramento River.

In addition to potential mortality due to water temperature, redd superimposition can be a major mortality factor for eggs and alevins that results in a density-dependent relationship in which subsequent fry production is inversely proportional to spawning escapement size (McNeil 1964). The Districts have conducted a range of studies examining potential egg mortality due to redd superimposition (TID/MID 1992, Appendices 6 and 7; TID/MID 1997, Report 96-7) as well as survival-to-emergence as a function of gravel quality in several studies (TID/MID 1992, Appendix 8; TID/MID 2001, Report 2000-6; TID/MID 2007, Report 2006-7). Estimates of egg survival-to-emergence for the lower Tuolumne River are on the order of 30% based upon both bulk gravel quality using the Tappel and Bjornn (1983) model as well as direct emergence trapping (TID/MID 1992, Appendix 8). Because intensive permeability sampling conducted in 1999 at 122 sampling locations across 12 riffles extending from RM 50.8–36.8 (TID/MID 2001, Report 2000-6) did not result in more precise estimates of survival-to-emergence at individual riffle locations, an initial estimate of 32% survival was selected based upon the previous emergence trapping results (TID/MID 1992, Appendix 8).

4.1.3 **Fry Rearing**

4.1.3.1 Fry Habitat Use

After hatching, Chinook salmon alevins remain in the gravel for two to three weeks and absorb their yolk sac before emerging from the gravels into the water column. Following emergence, fry rearing generally occurs in low velocity, shallow water habitat along channel margins (Everest and Chapman 1972) as well as in inundated overbank habitat locations with connectivity to the mainstem channel (Moyle et al 2007). To represent habitat availability for fry in the lower Tuolumne River, PHABSIM modeling conducted for the *Lower Tuolumne River Instream Flow Study* (Stillwater Sciences 2013) is used to estimate the area of suitable habitat at in-channel locations. Fry rearing habitat use has been related to WUA at the site scale in studies by USFWS (1991) and forms the basis of a related Chinook salmon population model (i.e., SALMOD) on the Trinity River (Bartholow et al 1993), a Chinook salmon production model developed by the Oak Ridge Chinook salmon model (ORCM) for the Tuolumne River (Jager et al 1997) and other population models. Estimates of in-channel fry rearing habitat availability as a function of flow and WUA are shown in Figure 4-5, as developed from habitat suitability criteria presented in the *Instream Flow Study* (Stillwater Sciences 2013). In order to represent fry rearing habitat availability at overbank locations occurring at higher flows, WUA estimates for study sites evaluated using 2D modeling for the *Pulse Flow Study Report* (Stillwater Sciences 2012) were expanded in proportion to overbank inundation occurring on a river-wide basis (Figure 4-5) using digitized historical aerial photography collected as part of the Tuolumne River GIS development (TID/MID 1997, Report 96-14). As noted in Stillwater Sciences (2012), the 2D model-derived estimates of suitable habitat at the site scale may not represent all conditions occurring river-wide. Figure 4-6 represents the estimate of suitable habitat availability from current information sources. It should be noted that estimates for the reach downstream of Shiloh Bridge (RM 3.5) may be strongly influenced by backwater effects from flood flow conditions occurring in the San Joaquin River at the time that air photos were flown for this analysis.

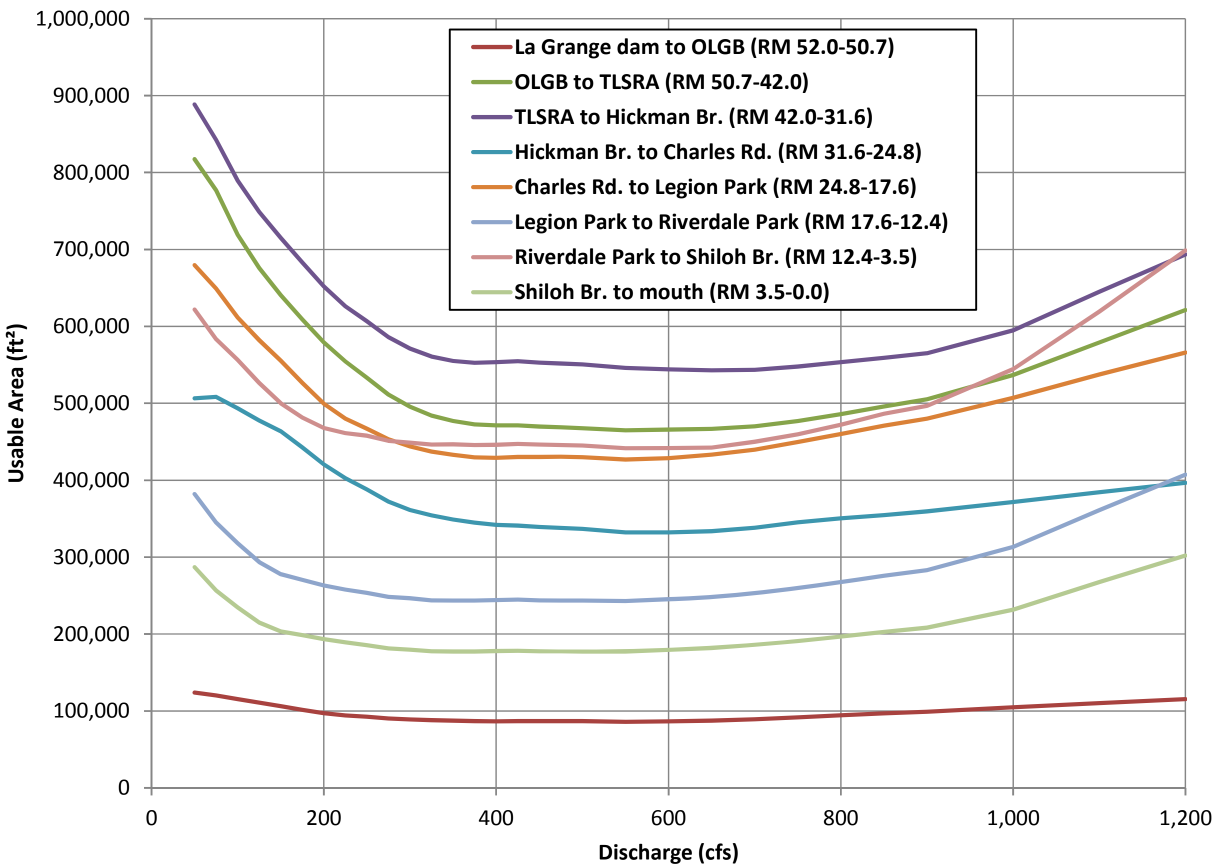

Figure 4-5. Variation of usable fry rearing area estimates with discharge for Chinook salmon in sub-reaches of the lower Tuolumne River.

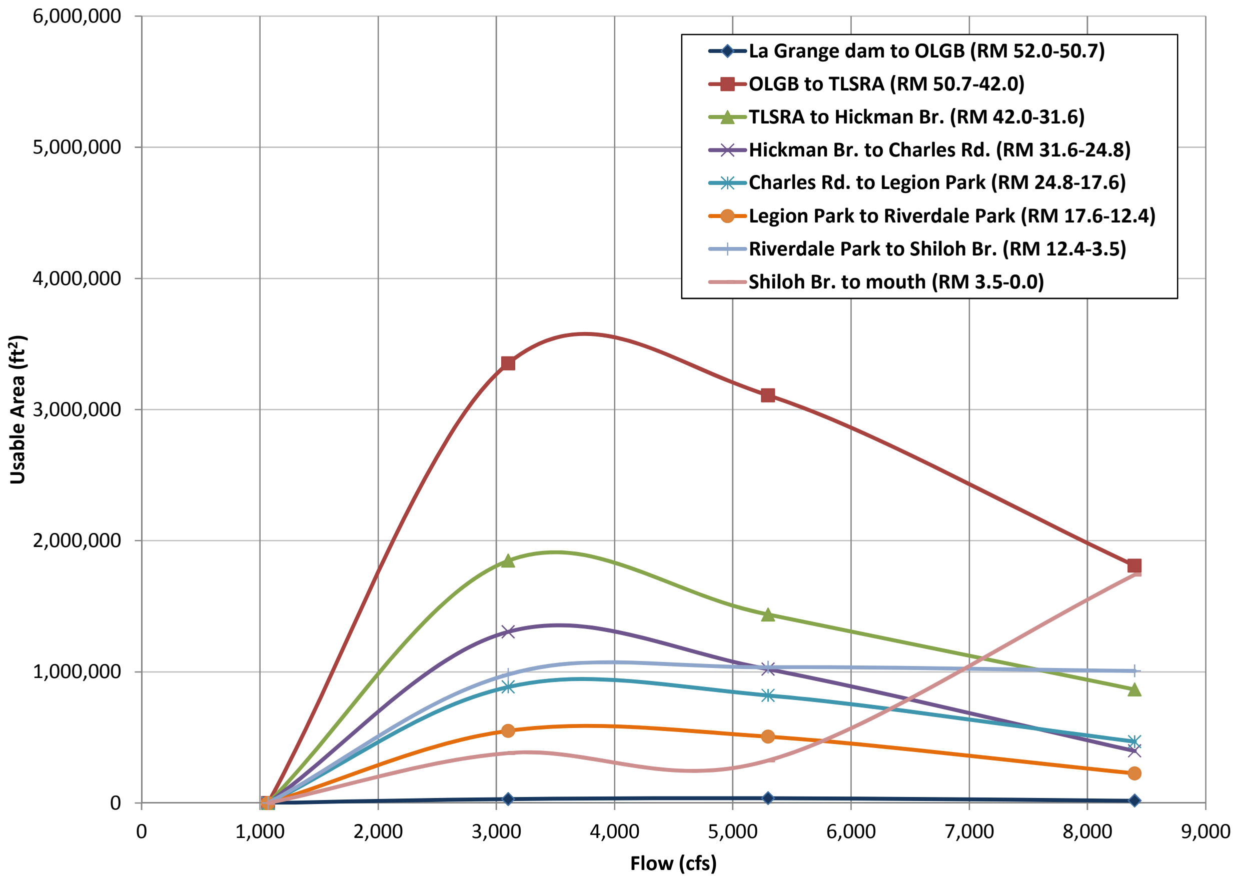

Figure 4-6. Estimated total usable overbank habitat for Tuolumne River Chinook salmon fry.

4.1.3.2 Fry Movement

In most years, early fry passage at the Waterford (RM 29.8) and Grayson (RM 5.2) rotary screw traps (RSTs) occurs in January and February, with apparent peaks associated with emergence from the spawning gravels. This is consistent with either flow displacement or active emigration of weakly swimming fry prior to the fry locating low velocity habitats along the channel margins. As discussed in the Synthesis Study (W&AR-5), RST catch data for the Grayson (RM 5.2) location exhibits large numbers of early emigrating fry in years following high escapements (e.g., 1998–2002) as well as in years with moderate escapement levels accompanied by extended flood control releases such as occurred in 2011 (TID/MID 2012, Report 2011-4). Juvenile Chinook salmon density estimates from seine data (1999–2012) provided in Attachment B suggest that fry rearing occurs at upstream locations in drier water year types without flood control releases (e.g., WY 2001–2004, 2007–2010, and 2012). Fry are distributed farther downstream during years with extended high flows (e.g., WY 1999–2000, 2005–2006, and 2011). Taken together, the RST and seining data observations are consistent with the combined mechanisms of flow displacement as well as volitional emigration found in other systems (Healey 1991) and leads to the following movement assumptions in the model. Upon emergence, 30% of all fry are assumed to emigrate from the Tuolumne River, with the remainder assumed to be displaced for a period of 30 minutes. To provide an estimate of the displacement distance at varying discharges, the displacement period is multiplied by reach-specific estimates of channel velocity developed using transect-based information from the ongoing IFIM Study (Stillwater Sciences 2013) fitted to a simple hydraulic geometry relationship between velocity (v) and stream discharge (Q) by Leopold and Maddock (1953) shown in Equation 4, with fitted parameters k, and m.

$$v = kQ^m \qquad \text{Equation 4}$$

In addition to volitional emigration following emergence, fry movement may be attributed to mechanisms of slower active migration found in other Central Valley Rivers (Williams 2006), as well as due to potential exclusion from nearshore rearing locations due to limited habitat availability. Based upon biweekly seine sampling summarized as part of the Synthesis Study (W&AR-5), seasonal fry movement rates were estimated at approximately 0.2 mi/day from relative changes in seining density vs. river mile in repeated sampling events in non-flood years (WY 2002–2004, 2009, 2012). To account for movement at other flows, these rates were represented as a daily movement probability of 0.05 d^{-1} using the same 2-hr movement period and velocity estimate as applied to newly emergent fry (Equation 4). For areas with fry densities in excess of habitat carrying capacity, defined as the maximum attainable densities under optimum habitat conditions (e.g., Burns 1971), fry movement is re-initiated using the duration and velocity estimates described above. Although the Synthesis Study (W&AR-5) suggested that it is unlikely that fry rearing habitat is limiting for Chinook salmon in the lower Tuolumne River, the maximum attainable fry density in the Tuolumne River is estimated at 16.1 fry/m^2 based upon individual seine haul data collected in years following moderately high escapements occurring in 1988, 1998, and 2002. This density is slightly in excess of the 90th percentile estimates of 15.3 fry/m^2 estimated for the Klamath River by Bartholow and Henriksen (2006) as well as the 15.5 fry/m^2 found by Grant and Kramer (1990) in studies examining territoriality of stream type salmonids. However, because ocean type fish such as fall-run Chinook salmon generally exhibit reduced site fidelity and territoriality (Taylor 1990) as compared to stream-dwelling salmonids, it is not unexpected that greater rearing densities have been observed on the Tuolumne than for other river systems.

4.1.3.3 Fry Growth

For fry not emigrating from the Tuolumne River, growth is modeled as a function of water temperature and estimated food availability for various sub-reaches of the lower Tuolumne River using a growth model by Stauffer (1973) shown in Equation 5. Stauffer's model for the change in weight (W^+) over a relatively short time interval Δt is represented as an exponential relationship as a function of starting weight W_0 and growth rate (g). The growth rate is estimated as a function of maximum growth rate (G_{MAX}), water temperature T, ration level R as a fraction of maximum food intake (R_{MAX}) at complete satiation, as well as ration for maintenance of body weight (R_{MAINT}).

$W^{+} = W_0 e^{g\Delta t}$, where

$$g = G_{MAX} \sin\left(\frac{\pi}{2}\frac{R - R_{MAINT}}{R_{MAX} - R_{MAINT}}\right)$$

Equation 5

$$G_{MAX} = (a_1 + a_2T + a_3T^2 + a_4T^3 + a_5T^4)(a_6W^{-a_7})$$
$$R_{MAINT} = (l_1 10^{l_2T})(l_3W^{-l_4})$$
$$R_{MAX} = (-l_5 + l_6 \ln T)(l_7W^{-l_8})$$

Other model fitting parameters used in Equation 5 (a_{1-7}, l_{1-8}) are included in Stauffer (1973). Weight-length conversions obtained by linear regression of log-weight and log-length of fish from RST sampling (Figure 4-7) conducted in the Tuolumne River between 2004–2010 (e.g., TID/MID 2013, Report 2012-4). Ration estimates are developed from historical sampling conducted during the 1980s (TID/MID 1992, Appendix 16). As summarized in the Synthesis Study, during 1983–1987 gastric lavage (i.e., stomach pumping) was conducted on juvenile Chinook salmon. Stomach content samples (n=525) were analyzed to examine invertebrate prey items and provide broad daily ration estimates on a river-wide basis (Rf ≈ 70% of maximum) for the Tuolumne River (TID/MID 1997, Report 96-9). With the exception of samples collected near the San Joaquin River confluence during high flow conditions occurring in 1983 and 1986, ration estimates at locations downstream of Modesto (RM 16.2) were generally lower than those samples collected nearer to La Grange Dam (RM 52.2). Based upon these data, in-channel feeding ration levels were represented as relatively high (R = 70%) from RM 52.2 downstream to Legion Park (RM 17.2), with a 30% ration estimated for the sand bedded reaches nearer the San Joaquin River confluence. Although no direct studies of overbank habitat use or growth have been conducted on the Tuolumne River, because of higher growth rates observed for juvenile Chinook in published floodplain rearing studies (Sommer et al 2001; Jeffres et al 2008), ration levels for any fry rearing in overbank habitat areas are assumed to be at least 70% of maximum at all overbank locations.

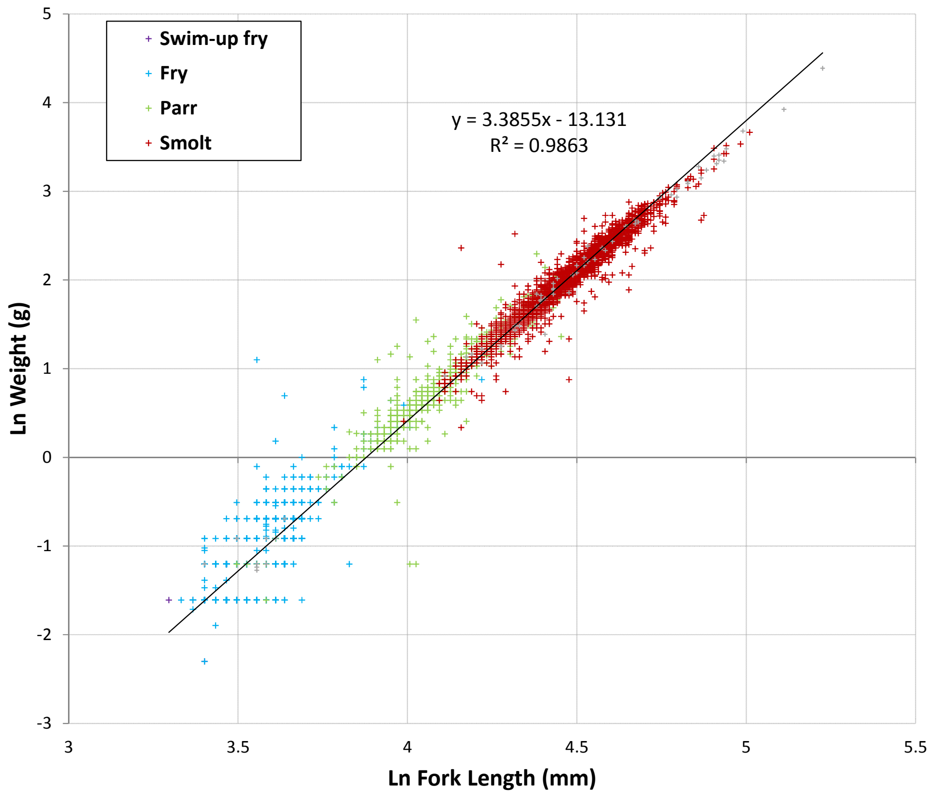

Figure 4-7. Length vs. Weight relationship for juvenile Chinook salmon in the Tuolumne River (2004–2010).

4.1.3.4 Fry Mortality

Potential mortality sources to Chinook salmon fry include predation effects due to the relative habitat availability for predators and juvenile salmon. As summarized in the Synthesis Study (W&AR-5), comparison of recovery data and estimated passage at RSTs located downstream of the spawning reach indicates substantial mortality of juvenile Chinook salmon (fry, parr, and smolt) in the approximately 25–26 miles between the upper (RM 29.8) and lower (RM 3.5 and RM 5.2) RSTs. Using whole season estimates of juvenile passage at the upper and lower traps, apparent survival in this reach has averaged 12% from 2008–2012, ranging from a low of 4% in 2012 to a high of 21% during extended flood control releases occurring in 2011 (TID/MID 2012, Report 2012-4). In order to represent mortality for fry rearing in differing locations as well as at differing flows, the apparent mortality across the distance separating the upper and lower RSTs is first converted to mortality per unit time using the estimated channel velocity in Equation 4. Next, the probability of fry survival for any incremental exposure time from t_1 to t_2 in the main channel where potential predation may occur is modeled as an exponential function of the instantaneous mortality $m(t)dt$ between times t_1 and t_2 shown in Equation 6 below.

$$Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt} \qquad \text{Equation 6}$$

In addition to fry predation mortality, fry emerging during late spring may potentially be subject to water temperature related mortality during periods of hot weather. In laboratory studies, UUILT for Chinook salmon juveniles has been estimated at 25.1ºC by Brett (1952) for Chinook salmon from the Pacific northwest that were acclimated at 20–24ºC. Orsi (1971) estimated UUILT at 24.9ºC for Sacramento River Chinook salmon acclimated at 21.1ºC. Based upon this information, an initial mortality threshold of 25°C (77°F) was selected for Chinook salmon fry as a daily average. Although potential water temperature related mortality may occur at higher water temperatures, this is unlikely to affect the majority of fry emerging in January and February of each year.

Lastly, a background mortality rate of 0.002 d^{-1} is applied to account for the potential for mortality due to other causes that may not be well represented in the model (e.g., disease, stranding, avian predation, and entrainment). Although no data are available to provide an estimate for the Tuolumne River, this rate is within the range as used in modeling conducted on the Klamath River (Bartholow and Henriksen 2006).

4.1.4 **Juvenile Rearing**

4.1.4.1 Juvenile Habitat Use

As rearing Chinook salmon juveniles progress from fry to the parr life stage, the increased body size is accompanied by increased swimming speeds. At this time broader foraging habitat use is necessary to meet increasing energy requirements (Everest and Chapman 1972). Following the same rationale for using WUA as a predictor of Chinook salmon fry habitat use (Section 4.1.3.1), juvenile salmon rearing from parr to pre-smolt sizes (50–69 mm) is represented using PHABSIM modeling. Estimates of in-channel juvenile rearing habitat availability as a function of flow is shown as WUA in Figure 4-8 using habitat suitability criteria presented in the *Lower Tuolumne River Instream Flow Study* (Stillwater Sciences 2013). In order to represent juvenile rearing habitat use on overbank habitat occurring at higher flows, WUA estimates for study sites evaluated using 2D modeling for the *Pulse Flow Study Report* (Stillwater Sciences 2012) were expanded in proportion to overbank inundation occurring on a river-wide basis (Figure 4-9) using digitized historical aerial photography (TID/MID 1997, Report 96-14). As noted for fry, it should be noted that estimates for the reach downstream of Shiloh Bridge (RM 3.5) may be strongly influenced by backwater effects from flood flow conditions occurring in the San Joaquin River at the time that air photos were flown for this analysis.

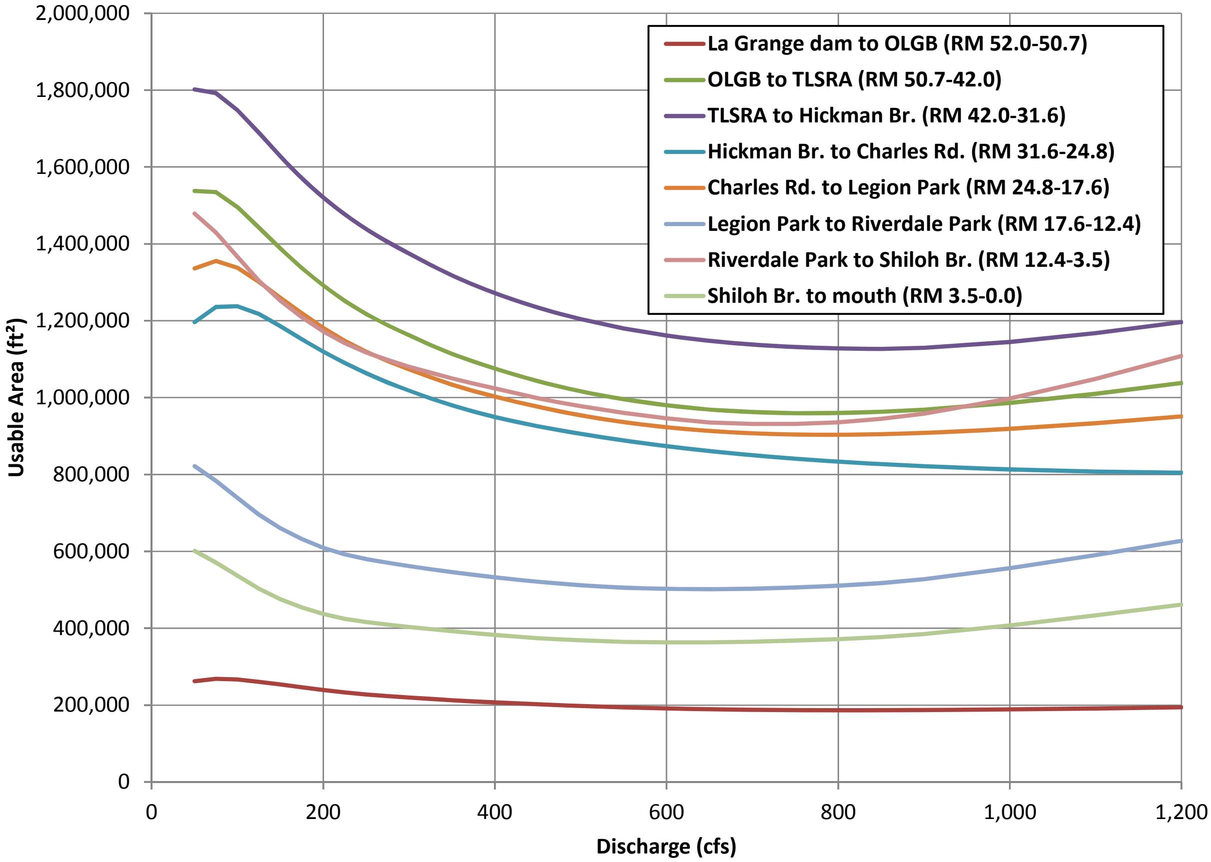

Figure 4-8. Variation of usable juvenile rearing area estimates with discharge for Chinook salmon in sub-reaches of the lower Tuolumne River.

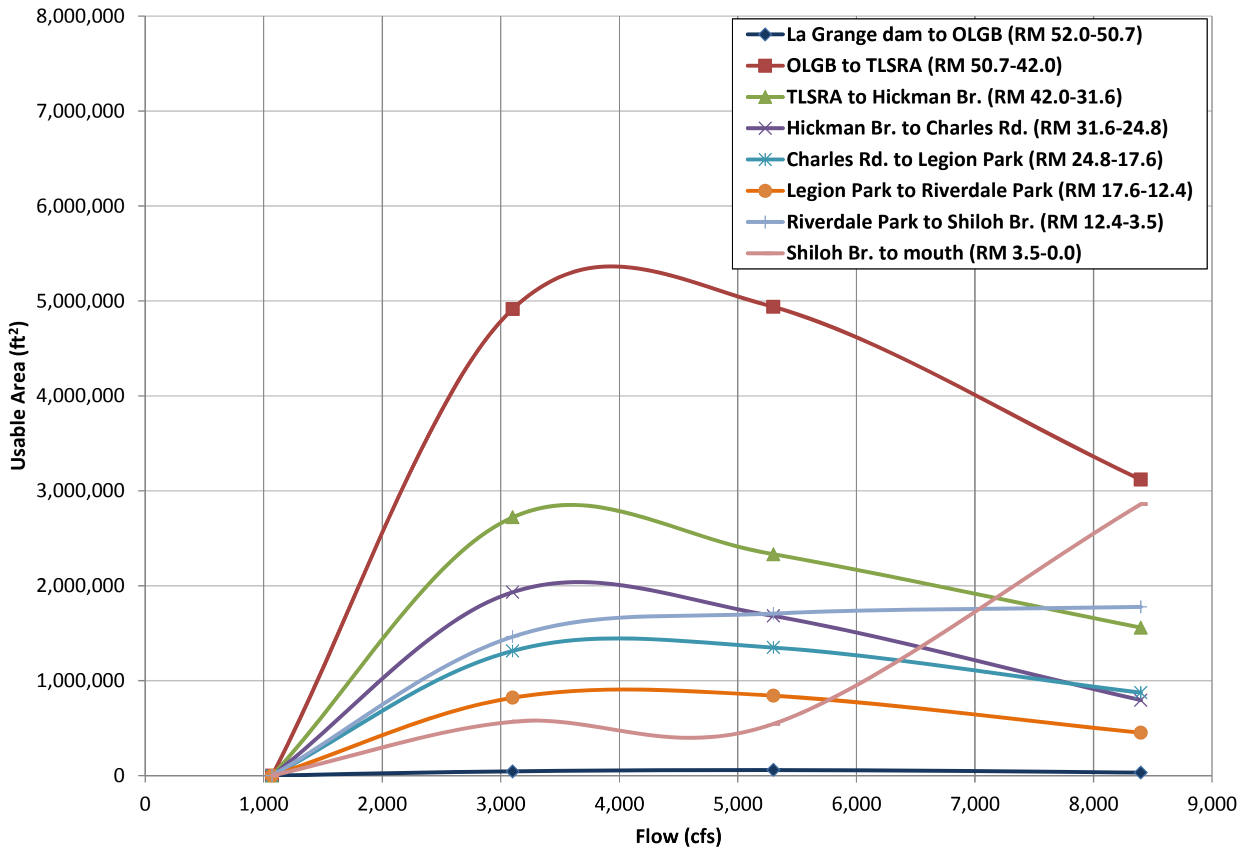

Figure 4-9. Estimated total usable overbank habitat for Tuolumne River Chinook salmon juveniles.

4.1.4.2 Juvenile Movement

In contrast to patterns of early Chinook salmon fry emigration found in RST monitoring on the Tuolumne River, juvenile emigration prior to smoltification is not assumed to occur. Movement during the juvenile rearing period includes the same 0.2 mi/day estimate as applied to fry (Section 4.1.3.2), which was estimated from relative changes in seining density vs. river mile in bi-weekly sampling during non-flood years (WY 2002–2004, 2009, 2012). To account for these seasonal movements at higher flows, movement rates were represented as a daily movement probability initially estimated at 0.01 d^{-1} followed by a movement period of 2 hrs and velocity estimate from Equation 4. For areas with juvenile densities in excess of habitat carrying capacity, juvenile movement is initiated using the same 2 hr movement period and velocity estimates as for daily movements above. Because existing seine data on larger Chinook salmon juveniles is generally collected nearer the channel margins, it may not be representative of habitat utilization nearer the channel thalweg with higher velocities. For this reason, the maximum attainable juvenile density in the Tuolumne River is estimated at 5 juveniles/m^2 based upon spatially explicit density estimates from long-term snorkel survey monitoring of juvenile habitat use on the Trinity River (USFWS 1991).

4.1.4.3 Juvenile Growth

Juvenile Chinook salmon growth in the lower Tuolumne River is represented in the same manner as for fry. Reach specific estimates of food availability are used in combination with daily water temperature as input variables into the growth model by Stauffer (1973) shown in Equation 5.

4.1.4.4 Juvenile Mortality

Potential mortality sources to Chinook salmon juveniles include predation effects due to the relative habitat availability for predators and juvenile salmon, as well as the potential for water temperature related mortality at higher water temperatures. Predation mortality for juveniles is represented in the same manner as for fry, using Equation 4 to convert from mortality as a function of distance between the upper and lower RSTs to mortality per unit time, and then calculating survival at incremental exposure times for fish at differing locations using Equation 6.

In addition to predation mortality discussed above, water temperature and background mortality for larger juveniles is the same as presented for Chinook salmon fry. Based upon information reviewed for Chinook salmon fry mortality (Brett 1952, Orsi 1971), an initial mortality threshold of 25°C (77°F) was selected for Chinook salmon juveniles as a daily average water temperature. A background mortality rate of 0.002 d^{-1} is also applied to account for the potential for mortality due to other causes that may not be well represented in the model (e.g., disease, stranding, avian predation, and entrainment).

4.1.5 **Smolt Emigration**

4.1.5.1 Smolt Movement

For juvenile Chinook salmon undergoing the physiological transformation from the parr to emigrant smolt life-stage, variations in the timing of the parr-smolt transition is influenced by genetics (Taylor 1990), fish size (Ewing et al. 1984), flow (Bjornn 1971), water temperature (Myrick and Cech 2001), and other environmental (e.g., lunar cycle, photo-period, turbidity) and demographic factors discussed by Høgåsen (1998). Smolt emigration timing for fall-run Chinook salmon in the Tuolumne River generally occurs from late April through mid- to late-May (e.g., TID/MID 2013, Report 2012-4), depending upon many of the above factors. Examining smolt emigration under various water year types occurring since the initiation of routine RST monitoring at the Waterford (RM 29.8) and Grayson (RM 5.2) locations in 2006, the dates at which smolts migrate past the traps are quite variable, within years, between years, and between trap locations. There is a general pattern of extended emigration periods in high flow years that is well explained on the basis of size at emigration. Although there is evidence that a portion of annual smolt emigration occurs at sizes as low as 70 mm in all years, in below normal water year types (2007–2009, 2012) Figure 4-10 shows that the size-distributions of emigrating smolts at the Waterford (dashed line) and Grayson (solid line) RSTs are normally distributed in each year as illustrated by blue shaded normal curves on each of the tiles along the diagonal. The distributions at the upstream and downstream locations area also very similar in each year as shown by the yellow band showing equality between the two distributions. The below normal water year type size distributions are normally distributed around a mean size near 80–85mm. In above normal water year types (2006, 2010, and 2011), Figure 4-11 shows that smolt size at emigration is also normally distributed, with a mean size at emigration peaking at a larger mean size between 90–100 mm. In examining the smolt passage dates, smolts tend to leave later in above normal water years than in below normal years, and this extended period of in-river rearing may explain the larger size at emigration. Extended rearing prior to smoltification has been associated with reduced growth rates and slower development at lower water temperatures in hatchery studies in British Columbia (Rombough 1985).

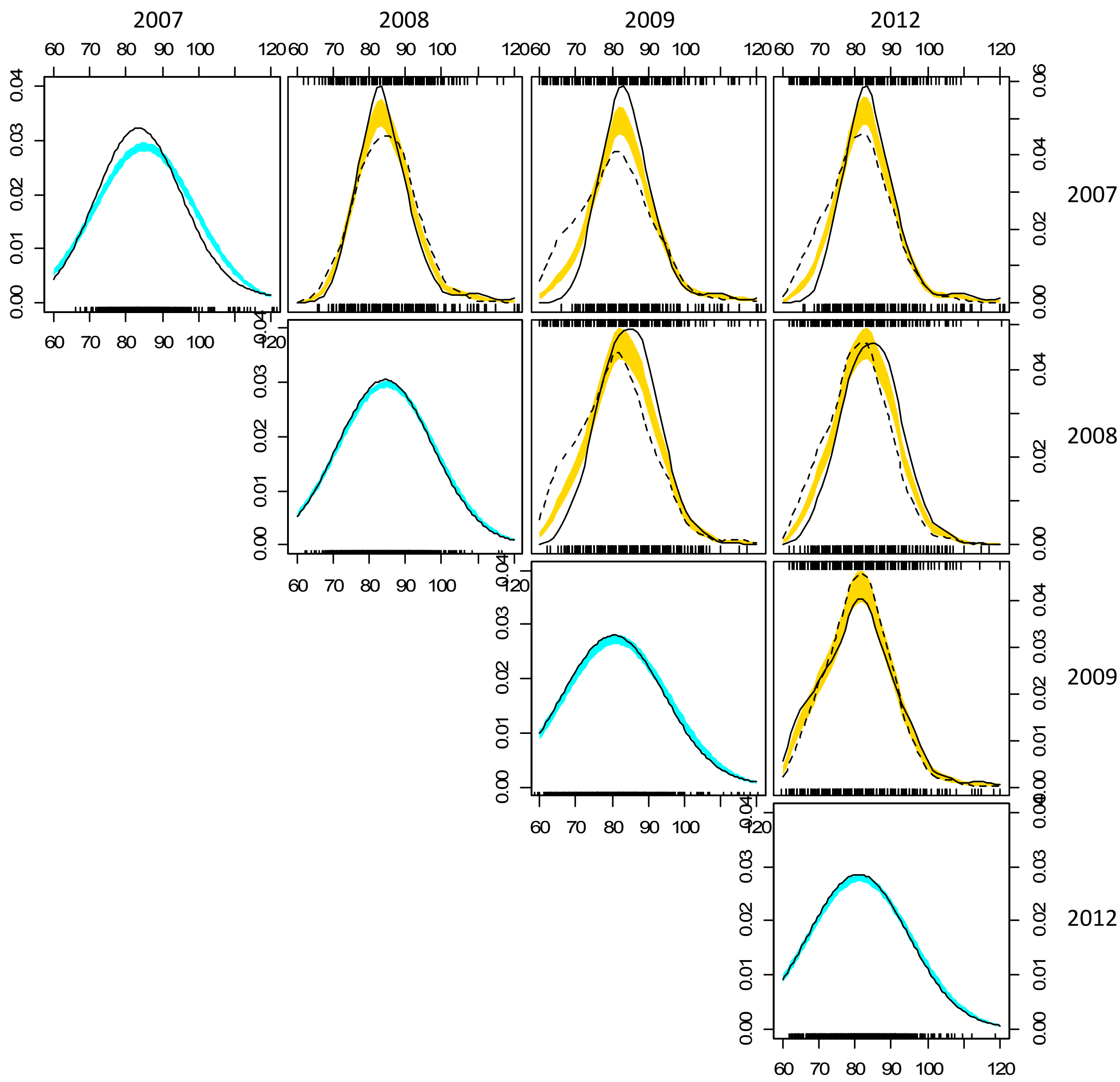

Figure 4-10. Comparisons of smolt size at emigration in below average water year types (2007–2009, and 2012) in the Tuolumne River.

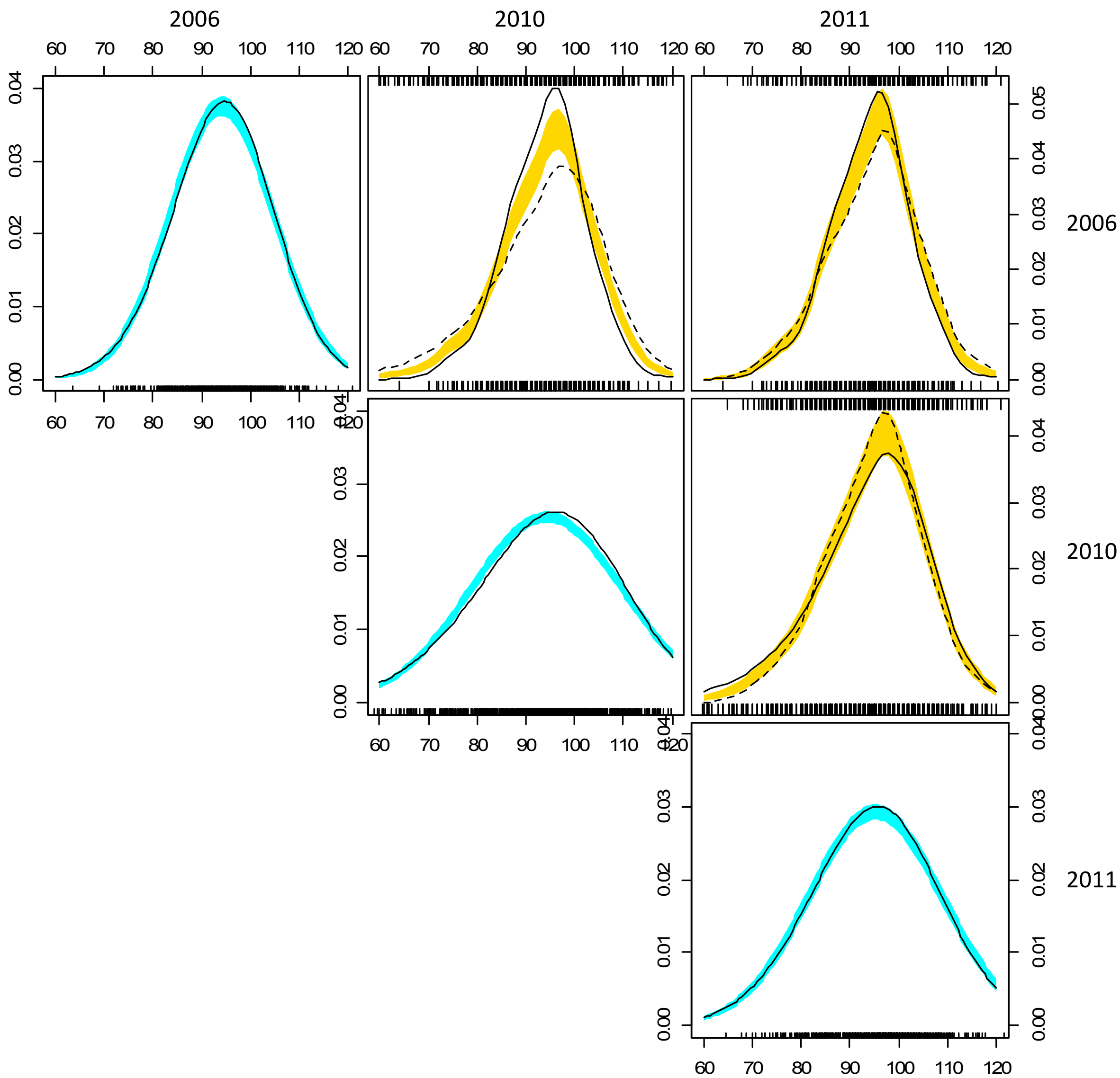

Figure 4-11. Comparisons of smolt size at emigration in above average water year types (2006, 2010, and 2011) in the Tuolumne River.

Based upon the observed smolt sizes in the Tuolumne River (Figure 4-10 and Figure 4-11), smolt movement is modeled on the basis of achieving a length based minimum development threshold to achieve "smolt-ready" status, followed by emigration movement on the basis of a probability distribution around the means sizes discussed above. The minimum threshold selected for smolt-ready status is 70mm, as found in other studies (Ewing and Birks 1982), with individuals emigrating according to the size distributions in above- and below-normal water years based upon their individual exposure history of various discharge levels. Assuming that the daily growth increment ΔL is small in comparison to the length of the individual fish, the probability (P) that an individual will smolt at a length between L and $L+\Delta L$ is shown using a normal distribution around the mean length (μ) in Equation 7 below.

$$P = \frac{\frac{1}{\sqrt{2\pi\sigma^2}}e^{-(L-\mu)^2/2\sigma^2}}{\int_L^\infty \frac{1}{\sqrt{2\pi\sigma^2}}e^{-(\lambda-\mu)^2/2\sigma^2}d\lambda}\frac{\Delta L}{\sigma}. \quad \text{Equation 7}$$

Based upon previous estimates of emigration speeds of up to 46 mi/day in multiple mark recapture smolt survival studies (TID/MID 2001, Report 2000-4), smolt emigration was represented as an outmigration speed of 26 mi/day in addition to reach specific velocity estimates (Equation 4).

In addition to emigration on the basis of size, outmigration pulse flows have been implemented on the Tuolumne River under the current FERC (1996) license to improve conditions for emigrating smolts. Flow has been broadly associated as a factor associated with emigration timing (Bjornn 1971, Sykes et al 2009) and short-term increases in smolt passage following pulse flow reductions has been observed on the Tuolumne River (Attachment C) as well as the neighboring Stanislaus River (Demko and Cramer 1996). However, because of the low sample size used in evaluating flow as a stimulatory cue for smolt emigration from the Tuolumne River as well as the high variability in daily smolt passage on the Tuolumne River outside of the pulse flow periods, flow magnitude or flow change have limited ability to explain the initiation of smolt outmigration (Attachment C). For this reason, no flow related outmigration cues have been included in the initial model development and smolt outmigration timing is based upon the Equation 7 probability function representing the historical observations of size at emigration (Figure 4-10 and Figure 4-11).

4.1.5.2 Smolt Mortality

As summarized in the Synthesis Study (W&AR-5), extensive smolt survival studies using paired releases of coded wire-tagged (CWT) hatchery salmon have provided only a broad estimate of a flow-survival relationship for the lower Tuolumne River. Higher smolt survival in the Tuolumne River was associated with the two tests occurring at 4,000 cfs and greater, lower survival was associated with tests done at low flows near 600 cfs, and more variable results were obtained at intermediate flows. Because only a limited number of smolt survival estimates were used in the development of the Tuolumne River Technical Advisory Committee (TRTAC) smolt survival relationship (TID/MID 2005, Report 2004-7), estimation of smolt survival at intermediate and high flows is not feasible. Further, survival of wild smolts may not be well represented by experimental results on large releases of hatchery reared fish. In addition to the behavioral differences between hatchery and wild counterparts (Berejikian and Ford 2004), other concerns regarding representing smolt survival from the existing TRTAC smolt survival relationship are related to biases from the “swamping” effects that large numbers of CWT fish may have on predation and the resulting survival estimates (Fritts and Pearsons 2008).

Because season wide estimates of outmigration survival in recent RST reports (2008–2012) are on the order of 4–21% (TID/MID 2013, Report 2012-4), well below that suggested by the TRTAC smolt survival relationship, additional examination of RST passage at Waterford (RM 29.8) and Grayson (RM 5.2) was conducted to further evaluate apparent smolt survival relationships with flow (Attachment C). Overall, the analysis indicates lower survival than the TRTAC smolt survival relationship over a range of flows, consistent with patterns in lower relative smolt passage between the upstream and downstream traps exhibited in RST monitoring reports. To provide consistency with RST data used in model fitting, a linear flow-survival relationship fitted to RST data (Equation 8) was selected for modeling smolt outmigration survival (Attachment C). In order to represent predation mortality of outmigrant smolts emigrating from different portions of the lower Tuolumne River, discharge-specific survival (S_{RST}) between the RST locations (RM 29.8 to RM 5.2) as a function of flow (Equation 8) was converted to a survival estimate per unit distance (S_D) travelled (Equation 9).

$$S_{RST} = \min(0.03287 + 2.347 \times 10^{-5} \times Q_{LaGrange}, 1) \qquad \text{Equation 8}$$

$$S_D = e^{-mD}, \text{ where } m = -\frac{\log S_{\mathrm{RST}}}{29.8-5.2} \qquad \text{Equation 9}$$

In addition to predation mortality discussed above, water temperature related mortality for Chinook salmon smolts is the same as presented for Chinook salmon juveniles above (Section 4.1.4.4). Based upon information reviewed for Chinook salmon juvenile mortality (Brett 1952), an initial mortality threshold of 25°C (77°F) was selected for Chinook salmon smolts as a daily average water temperature.

4.2 Model Implementation

The Tuolumne River Chinook population model is implemented within the publicly available "R" statistical software package (R Development Core Team 2008) with data and parameter inputs as well as outputs formatted as MS Excel spreadsheets. The model uses a generalized multi-stage stock production approach (Baker 2009) in which starting numbers of a particular life-stage (stock) are mathematically modeled to predict how the numbers change as the cohort goes through subsequent life stages. Each life stage is represented in the stock-production model as a data frame, with one record per individual, having attribute fields as presented in Table D-1 (Attachment D). However, because the numbers of individuals within the fry, juvenile, and smolt life stages are very large, it is not computationally practical to model every individual. In these cases, a large random sample of typical individuals is drawn from the population, and these are tracked; their outcomes are then extrapolated to the entire population of the subsequent life stage. The size of this sample is selectable as a user-provided parameter, independent of the population size; the default values used for the results presented in this document are 50,000 swim-up fry, 10,000 parr, and 5,000 smolts.

The stock-production models developed for each life stage are discussed in the following sections, with parameters in the form of discrete numbers or ranges that are dependent upon the attributes of an individual within the larger population. For example, fecundity may be dependent upon the age of an individual spawner. The model also includes random elements for many mechanisms affecting life history progression, relying on probability distributions for events such as upmigration timing, individual spawner age, spawning locations, fry and juvenile movements, predation related mortality, as well as size at emigration. Each stock production model also makes use of temporally and spatially varying environmental conditions while determining the progression of individuals within their respective life stages and promotion into the next life stage. For example, depending upon the spatial and temporal resolution of the discharge and water temperature time series data provided (e.g., discharge and water temperature data, output from *Operations Model*, output from *Water Temperature Model*), an interplolation module is employed to provide discharge and water temperature estimates at more specific locations and times through interpolation. As the simulation for each modeled individual progresses through time, the stock-production model queries the discharge and water temperature module to help define environmental conditions within a certain area on any given day. Several of the stock-production models also gather information from a "habitat generator" module (output defined in Attachment D, Table D-2), a set of flow-dependent habitat suitability models (which also retrieve information from the discharge and water temperature module). All input data for these environmental modules can be linked to historical environmental data records to provide opportunities for model validation. In addition, synthetic historical data from the *Project Operations/Water Balance Model* (W&AR-2) as well as the *Lower Tuolumne River Temperature Model* (W&AR-16) may be used to examine the potential effects of various operational scenarios. Below, individual stock production models are described along with their associated model parameters.

4.2.1 Adult Upmigration and Spawning

The adult upmigration and spawning stock-production model essentially follows the progression of a spawner life stage into a redd life stage and a carcass life stage. This model draws upon information from the following sources:

(1) spawner population data,
(2) the spawning habitat generator,
(3) the discharge and water temperature module, and
(4) a list of parameters (Table 4-1)

Table 4-1. Parameters and Associated References for Upmigration and Spawning

Parameter		Range (selected value)	Description	Reference
migration.rate		2–30 mi/day (1 mi/day)	rate at which adults move upstream from the weir to spawning gravels	Weir passage (TID/MID 2013, Rpt. 2012-7), redd counts (TID/MID 2011, Rpt. 2010-1), Strange 2010; Goniea et al 2006
fecundity	age 2	3425 eggs	number of fertile eggs produced by a successful female spawner	TID/MID 1992, App 1; Loudermilk et al 1990 as cited in TID/MID 1992, App 8
	age 3	5964 eggs		
	age 4	7524 eggs		
	age 5	7963 eggs		
male.surv.time		7–21 days (21 days)	time from arrival at spawning gravels to death	Sockeye salmon (Morbey et al 2005)
female.surv.time		7–21 days (21 days)	time from arrival at spawning gravels to death, unless able to construct a redd	Sockeye salmon (Morbey et al 2005)
spawn.wtemp.max		16–18.9°C (16°C)	maximum temperature at which spawning habitat will be considered usable by spawners	Groves and Chandler 1999, McCullough 1999
redd.disturb.area		24–172 ft^2 (52 ft^2)	area of region excavated by a spawning female	TID/MID 1992, App 6; Burner 1951; Chapman 1943
redd.defense.area		96–688 ft^2 (214 ft^2)	defended area excluding later arriving spawners (~ 4x redd disturbance area)	Burner, 1951
redd.defense.time		7–25 days (7 days)	time female will prevent other spawners from disturbing her redd	Neilson and Banford 1983; TID/MID 1992, App 6; TID/MID 1997, Report 96-6

The model must be provided with a "spawning run", represented by a table having one row per spawner and specifying such things as the date and river mile at which each spawner is considered to enter the population, gender, and age or size. This table can be based on data from the counting weir (RM 24.5) or synthesized from summary statistics such as the total run size, age composition, fraction of females, and the mean and standard deviation of arrival times.

The spawning habitat generator defines the suitability of spawning habitat at a specific location and time. Using functional relationships described in Section 4.1.1.1, the spawning habitat sub-model calculates temporally and spatially varying availability of suitable spawning gravels and assigns spawner usage probability based upon an MS Excel table of gravel feature areas, gravel quality, and spawner preferences by river mile and discharge. It also queries the discharge and water temperature module to obtain discharge and water temperature. Each spawner is assigned to a discrete gravel feature on the basis of the area and preference value for the feature at the time the spawner enters the population. Migration rates are provided in Table 4-1. Mortality during migration to the assigned feature is assumed to be negligible (Section 4.1.1.3), and spawning preferences are assumed not to change significantly on the time-scale of the migration.

Once an upmigrant spawner reaches its assigned feature, it is assumed to stay there. Males are assumed to die a fixed number of days after arrival, and females are assumed to die a fixed number of days after arrival only if they are unable to find room to construct a spawning redd. A female which is able to construct a redd is assumed to die after a fixed number of days defending the redd. If a female dies before spawning, her eggs are assigned to her carcass for tracking purposes, otherwise the eggs are assigned to her redd according to the spawner size at age (Table 4-1). The associated numbers of redds and carcasses produced by the model allow for validation or calibration from corresponding redd and carcass surveys.

The model keeps track of the gravel occupancy by spawners and redds over the course of a spawning season. Whenever a new spawner arrives or a redd location becomes undefended, the area of usable gravel for each feature is updated. Pending spawners are then allowed to build redds as long as there is room to accommodate them, and larger spawners are given priority. When a new redd is constructed in a gravel feature, it is assumed to disrupt a fraction of the undefended gravels in the feature, and destroy this same fraction of the eggs in undefended redds (TID/MID 1992, Appendix 6).

4.2.2 Egg Incubation and Fry Emergence

The Egg Incubation and Fry Emergence stock-production model follows the progression of a redd life stage into a swim-up life stage. This model draws upon information from the following sources:

(1) the adult upmigration and spawning stock-production model output,
(2) the discharge and water temperature module,
(3) results of the spawning habitat generator, and
(4) a list of parameters (Table 4-2)

Table 4-2. Parameters and Associated References for Egg Incubation and Fry Emergence

Parameter	Range (selected value)	Description	Reference
gravel.qual	0–100% (32%)	egg survival to fry emergence due to gravel quality effects upon intra-gravel conditions	TID/MID 1992, Appendix 8; Jensen et al 2009
embryo.uuilt	13.9–15.6°C (14.4 °C)	temperature at which mortality increases from 0% to 100%	Seymour 1956; USFWS 1998; Rich 2007

From these data sources, the model predicts the dates of alevin swim-up on the basis of fertilization dates (i.e. redd construction dates) provided by the adult upmigration and spawning stock-production model and water temperatures from the discharge and water temperature module. Using relationships described in Section 4.1.2, the model tracks development of individual eggs as a function of temperature as well as tracking egg and alevin mortality attributable to excessive temperatures, gravel quality, and redd superimposition. An individual becomes a “swim-up fry” once it successfully emerges from the gravels.

4.2.3 Fry Rearing

The Fry Rearing stock-production model follows the progression of a swim-up life stage into a parr life stage or a dead fry life stage. Additionally, it tracks the movement of fry past landmarks using the passage fry life stage. This stock-production model draws upon information from the following sources:

(1) the egg incubation and fry emergence stock-production model,

(2) the discharge and water temperature module,
(3) the fry habitat generator, and
(4) a list of parameters (Table 4-3)

Table 4-3. Parameters and Associated References for Fry Rearing

Parameter	Range (selected value)	Description	Reference
length.swimup	32–38 mm (33 mm)	fork-length at swim-up	TID/MID 2007, Report 2006-7
fry.emigrate.p	0.3	fraction of swim-ups assumed to leave the river entirely	Fitted to RST data by date (TID/MID unpublished)
fry.displace.rate	0.05 days^{-1}	instantaneous rate at which fish will become displaced	Fitted to seine/RST data (TID/MID unpublished) by RM/date
fry.displace.time.mean	0.0208 days	mean interval between time a fish is displaced and time it becomes re-established	
fry.displace.time.CV	1	coefficient of variation of displacement time	
fry.density	1.496 ft^{-2}	maximum fry rearing density	Historical maximum from seine haul data (1989, 1999, 2003) (TID/MID unpublished)
Rf	0.7, 0.3	feeding ration fraction as proportion of maximum	TID/MID 1997, Report 96-9, Sommer et al 2001, Jeffres et al 2008
fry.migr.mrate	5.408 days^{-1}	mortality rate applied to fry moving downstream	Fitted to RST passage data (TID/MID unpublished)
fry.mrate	0.002 days^{-1}	mortality rate applied to all fry	Bartholow and Henriksen 2006
fry.uuilt	24–25°C (25°C)	temperature at which mortality increases from 0% to 100%	Brett 1952; Orsi 1971; McCullough 1999
length.parr	50 mm	fork-length at parr	Operational size class (TID/MID 2013, Report 2012-4)

Following the emergence of swim-up fry, as simulated by the egg incubation and fry emergence stock-production model, this stock-production predicts the dates of parr promotion (attainment of a given fork length) on the basis of emergence dates, water temperatures, and feeding rations in various locations along the lower Tuolumne River. The fry habitat generator defines daily in-channel and floodplain habitat suitability based upon discharge and water temperature. It draws upon a user-provided table of reach-specific estimates of mortality rates, feeding ration levels, fry densities, and flow-dependent velocities and useable habitat areas. It receives discharge and water temperature values from the discharge and water temperature module. Using relationships discussed in Section 4.1.4, the model simulates fry growth at a daily times step as a function of its current fork length, the water temperature at its current location, and a measure of food availability in its current reach.

The model tracks the redistribution of fry from the spawning gravels to downstream habitat (in some cases out of the system), on the basis of discharge and habitat usage. Upon emergence from the gravels, some fraction of the new swim-ups is assumed to emigrate from the river entirely. This fraction is given by the parameter “p.emigrate.” As the model progresses through time, the remaining swim-ups and any rearing fry in excess of the current carrying capacity of the reach they are in (defined as exceedance of the user-defined reach density within usable habitat areas for the reach), are assumed to be displaced. These fry are carried downstream for a random length of time, implemented as a lognormal deviate whose mean and coefficient of variation are provided by the user (as parameters “displace.time.mean” and “displace.time.CV”, respectively). All fry (both “emigrant” and “temporarily displaced”) are subjected to “migration mortality” for as long as they are in motion. This is intended to represent predation. In addition, all fry are subjected to “background mortality”, intended to account for things like disease or avian predation and to immediate death if temperatures exceed a critical value. The model reports the passage of weir-specified landmarks, such as, the RSTs of Waterford (RM 29.8) and Grayson (RM 5.2) as the pseudo-life stage of “passage fry”, and exit from the mouth of the Tuolumne River as the lifestage “emigrant fry.” In addition to water temperature (Table 4-3), reach-specific estimates of mortality probability per unit time are based upon estimates from juvenile passage at the upstream and downstream RSTs (Section 4.1.3.4). Fry which die or leave the Tuolumne River before attaining parr status are labeled as a dead fry and are passed into the dead fry life stage.

4.2.4 **Juvenile Rearing**

The Juvenile Rearing stock-production model follows the progression of a parr life stage into a smolt-ready life stage or a dead parr life stage. It also tracks the movement of juvenile Chinook past landmarks with the passage juvenile life stage. The juvenile rearing model is very similar to the fry rearing model, but it is represented as a separate life stage because juveniles have somewhat different habitat requirements from fry. Juveniles are strong swimmers, already established in rearing habitat, so dispersal is modeled as a less important a mechanism. This stock-production model draws upon information from the following sources:

(1) results of the Fry Rearing stock-production model,
(2) the discharge and water temperature module,
(3) the juvenile habitat generator, and
(4) a list of parameters (Table 4-4)

Table 4-4. Parameters and Associated References for Juvenile Rearing

Parameter	Value	Description	Reference
juv.displace.rate	0.01 $days^{-1}$	instantaneous rate at which fish will become displaced	Fitted to seine/RST data by RM/date (TID/MID unpublished) by RM/date
juv.displace.time.mean	0.0833 days	mean interval between time a fish is displaced and time it becomes re-established	
juv.displace.time.CV	1	coefficient of variation of displacement time	
juv.density	0.465 ft^{-2}	Maximum fry rearing density	USFWS (1991) Trinity River snorkel data
Rf	0.7, 0.3	feeding ration fraction as a proportion of maximum	TID/MID 1997, Report 96-9, Sommer et al 2001, Jeffres et al 2008
juv.migr.mrate	0.1386 $days^{-1}$	aquatic predation rate due to downstream movement	Fitted to RST passage data (TID/MID unpublished)
juv.mrate	0.002 $days^{-1}$	background mortality rate due to disease, stranding, avian predation, and entrainment	Bartholow and Henriksen 2006
smolt.fraction	0.9	proportion of juveniles becoming smolts	Approximation based upon summer rearing population estimates (Stillwater Sciences 2008, 2009, 20011, 2012)
smolt.promotion.jday	151 days	last day (from 1 January) that smolting can occur in the spring	Operational threshold (not used)
length.smoltmin	70 mm	minimum size threshold for smolting	Operational size class (TID/MID 2013, Report 2012-4)
length.smoltmu	83.46 mm	Median size of smolts passing RSTs	Size distributions from 2006–2012 RST data (TID/MID unpublished)
	0.0018 mm/cfs	Estimated size increase by flow	
length.smoltsd	7.63 mm	coefficient of variation of smolt size	
length.smoltmax	120 mm	maximum size threshold before smolting	Upper estimate in RST reports (e.g., TID/MID 2013, Report 2012-4)
juvenile.uuilt	24–25°C (25°C)	temperature at which mortality increases from 0% to 100%	Brett 1952; Orsi 1971; McCullough 1999

This stock-production model tracks groups of Chinook juveniles from their promotion to parr status until they emigrate out of the system, attain smolt status, or die, all the while making note of landmark passages such as the RSTs at Waterford (RM 29.8) or Grayson (RM 5.2). The juvenile habitat generator defines daily in-channel and floodplain habitat suitability based upon discharge and water temperature. It draws upon a user-provided table of mortality rates, feeding ration levels, maximum fry and juvenile densities, as well as flow-dependent useable habitat areas by reach. It receives discharge and water temperature values from the discharge and water temperature module. The model predicts the dates of smolt-ready promotion (attainment of a given fork length) using growth relationships on the basis of parr promotion dates, and growth estimated from water temperatures and feeding rations (Section 4.1.4.3). During each time step (one day), each juvenile grows by an increment determined from its current fork length, the water temperature at its current location, and a measure of food availability in its current reach.

The model tracks the redistribution of juveniles on the basis of discharge and habitat usage, as well as juvenile emigration. The model tracks individuals as they pass any of a number of user-specified landmarks such as the RSTs. Mortality during any movements or redistribution is estimated by exposure to predation and excessive temperatures. As the model simulation progresses through time, juveniles in excess of the current carrying capacity of the reach they are in (defined as exceedance of the user-defined reach density), are assumed to be displaced. These juveniles are carried downstream for a random length of time, implemented as a lognormal deviate whose mean and coefficient of variation are provided by the user (as parameters "displace.time.mean" and "displace.time.CV", respectively). In addition to water temperature (Table 4-4), reach-specific estimates of mortality probability per unit time are based upon estimates from juvenile passage at the upstream and downstream RSTs (Section 4.1.4.4). Juveniles which die or leave the Tuolumne River before attaining smolt status are labeled as a dead juvenile and are passed into the dead juvenile life stage.

Smoltification of rearing juveniles is based upon attainment of a minimum size threshold (parameter "length.smoltmin") with the probability that a smolt-ready individual will smolt based upon fish size relative to typical distributions of size at emigration developed in Section 4.1.5.1. The model uses a truncation of the tails of the size distribution, with any fish reaching the maximum size ("length.smoltmax") being automatically promoted to smolts. Rather than applying temperature limits for smoltification, the model assumes a fixed proportion of smolt-ready individuals ("smolt.fraction") will continue rearing (i.e., over-summer) to become yearling smolts in the following year.

4.2.5 Smolt Emigration

The Smolt Emigration stock-production model follows the outmigration of a smolt life stage from the Tuolumne River, tracking movements of smolts past landmarks. This stock-production model draws upon information from the following sources:

(1) results of the Juvenile Rearing stock-production model,
(2) the discharge and water temperature module, and
(3) a list of parameters (Table 4-5)

Table 4-5. Parameters and Associated References for Smolt Emigration

Parameter	Value	Description	Reference
smolt.uuilt	24–25°C (25°C)	temperature at which mortality increases from 0% to 100%	Brett 1952; Myrick and Cech 2001, McCullough 1999
smolt.surv.rstreach.byq	0.00002347/cfs	fitted slope of survival from Waterford (RM 29.8) to Grayson (RM 5.2)	RST data (e.g., TID/MID 2013, Report 2012-4) estimates of flow vs. survival (Attachment C)
	0.03287	fitted intercept of survival at zero flow	

Mortality during smolt emigration is estimated by exposure to predation and excessive temperatures. In addition to water temperature mortality thresholds (Table 4-5), reach-specific estimates of mortality probability per unit distance and discharge are based upon estimates from juvenile passage at the upstream and downstream RSTs (Section 4.1.5.2).

4.3 Model Calibration and Validation

As described in the Study Plan, calibration and validation was conducted by comparisons of modeling results of fry and/or smolt production with annual production estimates available from RST sampling conducted in the lower Tuolumne River. Some model mechanisms and functional relationships discussed in Section 4.2 have been studied in detail, under controlled conditions, and the appropriate values for the relevant model parameters (Section 4.2) are constrained by experimental data. Other relationships are purely empirical, or based on simple models, and use parameter values constrained only loosely by "common sense" arguments. The calibration and validation phase of the model has two purposes: 1) to fine-tune the less well constrained parameter values in order to maximize the agreement between the model and monitoring data, and 2) to examine the degree to which the modeled mechanisms account for the year-to-year variability in these data. Two sources of data were used, RST sampling as well as river-wide seining data.

4.3.1 **Calibration to recent RST data**

The most recent RST data collected in the Tuolumne River were used as the primary data source to calibrate the model, including the 2010, 2011, and 2012 sampling seasons. The rationale for using data from these years is that they overlap the period of operation for the counting weir (RM 24.5) as well as recent mapping efforts conducted as part of the *Redd Mapping Study* (W&AR-8). For these years, weir passage data were reviewed to ensure the adult upmigration and spawning stock-production model (Section 4.2.1) was provided with well constrained numbers, sizes, arrival dates of spawners, as well as spawning dates. Subsequent stock-production models for egg incubation through juvenile rearing and emigration allow prediction of fork-lengths, and passage dates of fish passing the RST monitoring locations as fry, juveniles, and smolts. These model quantities correspond precisely to the data collected in annual RST monitoring reports. A data quality review for RST passage data (Attachment C) was used to re-estimate juvenile Chinook salmon passage for the period 2007–2012 to ensure the best available data were available for model calibration. Using parameter estimates for upmigration, spawning, egg incubation, and fry rearing (Table 4-1 through 4-3), fry passage at Waterford (RM 29.8) and Grayson (RM 5.2) was fit through adjustment of movement related parameters (fry.emigrate.p, fry.displace.rate, fry.displace.time) as well as mortality (fry.mrate and fry.migration.mrate). Because downstream movement of juveniles is assumed to be slower than for fry, smolt passage was fit through adjustment of juvenile mortality related parameters only (juv.mrate and juv.migration.mrate). Smolt survival parameters (smolt.surv.rstreach.byq) developed from the updated flow survival relationship in Attachment C were not adjusted during calibration.

4.3.2 **Validation to historical RST data not used in model calibration**

Following calibration to recent RST data, model validation was conducted by comparing modeling results for other years of paired RST operations that were not included in the calibration. As discussed in the Synthesis Study (W&AR-5), paired RST monitoring has been conducted at the Waterford (RM 29.8) and Grayson (RM 5.2) locations since 2006 with only partial sampling of the Grayson location occurring in 2007. Although no upstream passage information exists prior to installation of the RM 24.5 counting weir in September 2009, CDFW spawner count information for escapement years 2005–2008 was used in the model to estimate juvenile production for the corresponding outmigration years (2006–2009) and compared to RST production estimates.

4.3.3 Validation using historical seining data

Because existing RST data only provide direct information at two locations (RM 29.8, RM 5.2), and only for fish in motion, model validation was conducted using seining data corresponding to the outmigration occurring in the combined calibration and validation period (2007–2012). The model predicts the dates and locations at which fish are promoted from one life stage to another, for example, the dates and locations at which fry emerge from spawning redds, the dates and locations at which fry are promoted to parr status (FL >50mm), and the dates and locations at which smolt-ready juveniles (FL >70mm) undergo smoltification. These model results may be used to examine spatial and temporal patterns in the distributions of non-migrating fish rearing at various locations in the lower Tuolumne River–patterns that are observable in the historical seining data (Attachment B) and are primarily used to confirm assumptions and parameters affecting development rates (hence temporal patterns) as well as those related to movement and emigration rules (hence spatial patterns).

4.4 Sensitivity Analyses

Using hydrology for WY 2009 (Dry) and WY 2011 (Wet) and corresponding water temperature data, variations in juvenile production was examined using sensitivity testing by varying parameter values in the validated model. The sensitivity analysis consisted of making a large number of model runs, varying one parameter at a time. For each change in a particular parameter value, the model was used to recalculate the estimated juvenile production, holding all other values constant. Table 4-6 shows the thirty parameters that were selected for examination along with the calibrated value and the parameter range tested (i.e., Min, Max). Parameters excluded from sensitivity testing were of two types. First, some parameters have very subtle effects: for example, the model has a parameter representing the number of days a male will survive after it reaches the spawning grounds (male.surv.time), but this number has no effect at all on the rest of the life history (the model assumes that there are always enough males around to fertilize any redds constructed), and so is omitted from the sensitivity analysis. Second, some collections of parameters function together in such a way that it would be redundant to consider them all separately. For example, the number of eggs per spawner and the survival of embryos from fertilization to alevin swim-up are separate parameters, but only the product of the two has visible consequences, and so only the latter is varied in the analysis.

Table 4-6. Model parameters selected for sensitivity testing

Model Parameter	Description	Calibrated Value	Min Tested	Max Tested
Upmigration and Spawning				
spawn.wtemp.max	maximum temperature for spawning (C)	16	14	18
redd.disturb.area	area reworked by redd construction (ft2)	52	13	208
redd.defense.time	redd defense time (d)	7	4	14
Egg Incubation and Fry Emergence				
embryo.development	number of "weighted thermal units" from fertilization to swim-up	1	0.5	1.5
embryo.survival	egg survival-to-emergence	0.32	0.16	0.64
embryo.uuilt	upper incipient lethal temperature for egg/alevin (C)	14.44	12	16
Fry Rearing				
fry.emigrate.p	fraction of fry emigrating at swim-up	0.3	0.2	0.4
fry.displace.time.mean	mean duration of fry displacement (d)	0.02	0.01	0.04
fry.ration (in-channel)	fry in-channel feeding ration levels (% max)	0.7	0.4	1
fry.ration (floodplain)	fry floodplain feeding ration levels (% max)	0.7	0.4	1
fry.density (in-channel)	fry in-channel rearing densities (#/ft2)	1.496	0.374	5.984
fry.density (floodplain)	fry floodplain rearing densities (#/ft2)	1.496	0.374	5.984
fry.uuilt	upper incipient lethal temperature for fry (C)	25	17	25
fry.mrate (in-channel)	fry in-channel background mortality rates (1/day)	0.002	0.001	0.004
fry.mrate (floodplain)	fry floodplain background mortality rates (1/day)	0.002	0.001	0.004
fry.migr.mrate	fry migration mortality rates (1/day)	2.704	1.352	5.408
Juvenile Rearing				
juv.displace.time.mean	mean duration of juvenile displacement (d)	0.0833	0.04165	0.1666
juv.ration (in-channel)	juvenile in-channel feeding ration levels (% max)	0.7	0.4	1
juv.ration (floodplain)	juvenile floodplain feeding ration levels (% max)	0.7	0.4	1
juv.density (in-channel)	juvenile in-channel rearing densities (#/ft2)	0.464	0.116	1.856
juv.density (floodplain)	juvenile floodplain rearing densities (#/ft2)	0.464	0.116	1.856
juvenile.uuilt	upper incipient lethal temperature for juveniles (C)	25	17	25
juv.mrate (in-channel)	juvenile in-channel background mortality rates (1/day)	0.002	0.001	0.004
juv.mrate (floodplain)	juvenile floodplain background mortality rates (1/day)	0.002	0.001	0.004
juv.migr.mrate	juvenile migration mortality rates (1/day)	0.1386	0.0693	0.2772
length.smoltmu (intercept)	size at smoltification (zero discharge) (mm)	83.46362	75	90
length.smoltmu (slope)	size at smoltification as a function of flow (mm/cfs)	0.001833	0.001	0.003
Smolt Emigration				
smolt.uuilt	upper incipient lethal temperature for smolts (C)	25	17	25
smolt.surv.byq (intercept)	smolt survival between RM 29.5 and RM 5.2 RSTs at zero discharge (dimensionless)	0.03287	0	0.1
smolt.surv.byq (slope)	smolt survival between RM 29.5 and RM 5.2 as a function of flow (1/cfs)	2.35E-05	1.17E-05	4.69E-05

Parameters ranges shown in Table 4-6 may be varied as a proportion as shown in the Study Plan (e.g., ± 25% of initial value) or may be varied across a typical range. For sensitivity testing, the typical range approach was used for most parameters (e.g., UUILT), but the proportionate approach was used when a typical range could not be identified from existing Tuolumne River data or the literature (e.g., fry.mrate, fry.migr.mrate, juv.mrate, juv.migr.mrate). Lastly, although key model input variables are not directly assessed through sensitivity testing (e.g., flow, spawning population size), sensitivity testing was conducted using the WY 2009 (Dry) and WY 2011 (Wet) hydrology and over two run sizes representing low (200 females) and high (10,000 females) escapement.

4.5 Evaluation of Juvenile Chinook salmon Production under Current and Potential Future Project Operations Scenarios

Using the parameterized and validated model, juvenile Chinook salmon production was estimated under "base case" conditions contained in the *Project Operations/Water Balance Model Study* (W&AR-2). The "base case" depicts the operation of the Project in accordance with the current FERC license, ACOE flood management guidelines, and the Districts' irrigation and M&I water management practices since completion of Don Pedro Dam in 1971. For the purposes of this study, the base case hydrology represents instream flow conditions downstream of La Grange Dam for Chinook salmon spawners arriving from the fall of 1971 through juvenile outmigration occurring in the spring of 2009, with accompanying water temperature estimates provided by the *Reservoir Temperature Model* (W&AR-03) and *Lower Tuolumne River Temperature Model* (W&AR-16) studies. The base case provides a thirty seven year time series of varying hydrology and meteorology to examine variations in juvenile salmon production under a variety of water year types as well as to provide a basis of comparison for any alternative operating scenarios.

For the base case hydrology and water temperature data, juvenile Chinook salmon production was estimated at three levels of spawning escapement: 200 female spawners (Low), 2,000 females (Medium), and 10,000 females (High). Using long-term averages of run timing, run composition (age, sex ratio), and spawner fecundity, variations in juvenile Chinook salmon production metrics were evaluated for the simulation period. Production metrics include river-wide fry passage at the San Joaquin River confluence (RM 0.0), as well as smolt passage at RM 0.0 divided by the number of female spawners.

5.0 RESULTS

5.1 Model Calibration

Model calibration was conducted using RST data collected in the 2010, 2011, and 2012 sampling seasons. Modeled fry and smolt passage for each of the outmigration years above are plotted in Figure 5-1 through Figure 5-3, respectively, along with daily juvenile passage estimates from the RSTs. Since the absolute number of fry or smolts passing Waterford (RM 29.8) should primarily reflect production of fry or smolts upstream of this location, patterns in seasonal passage were used to assess the adequacy of the model growth, rearing, and survival mechanisms. That is, temporal patterns of fry and smolt passage at Waterford (RM 29.8) should primarily reflect growth rates, parameters and criteria used to simulate promotion from one life stage to the next. For the three years used in calibration, modeled fry passage timing occurred earlier in 2010 than corresponding RST passage estimates (Figure 5-1), with greater overlap in model- and RST-based estimates occurring in 2011 (Figure 5-2) and 2012 (Figure 5-3). Model estimates of smolt passage timing at Waterford (RM 29.8) and Grayson (RM 5.2) corresponded to estimates of RST passage at these locations in all three years. Annual smolt passage at the two trap locations over the three years used for calibration (2010–2012) is shown in Table 5-1 below along with corresponding model estimates. Although the three year sample size is too small to apply goodness-of-fit statistics, model predictions were close to RST passage estimates for emigrant fry and smolts at Grayson (RM 5.2), fry at Waterford (RM 29.8), but did not match smolt passage well at the Waterford location.

Table 5-1. Estimated Chinook salmon fry and smolt passage at Waterford (RM 29.8) and Grayson (RM 5.2) for 2010–2012

Outmigration Year	Waterford (RM 39.8)				Grayson (RM 5.2)			
	Fry		Smolt		Fry		Smolt	
	Model	RST	Model	RST	Model	RST	Model	RST
2010	12,220	10,595	5,325	62,876	874	92	811	1,964
2011	320,762	284,444	4,535	74,494	51,923	71,071	21,863	21,955
2012	50,185	29,907	44,349	24,601	1,494	72	3,976	2,186

The temporal patterns of fry and smolt passage at Waterford (RM 29.8) should primarily reflect growth rates, parameters and criteria used to simulate promotion from one life stage to the next. These patterns can therefore be used qualitatively to assess the adequacy of the model mechanisms for growth and development, and quantitatively to adjust the parameters used in these mechanisms. Although the lack of model fit for smolt passage at Waterford may be due to model assumptions regarding the fry movement and rearing locations, because the model predictions matched RST passage estimates for both fry and smolts at Grayson (RM 5.2) over a broad flow range, model calibration was accepted and a broader validation was conducted using data from outmigration years 2007–2009.

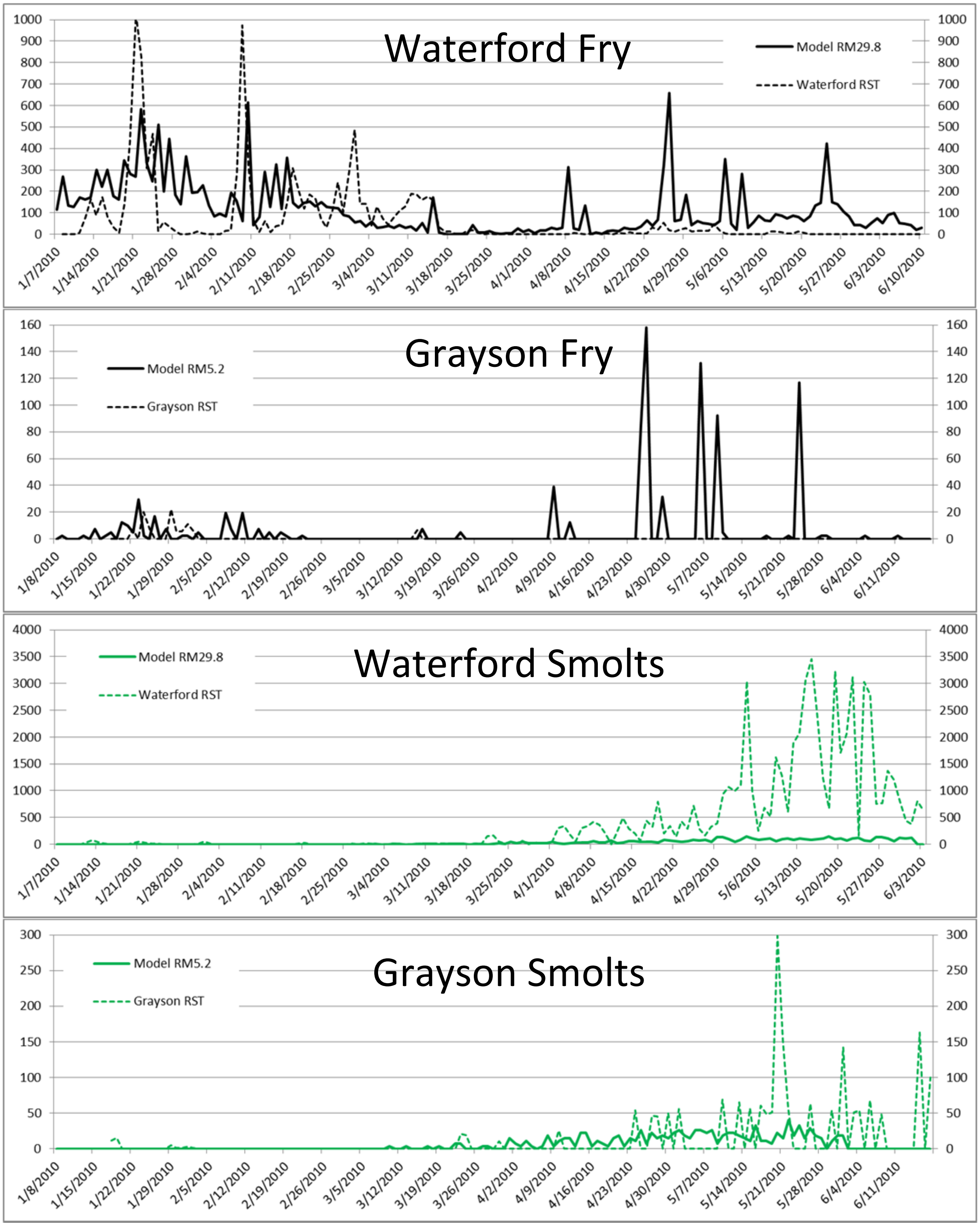

Figure 5-1. Model-based and RST based passage of Chinook salmon fry (upper panels) and smolts (lower panels) in the Tuolumne River during 2010.

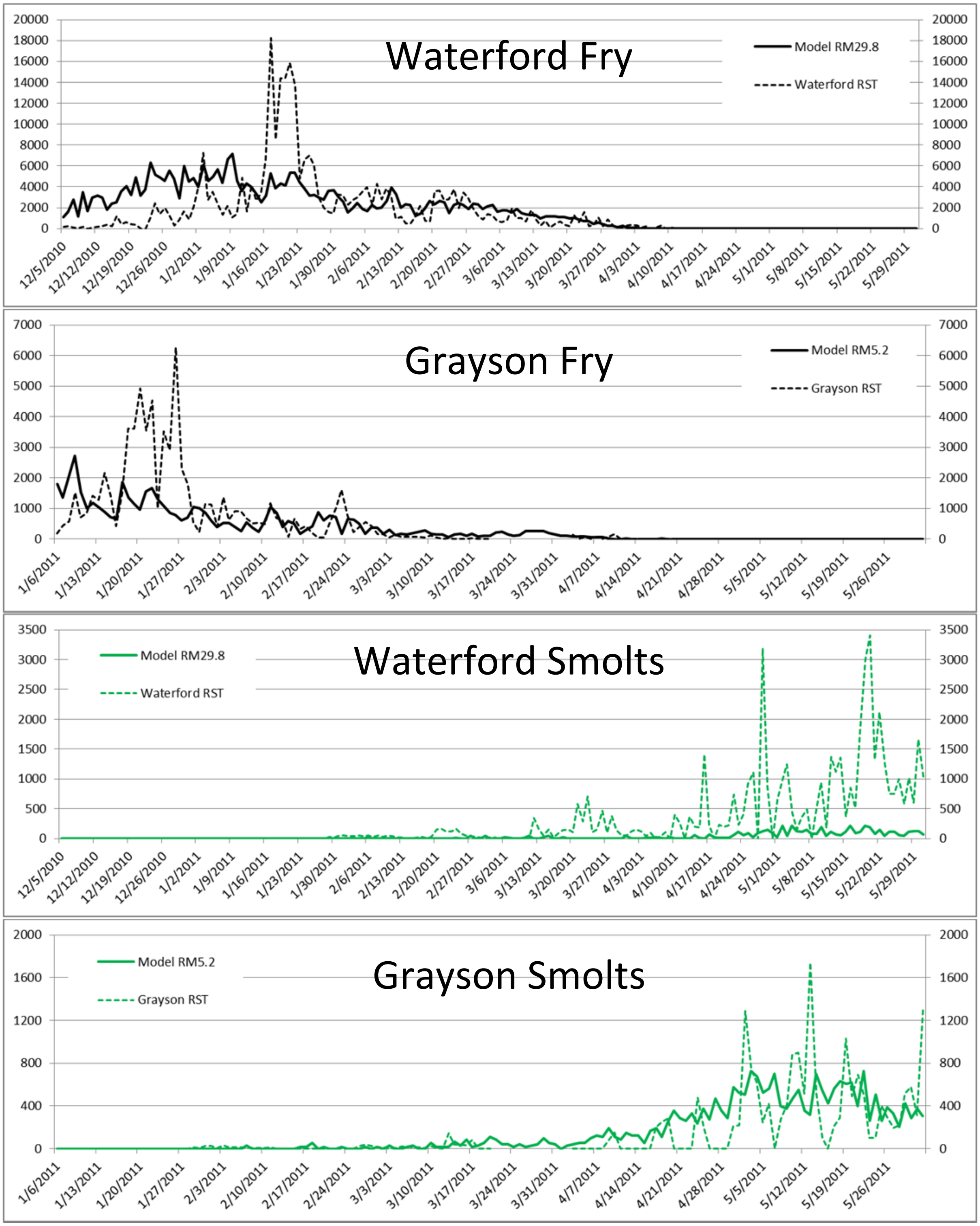

Figure 5-2. Model-based and RST based passage of Chinook salmon fry (upper panels) and smolts (lower panels) in the Tuolumne River during 2011.

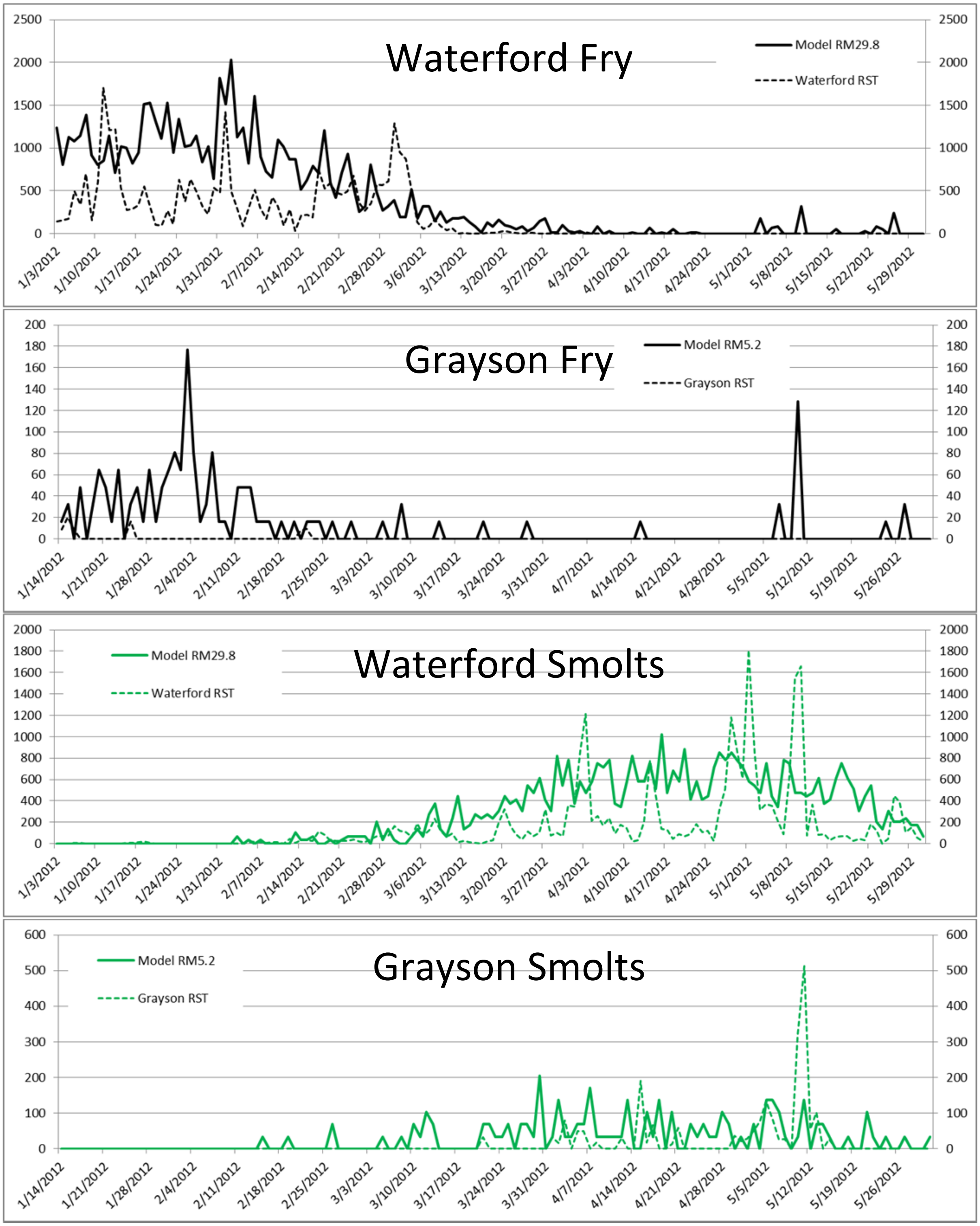

Figure 5-3. Model-based and RST based passage of Chinook salmon fry (upper panels) and smolts (lower panels) in the Tuolumne River during 2012.

5.2 Model Validation

Model validation was conducted using RST data collected in the 2007, 2008, and 2009 sampling seasons. Seasonal total fry and smolt passage estimates for the combined calibration and validation period (2007–2012) are in Figure 5-4 and Figure 5-5, respectively. For the validation period (2007–2009), instead of weir passage estimates at RM 24.5, upmigrant arrival timing at the spawning grounds was estimated from CDFW carcass survey data (Figure 4-2). Berceuse fry passage estimates at the Grayson (RM 5.2) RST are low in all years except for the high flow conditions occurring in 2011, Figure 5-4 shows an expected model fit across the combined calibration and validation periods (2008–2012). For smolts, Figure 5-5 shows greater variation occurring in years using redd count information and timing (i.e., 2008–2009 plus additional 2010 estimate from spawning survey data) than years using weir count information (2010–2012). A second estimate is also provided for 2010 that reflects a higher percent female estimate at the counting weir (TID/MID 2010, Report 2009-8) than those found in the CDFW spawning survey report (TID/MID 2011, Report 2010-1). Although the model represents variations in fry and smolt passage at Grayson well, the corresponding model fit (r^2=0.95) primarily reflects the influence of high passage estimates corresponding to extended high flow conditions during 2011, the XXX wettest year .

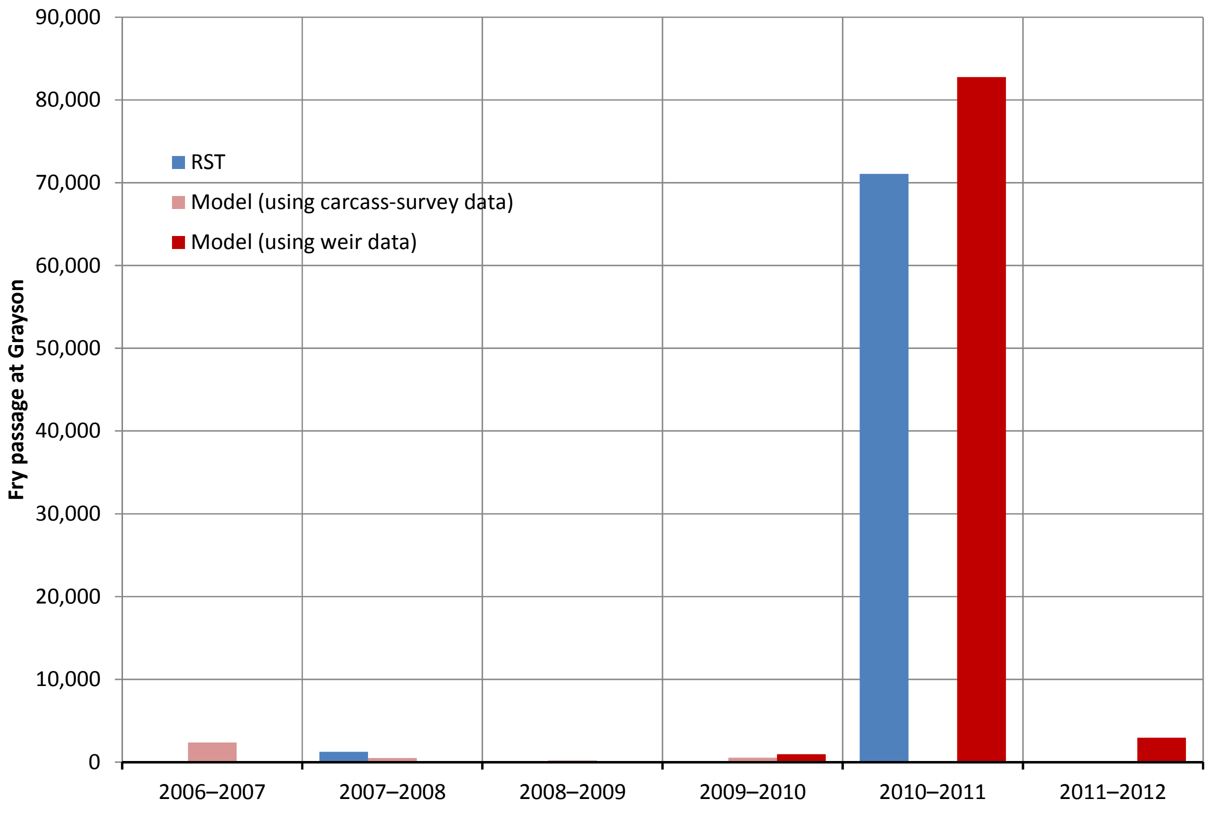

Figure 5-4. Seasonal Chinook salmon fry passage at Grayson (RM 5.2) using model-based and RST-based estimates (2007–2012).

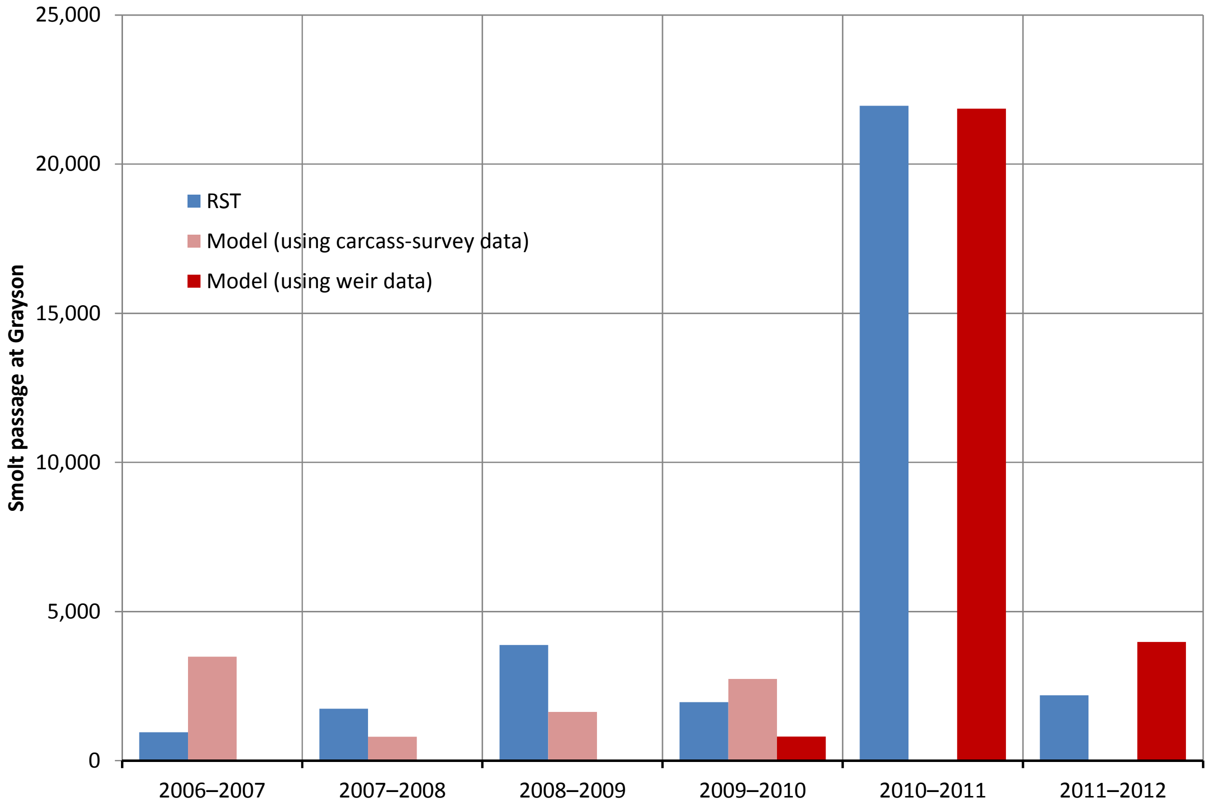

Figure 5-5. Seasonal Chinook salmon smolt passage at Grayson (RM 5.2) using model-based and RST-based estimates (2007–2012).

Based upon calibration and validation comparisons with RST data, additional validation was conducted by comparison of the spatial-temporal patterns predicted by the model with those found in historical seining data. Attachment C provides plots of seining density and fork lengths of Chinook salmon by location and date using seining data collected over eight survey sites along the river, sampled at two-week intervals (e.g., TID/MID 2013, Report 2012-3). Using modeled years representing lower and higher seasonal discharge corresponding to water year types occurring in 2008 (Dry) and 2011 (Wet), Figure 5-6 and Figure 5-7 show the seasonal distribution of juvenile Chinook salmon as swim-up fry (33 mm), parr (50 mm), and smolts (70 mm). Although not directly comparable to plots showing seine density in Attachment C (Figures B-11 and B-13), model results are consistent with upstream rearing in drier water years (Figure 5-6) and downstream displacement during wetter water year types (Figure 5-7).

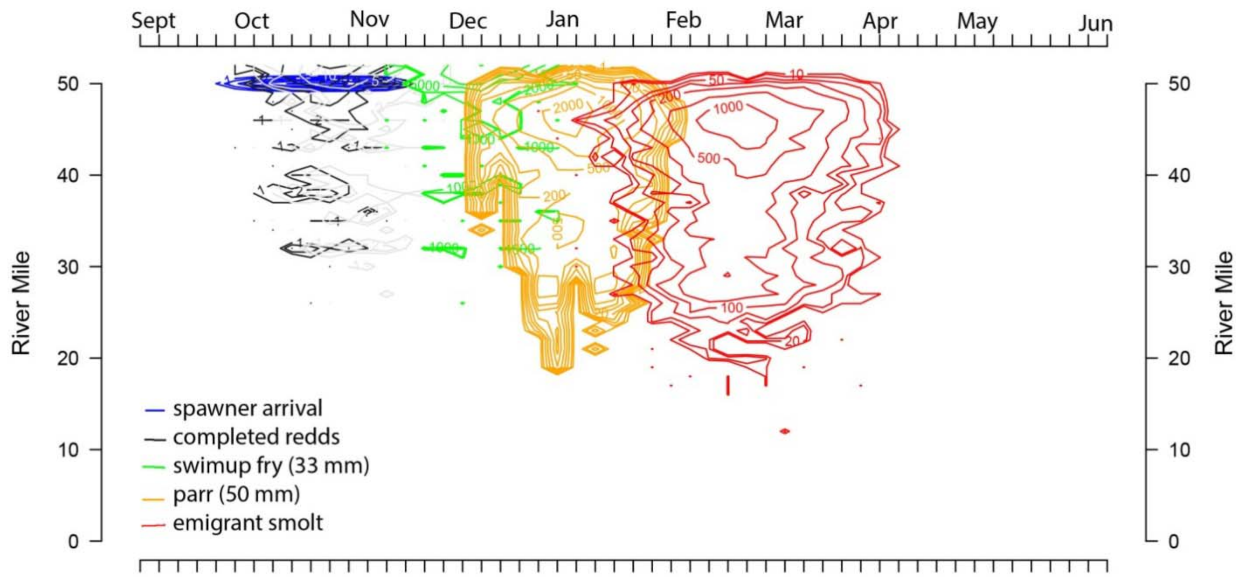

Figure 5-6. Modeled locations of swim-up fry (33 mm FL), parr (FL = 50 mm), and emigrant smolts in the Tuolumne River during WY 2009

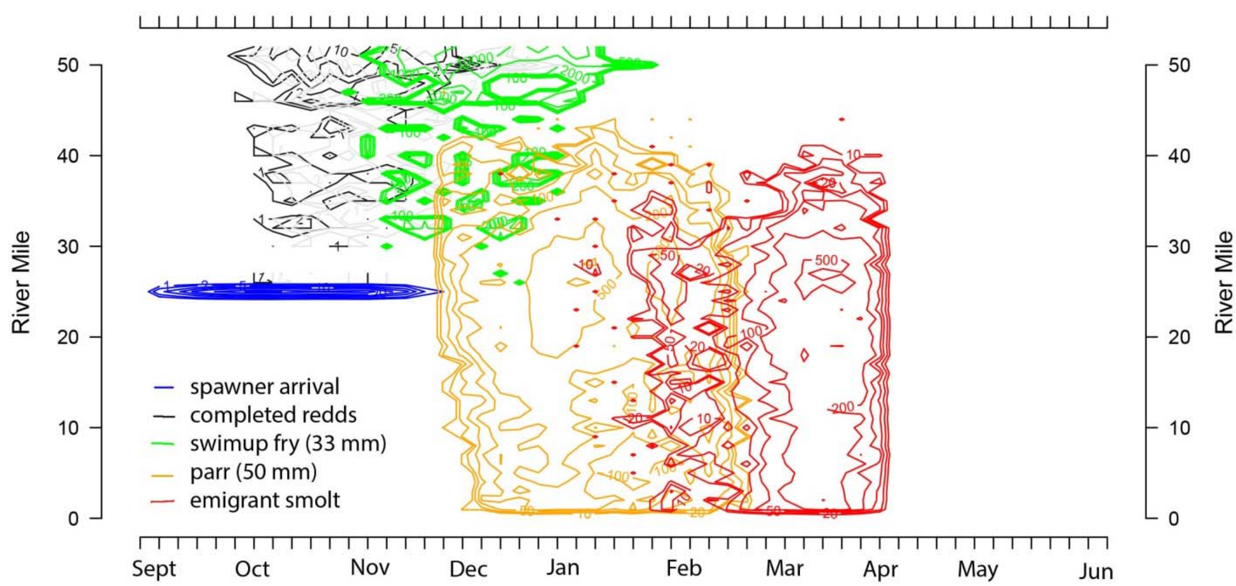

Figure 5-7. Modeled locations of swim-up fry (33 mm FL), parr (FL = 50 mm), and emigrant smolts in the Tuolumne River during WY 2011.

5.3 Sensitivity Analyses

Model sensitivity testing was conducted using the calibrated parameter values and ranges shown in Table 4-6. Four combinations of run size and hydrologic conditions were explored: a low escapement, dry year (200 female spawners, WY 2009 flows and water temperatures); a low escapement, wet year (200 female spawners, WY 2011 hydrology); a high escapement, dry year (10,000 females, WY 2009 hydrology); and a high escapement, wet year (10,000 females, WY 2011 hydrology). For each of these sixteen scenarios, and each of the thirty parameters, a model run was made at four parameter values across the ranges shown in Table 4-6. In all, 1,920 model simulations were performed. The metric used in the sensitivity tests was smolt productivity per spawner calculated as the ratio of the total number of smolts predicted to pass the mouth of the Tuolumne River (RM 0) divided by the contributing number of female spawners. Figure 5-8 shows the sensitivity test results as this smolt/spawner "productivity" metric shown with the calibration value for each parameter as a vertical black line and the results for each sensitivity test (i.e., alternate parameter value, WY and spawner scenario) connected by a horizontal or sloping colored line. Parameters exerting greater influence over the resulting variation in smolt productivity are shown with a greater slope above or below horizontal. For many of the parameters, however, the productivity line for each scenario is roughly horizontal, showing that the model is fairly insensitive to the exact value of the parameter selected across the ranges in Table 4-6.

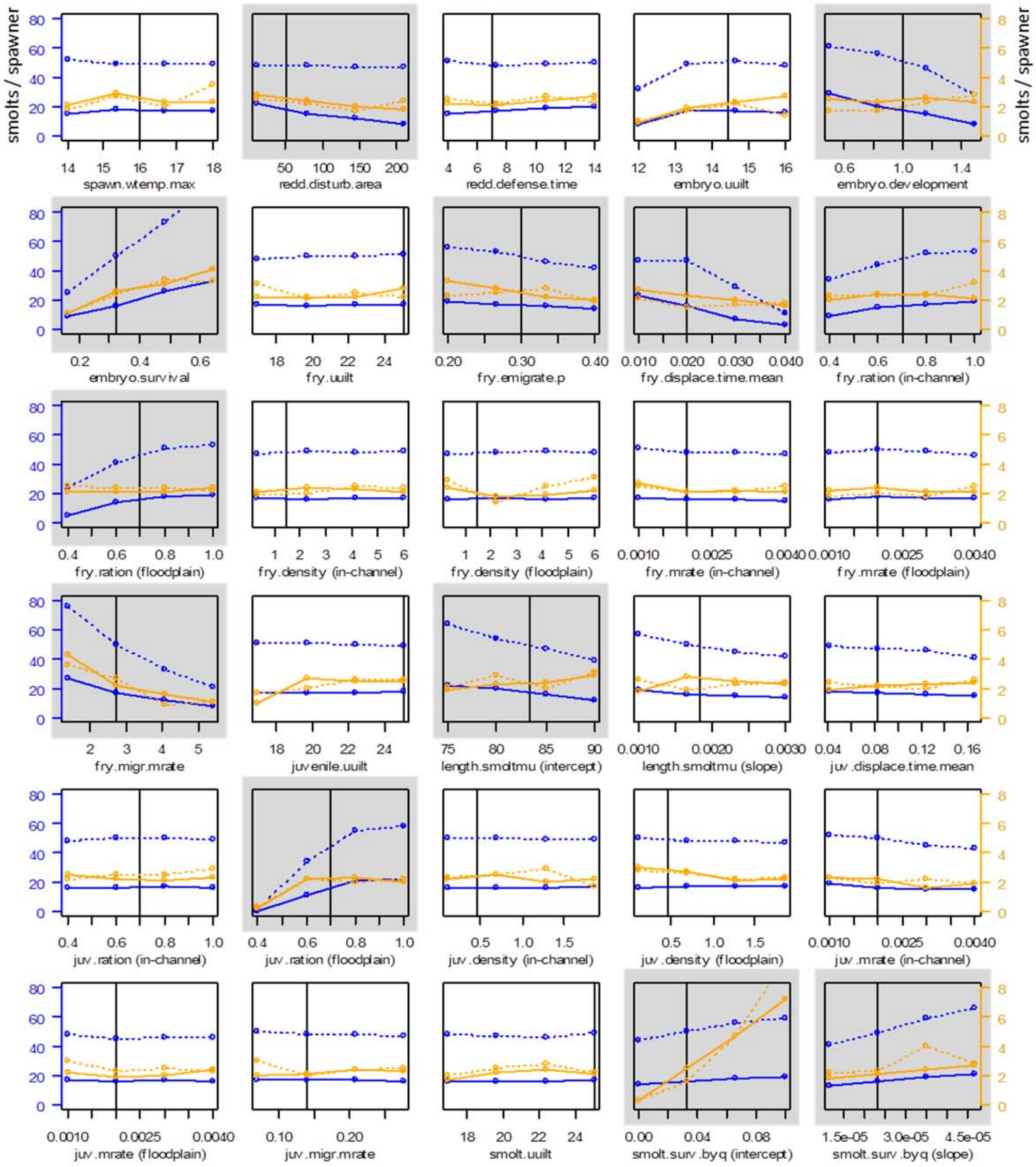

Figure 5-8. Model sensitivity to parameter variations expressed as smolts passing the San Joaquin River confluence (RM 0) divided by the number of female spawners.

Notes:

1. Results shown for low escapement (200 females, dashed lines) and high escapement (10,000 females, solid lines) under Dry (WY 2009, orange lines) and Wet (WY 2011, blue lines) water year hydrology.
2. Sensitive parameters (shaded tiles) shown by larger variation in smolt productivity across modeled range.
3. Parameter units provided in Table 4-6.

In addition to identifying individual model parameter sensitivity, parameters that are shown to result in greater changes in smolt productivity (Figure 5-8) may also be used to indicate potential factors controlling overall population levels Within the overall life-history framework (Figure 3-1), juvenile Chinook salmon production is represented in the model as a series of independent sub-models linking a parent stock of a given life stage with production into the subsequent life stage, for example the number of spawners leads directly to the number of deposited eggs, and so on. This approach, first used by Reeves et al (1989) to identify habitat needs for Coho salmon (*O. kisutch*), assumes that when habitat or other issues limit the progression of an individual life stage cohort (e.g., growth, survival), subsequent life stages and long-term populations may also be affected. In the sections below, the relative sensitivity of model parameters shown in Figure 5-8 is discussed in the context of potential issues affecting life stage progression identified as part of literature reviews conducted for the Synthesis Study (W&AR-5).

5.3.1 Adult upmigration and spawning

Of the parameters used to represent the influences of spawning success upon juvenile production, redd disturbance area (redd.disturb.area) is shown to exert a strong influence on smolt productivity at the highest escapement levels (Figure 5-8). Increasing this parameter is functionally equivalent to decreasing the amount of spawning habitat; thus the model finds smolt productivity is sensitive to spawning habitat availability at only high escapement levels for wet water year conditions such as 2011, but at both low and high escapement levels under dry year conditions such as 2009. As documented in the Synthesis Study (W&AR-5), the potential for redd superimposition, is low under current escapement levels but may result in increased density dependent mortality of deposited eggs at higher escapement levels. Prior redd superimposition studies (TID/MID 1992, Appendix 6) as well as the current *Redd Mapping Study* (W&AR-8) have shown that redd superimposition occurs to some degree at all escapement levels, exerting a greater influence on juvenile production as escapement increases.

5.3.2 Egg Incubation and Fry Emergence

Of the parameters used to represent conditions affecting egg incubation, incubation rates (embryo.development) as well as egg survival-to-emergence (embryo.survival) are shown to exert a strong influence upon smolt productivity (Figure 5-8). Although egg development rates are well constrained by laboratory studies (Equation 3), increases in the embryo.development parameter can be used to indicate the effect of longer development times, with the effect on smolt productivity decreasing in Figure 5-8 due to longer incubation times and increased risk due to redd superimposition and delayed smoltification. Although gravel quality was not considered of greater importance than other issues discussed in the Synthesis Study (W&AR-5), the effect of gravel quality upon egg survival-to-emergence (embryo.survival) is shown for all flow scenarios and escapement levels (Figure 5-8). This suggests that potential measures to improve gravel quality (e.g., gravel augmentation, gravel cleaning) would result in proportionate increases in juvenile Chinook salmon production. The remaining parameter evaluated in the sensitivity testing, embryo.uuilt, was not shown to be sensitive within the 13.9–15.6°C (57–60°F) typical range identified by laboratory studies (Seymour 1956, USFWS 1998). This is consistent with the majority of spawning occurring at upstream locations (Figure 4-4) or later in the season (Figure

4-2) when water temperatures are unlikely to affect incubation conditions or subsequent juvenile production.

5.3.3 Fry Rearing

Of the parameters used to represent fry rearing, parameters related to fry movement (p.emigrate, fry.displace.time), mortality due to predation (fry.migr.mrate), as well as food availability at overbank locations (fry.ration [floodplain]) were shown to affect the resulting smolt productivity (Figure 5-8). The proportion of fry emigrating upon emergence (p.emigrate) directly affect subsequent smolt production, with lower resulting smolt productivity from the Tuolumne River, many of these fish may potentially rear at downstream locations in the San Joaquin River and Delta. For fry remaining to rear in the Tuolumne River, predation related parameters (fry.displace.time, fry.migr.mrate) are shown to exert a strong influence on smolt productivity. Because these parameters were estimated through model fitting, more direct estimates of fry survival as a function of flow may be required to assess model uncertainty. For example, marked fry releases in conjunction with paired RST monitoring at Waterford (RM 39.5) and Grayson (RM 5.2) may be used to develop a fry survival relationship similar to the analysis conducted in Attachment C. For the parameter related to food availability at overbank locations (fry.ration [floodplain]), increases in the assumed ration for overbank locations are not accompanied with an increase in smolt productivity (Figure 5-8). However, lower ration levels than those assumed (Rf = 0.7) could result in lower juvenile production and the corresponding smolt productivity. Food availability at in-channel locations (fry.ration [in-channel]) was not shown to affect smolt productivity (Figure 5-8) and given the increased attention to improved food availability at overbank locations relative to in-channel locations (Sommer et al 2001, Jeffres et al 2008), food availability is unlikely to be limiting fry rearing during high flows resulting in extended floodplain inundation. As suggested in the Synthesis Study (W&AR-5), juvenile production was shown to be insensitive to changes in fry rearing habitat availability as expressed by maximum rearing density (fry.density [in-channel, floodplain]). Lastly, smolt productivity was also shown to be insensitive to the water temperature mortality threshold for fry (fry.uuilt) (Figure 5-8). This is consistent with fry rearing occurring at low water temperatures during winter and early spring.

5.3.4 Juvenile Rearing

Of the parameters used to represent juvenile rearing, parameters related to food availability at overbank locations (juv.ration [floodplain]) were shown to affect smolt productivity (Figure 5-8). The number of smolts/spawner was insensitive to variations in the movement related mortality (juv.migr.mrate) attributed to predation. For the very high discharge levels associated with WY 2011 hydrology, increases in the parameter affecting downstream movement rates (juv.displacement.time) is shown to initially increase smolt productivity, with decreases at the longest displacement times. This is possibly due to changes in the primary rearing location to areas with large increases in overbank habitat, such as that shown for the reach between Shiloh Bridge (RM 3.4) and the San Joaquin River confluence (RM 0)(Figure 4-9). At the highest displacement times, however, the predicted smolt productivity is shown to decrease, which is consistent with early juvenile emigration effects on the number of potential smolts remaining as well as increased exposure to predation related mortality due to these movements. As found for fry rearing, food availability at overbank locations (juv.ration [floodplain]) at levels below those assumed in the model (Rf = 0.7) could result in lower juvenile production and the corresponding smolt productivity (Figure 5-8). As suggested in the Synthesis Study (W&AR-5), juvenile production was shown to be insensitive to changes in juvenile rearing habitat availability as expressed by maximum rearing density (juv.density [in-channel, floodplain]). The size at smoltification, as represented by parameterization of Equation 7 as a function of flow (length.smoltmu [intercept, slope]), was shown to directly affect smolt production and the resulting smolt productivity (Figure 5-8). This reflects that extended rearing periods in the Tuolumne River would result in increased numbers of juveniles oversummering rather than emigrating. Lastly, smolt productivity was shown to be insensitive to the water temperature mortality threshold for juveniles (juv.uuilt) for most of the range tested (Figure 5-8), but assuming lethal mortality occurs at temperatures as low as 18°C would hypothetically result in decreased productivity.

5.3.5 **Smolt Emigration**

Of the parameters used to represent smolt emigration, smolt survival as a function of flow (smolt.surv.by.q [intercept, slope]) is shown to be proportionate to smolt productivity (Figure 4-8) with some sensitivity to the length at smoltification. As discussed in the Synthesis Study (W&AR-5), high levels of predation related mortality have been documented in direct surveys by the Districts, in multi-year smolt survival tests, and by comparisons of upstream and downstream smolt passage at rotary screw traps (Attachment C). The model sensitivity to parameter values is reflective of the strong effect of predation upon juvenile production and suggests that identified uncertainties in the smolt survival relationship (Attachment C) may affect predictions of smolt passage in any given year. Interestingly, the non-flow-dependent intercept of the smolt survival relationship (smolt.surv.byq [intercept]) is shown to exert a greater influence on smolt productivity than the flow related parameter (smolt.surv.byq [intercept])(Figure 5-8). This suggests that additional non flow factors may affect smolt survival separately from flow. Since smolt productivity was shown to be insensitive to the water temperature mortality threshold for smolts (smolt.uuilt) (Figure 5-8), this suggests that predation effects have a flow based component (e.g., exposure time, spatial separation at high velocities) as well as a non-flow component (e.g., predator abundance). For example, multiple mark recapture smolt survival studies conducted in 2000 suggested lower survival in reaches with greater pool habitat frequency resulting from historical in-channel mining (TID/MID 2001, Report 2000-4). Planned predation studies in 2014 may provide additional information regarding reach-specific survival.

5.4 Evaluation of Relative Salmon Production under Current and Potential Future Project Operations

Using long-term averages of run timing, run composition (age, sex ratio), and spawner fecundity, variations in juvenile Chinook salmon production metrics were evaluated for the base case simulation period (1971–2009). For the base case hydrology and water temperature data, the ratio of smolt passage at the San Joaquin River confluence (RM 0) to female spawners is presented in Figure 5-9 for three “reference” runs of 200, 2,000, and 10,000 female spawners. It should be noted that the model simulation is restarted in each year with the same reference runs, and the results do not reflect year-to-year variations in out of basin factors that may affect adult recruitment and subsequent escapement. Nevertheless, the general pattern shown in Figure 5-9 is consistent with variations in the historical adult escapement record, including lower productivity occurring during periods of extended droughts as well as higher productivity in years with extended flood control releases.

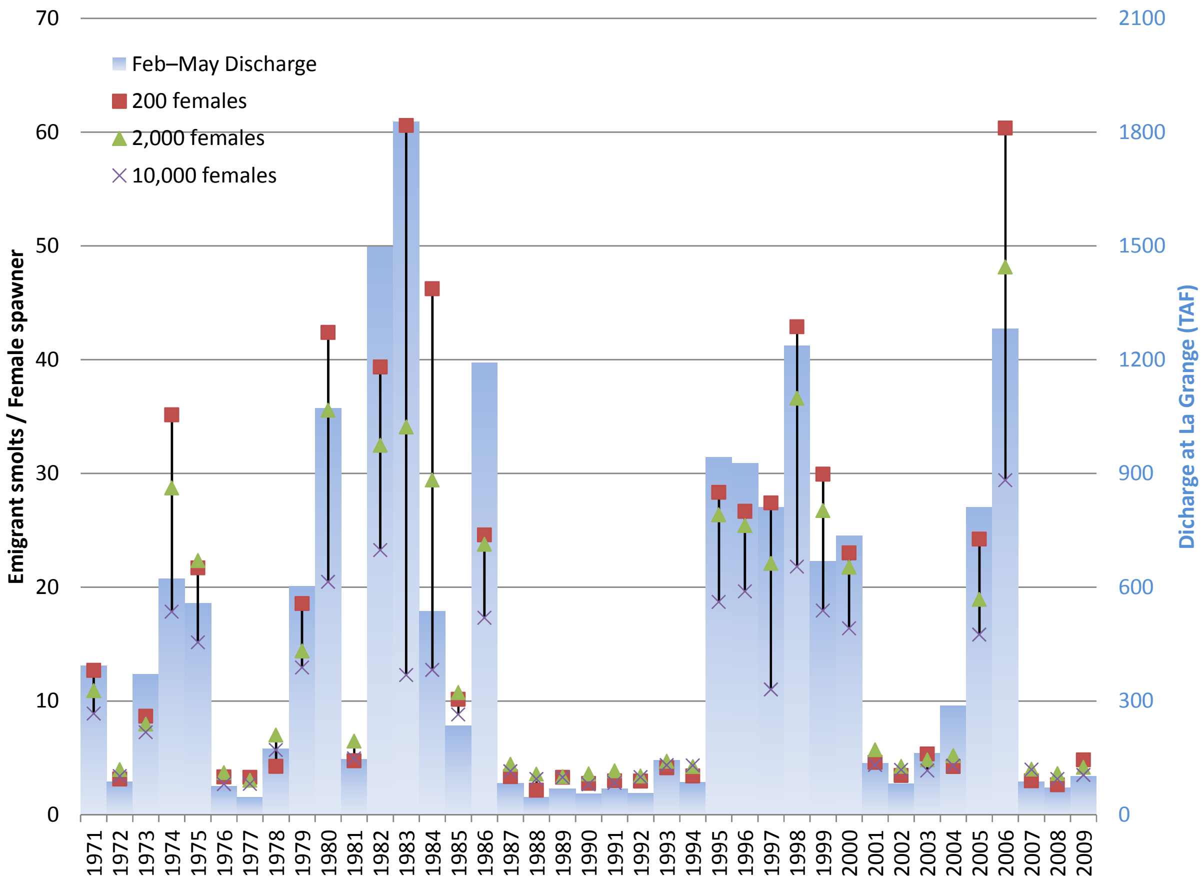

Figure 5-9. Modeled Chinook salmon smolt productivity for the base case (1971–2009) plotted with La Grange discharge (February–May) for three reference runs.

The smolt productivity results for the base case are grouped by water year type and plotted by decreasing La Grange discharge from February–May (TAF) in Figure 5-10. For the broad range in hydrologic conditions evaluated, Figure 5-10 shows that smolt productivity occurring in Above Normal and Wet water year types is consistently higher than those for Below Normal and drier types. Exceptions to this pattern relate to the occurrence of flood control releases in several years. For example, no flood control releases occurred in WY 1978 and WY 1993, which corresponded to reservoir filling following Critical water year conditions in the prior drought years. As another example, record flood flows occurring in January 1997 were followed by the cessation of flood control releases by mid-March due to below normal precipitation during later winter and spring months.

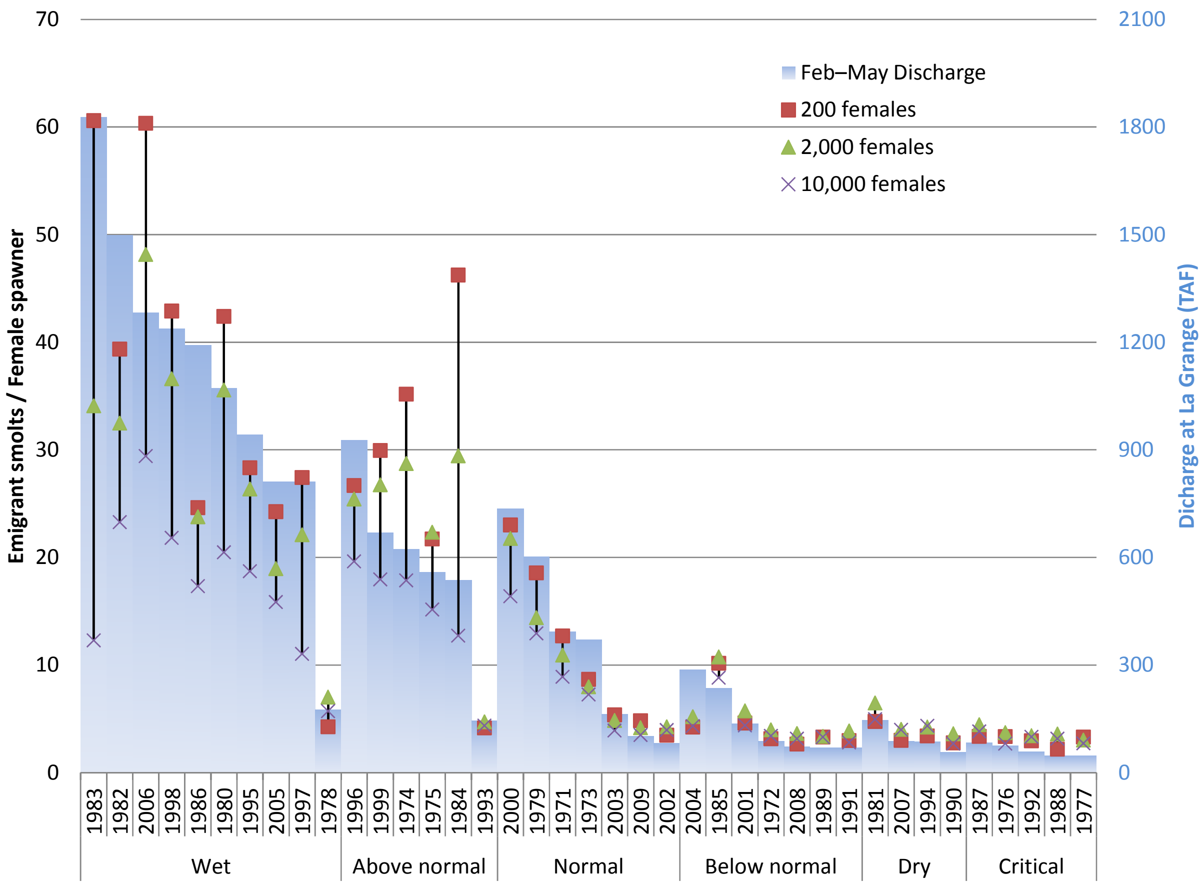

Figure 5-10. Modeled Chinook salmon smolt productivity for the base case (1971–2009) sorted by La Grange discharge (February–May) and water year type for three reference runs.

For smolts, the increased smolt productivity with increasing La Grange discharge generally reflects increased survival at higher flows (Equations 9 and 10; Attachment C). As discussed in the Synthesis Study, these results are generally consistent with historical observations of increased juvenile passage at the Grayson (RM 5.2) RST in years with larger flood control releases as well as increased spawning escapement observed 3 years later. Although the two wettest years shown in Figure 5-10 (WY 1997, WY 1983) appear to have lower productivity than some other wet years, potentially due to displacement of many fry out of the river in high flows, the general pattern of increasing productivity with La Grange discharge is retained for all water year types.

To provide a basis of comparison of the base case results above to additional scenarios to be developed with relicensing participants at Workshop No. 2 in August 2013, Table 5-2 and Table 5-3 show the geometric mean productivity for fry and smolts passing the Tuolumne River confluence with the San Joaquin River (RM 0), respectively, separated by water year types occurring during the simulation period (1971–2009). When separated in this manner, the results generally show the expected increase in productivity with increased runoff and discharge, but also show variations that may be reflective of the numbers of years represented in each water year type as well as the influences of seasonal flow patterns occurring within individual years.

Table 5-2. Chinook salmon productivity as Tuolumne River fry emigrants per spawner by water year type and escapement level for the base case (1971–2009)

Water Year type	years	Geometric mean productivity (fry/spawner) for three constant reference runs		
		200 females	2,000 females	10,000 females
WET	10	46.51	50.30	47.47
ABOVE NORMAL	6	36.76	41.97	37.76
NORMAL	7	3.77	5.04	4.71
BELOW NORMAL	7	1.37	2.11	1.97
DRY	4	1.61	2.14	2.35
CRITICAL	5	1.49	1.82	1.95
All	39	6.69	8.15	7.89

Table 5-3. Chinook salmon productivity as Tuolumne River smolt emigrants per spawner by water year type and escapement level for the base case (1971–2009)

Water Year type	years	Geometric mean productivity (smolts/spawner) for three constant reference runs		
		200 females	2,000 females	10,000 females
WET	10	29.59	25.73	20.39
ABOVE NORMAL	6	22.09	19.80	16.63
NORMAL	7	8.83	8.12	8.03
BELOW NORMAL	7	3.99	4.81	4.72
DRY	4	3.40	4.46	4.37
CRITICAL	5	2.98	3.60	3.49
All	39	8.64	8.69	7.83

In addition to the effects of increasing discharge on smolt productivity (Figure 5-10), the results also suggest decreased productivity with increases in escapement size (Table 5-3). These results are consistent with redd superimposition effects suggested in by the sensitivity analyses (Figure 5-8), which results in a range of effects identified in the Synthesis Study (W&AR-5), including exclusion from preferred spawning locations, egg/alevin mortality due to redd superimposition, as well as later emigration for emergent fry. Interestingly, Table 5-3 shows higher smolt productivity at intermediate escapement sizes (i.e., 2,000 spawners simulated) in Normal water years and all other drier water year types. For these drier water year types with lower La Grange discharge, the apparent increase in productivity at intermediate run sizes appear to be related to subtle interactions between emigration periods and pulse flow timing. As escapement levels rise, increasing rates of superimposition has the effect of shifting fry emergence timing by several days later in the season. This in turn leads to later rearing periods and later emigration of smolts. Depending upon emigration timing, greater or lesser proportions of emigrant smolts may leave the river within the pulse flow period assumed for the base case (i.e., April 15th through May 15th).

Because of the higher smolt survival expected at higher flow rates (Equations 9 and 10), pulse flow timing is shown to affect smolt productivity, suggesting that variable pulse flow timing or duration by water year type or other means (e.g., real-time monitoring of fish sizes) could be used to optimize productivity. For example, in drier water year types smolt emigration can be expected to occur earlier due to faster juvenile growth rates at higher water temperatures (Sections 4.1.3.3 and 4.1.4.3) and an increased tendency to emigrate at a smaller size (Section 4.1.5.1). In contrast, smolt emigration can be expected to occur later in wetter water years due to slower growth at lower water temperatures and an increased tendency to emigrate at a larger size. Figure 5-11 shows modeled dates of smolt emigration occurring for the base case (1971–2009) at an assumed escapement size of 2,000 female spawners and fixed spawning timing. The center (green) portions of the bars represent the timing window for 50% of the smolt emigration, whereas the outer (white) bars represent emigration of 80% of the smolts. For the base case, considerable year-to-year variability in the model results is apparent extending both earlier and later than the pulse flow period (April 15th to May 15th). There is also a pattern of earlier and later emigration in dry and wet WY types, respectively. Year-to-year variations in spawning timing may also affect subsequent smolt emigration timing, suggesting that peaks in smolt emigration may not always coincide with the pulse flow period. Although spawning run size may affect emigration timing as well (i.e., larger spawning runs resulting in later emigration), it should be emphasized that this superimposition effect is subtle and should affect timing of the overall peak emigration period by only a few days.

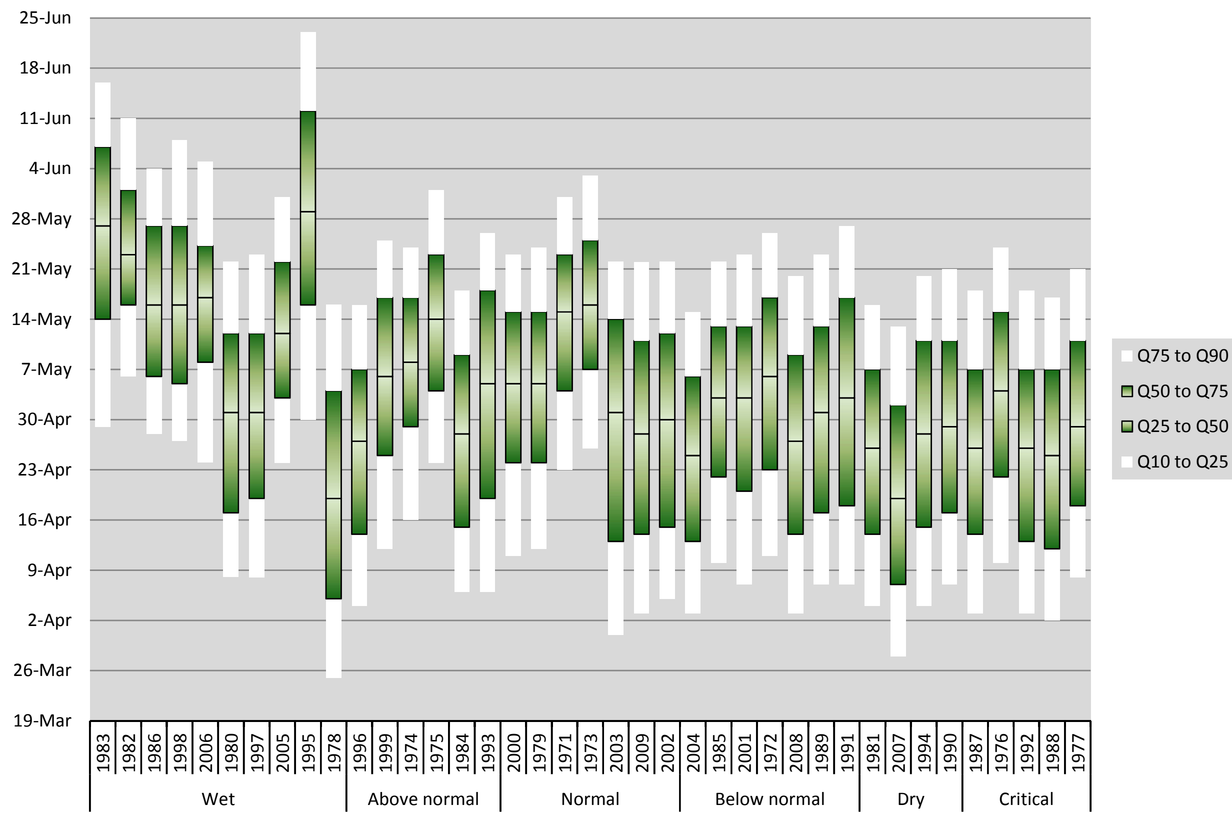

Figure 5-11. Modeled smolt emigration timing quantiles from 2,000 spawners for the base case (1971–2009) sorted by water year type and decreasing La Grange discharge (February–May).

6.0 DISCUSSION AND FINDINGS

As recommended in the June 2011 Integrated Life Cycle Models Workshop Report (Rose et al. 2011), this *Tuolumne River Chinook Salmon Population Model Study* was developed to predict juvenile Chinook salmon production within the Tuolumne River for different water year types, drawing upon existing literature and additional information identified in the Synthesis Study (W&AR-5), including previously conducted Tuolumne River studies and interrelated relicensing studies. Independent life-stage specific sub-models were developed using a series of functional relationships and associated parameters to predict life history progression from upmigration through spawning, egg incubation, fry and juvenile rearing, to smolt emigration. The calibrated model may be used to examine the relative influences of various factors on the life-stage specific production of Chinook salmon in the Tuolumne River, identify critical life-stages that may represent a life-history "bottleneck," as well as to compare relative changes in juvenile production between alternative management scenarios.

6.1 Model Calibration and Validation

Using recent spawning estimates from counting weir operations at RM 24.5 along with recorded river discharge and water temperature data, model calibration was carried out by comparisons of modeling results of fry and/or smolt passage with annual estimates from RST sampling in the lower Tuolumne River (RM 29.8, RM 5.2) for the period 2010–2012. Model validation was conducted by comparison of simulated and observed RST passage for the period 2007–2009 using data from the fall CDFW spawning surveys along with recorded river discharge and water temperature data. Overall, model results matched both fry and smolt passage estimates at the Grayson RST location (RM 5.2) for the combined calibration and validation period (2007–2012). In comparisons to patterns in bi-weekly seining data (Attachment C), model results also represented variations in river-wide distribution as well as seasonal rearing patterns documented under representative "dry" (2009) and "wet" (2011) water year hydrology.

6.2 Model Scenario Results

Using the validated model, juvenile Chinook salmon smolt productivity was evaluated for the base case simulation period (1971–2009). The base case provides a thirty seven year time series of varying hydrology and meteorology to examine variations in juvenile salmon production under a variety of water year types as well as to provide a basis of comparison for any alternative operating scenarios. Using water temperature estimates provided by the *Reservoir Temperature Model* (W&AR-3) and *Lower Tuolumne River Temperature Model* (W&AR-16) studies, juvenile Chinook salmon production was estimated at three reference levels of spawning escapement: 200 female spawners (Low), 2,000 females (Medium), and 10,000 females (High). Modeling results showed that the ratio of smolt passage at the San Joaquin River confluence (RM 0) to female spawners during "wet" water year scenarios was consistently higher than for "dry" water year scenarios. The increased smolt productivity generally reflects increased smolt survival during emigration at higher flows. As discussed in the Synthesis Study (W&AR-5), these results are generally consistent with historical information showing increased juvenile passage at the Grayson (RM 5.2) RST in years with larger flood control releases as well as observations of increased spawning escapement 3 years later. In addition to the results of the base case hydrology, alternative scenarios will be developed with relicensing participant at Workshop No. 2 in August 2013.

As discussed in the sections below, the identified model sensitivity to particular parameters suggests that some non-flow measures could potentially influence overall juvenile production (e.g., gravel additions, gravel cleaning, spawning barriers, predator removal, predator suppression, etc.). Evaluation of such potential measures using the model could be discussed with relicensing participants along with any potential flow scenarios developed as part of Workshop No. 2. Along with information developed in the Synthesis Study (W&AR-5) as well as interrelated relicensing studies, the results of these scenario evaluations will be included in the Draft License Application to inform the effectiveness of any potential management measures.

6.3 Evaluation of Factors Affecting Chinook Salmon Production

Model sensitivity testing was used to identify model parameters affecting juvenile production and overall population levels. Using an overall productivity metric of smolts/spawner, parameters related to the following life stage processes were shown to exert the greatest influence on subsequent juvenile production in the calibrated model.

- **Upmigration and Spawning**
  - Sensitivity to parameters related to redd disturbance suggest modeled smolt productivity is affected by spawning habitat availability.
- **Egg incubation and fry emergence**
  - Sensitivity to parameters related to redd disturbance suggest modeled smolt productivity is affected by spawning habitat availability (i.e., area of suitable gravel).
  - Sensitivity to parameters related to egg development rates suggest modeled smolt productivity is affected by egg survival-to-emergence (e.g., gravel quality, intra-gravel flow, etc.).
- **Fry rearing**
  - Sensitivity to parameters related to fry movement suggests modeled smolt productivity is affected by predation related mortality.
  - Sensitivity to lower ration parameter estimates suggests fry growth and modeled smolt productivity may only be affected by variations in food availability below those used in the model calibration.
- **Juvenile rearing**
  - Sensitivity to lower ration parameter estimates suggests juvenile growth and modeled smolt productivity may only be affected by variations in food availability below those used in the model calibration.
- **Smolt emigration**
  - Sensitivity to parameters related to smolt survival suggests modeled smolt productivity is affected by predation related mortality and flow.

Below we discuss the results of the sensitivity testing results and base case scenario results in the context of issues identified in the Synthesis Study (W&AR-5).

6.3.1 Spawning Habitat Availability

Reductions in smolt productivity with increasing escapement are consistent with redd superimposition effects suggested by the sensitivity analyses conducted for this study as well as the results of Tuolumne River spawning habitat investigations summarized as part of the Synthesis Study (W&AR-5). Redd superimposition effects are shown in Figure 5-9 and Figure 5-10 by the distance between the smolt productivity estimates for each of the three reference run sizes (200, 2,000, 10,000 females) evaluated for the base case. Because usable spawning habitat for Chinook salmon spawning (Figure 4–3) is near optimal based upon results of the *Lower Tuolumne River Instream Flow Study* (Stillwater Sciences 2013), increases in spawning flows may be expected to result in only minor increases in available spawning habitat. The *Spawning Gravel Study* (W&AR-4) indicates relatively little change in available spawning areas as compared to historical estimates. Potential non-flow measures that could be evaluated with the model to increase spawning habitat improvements include gravel augmentation projects at upstream locations of the lower Tuolumne River (McBain & Trush, 2000, 2004) as well as the use of movable spawning barriers to force increased use of downstream spawning areas (TID/MID 1992, Volume 2). In addition, gravel cleaning identified in previous studies (TID/MID 1992, Appendix 9; McBain & Trush 2004) may potentially improve gravel quality conditions by reducing fine sediment intrusion, thereby increasing intragravel flow, egg survival-to-emergence, and subsequent smolt productivity.

6.3.2 Juvenile Rearing Habitat Availability

Modeling results to date show that rearing habitat is not limiting smolt productivity under current conditions, consistent with findings of the Synthesis Study (W&AR-5). Sensitivity testing conducted for this study show that reductions in fry and juvenile rearing density parameters used in the calibrated model are not accompanied by reductions in subsequent smolt productivity. For the highest run sizes evaluated (10,000 female spawners), the resulting fry and juvenile production is shown to be insufficient to fully saturate available rearing habitat under current conditions. The implication of the low sensitivity to fry and juvenile rearing density is that changes in in-channel rearing habitat area through measures recommended to improve access to potential floodplain rearing areas, such as floodplain recontouring (McBain & Trush 2000) as well as extended high flows to maintain floodplain inundation (Mesick 2009), will not result in large increases in subsequent smolt productivity on the basis of relieving any rearing habitat limitation. Although food availability can be shown to reduce modeled smolt productivity at levels below those used in the calibrated model, increases in assumed food availability at in-channel and overbank locations are not accompanied by increased smolt productivity. This is consistent with materials reviewed as part of the Synthesis Study (W&AR-5) which found adequate food resources supporting juvenile rearing of Chinook salmon were present in the lower Tuolumne River.

6.3.3 Flow Effects

Modeling results for the base case show that smolt productivity is consistently higher with increased La Grange discharge as measured by the summation of flows for the period from February to May inclusive (Figure 5-8 and Figure 5-9). Flow variations affect all life stages to some degree, affecting water temperatures, habitat area and suitability, as well as movement related mortality due to predation on fry and juveniles. However, sensitivity testing shows that smolt productivity is strongly influenced by parameters of the smolt survival vs. flow relationship (Equation 8). This is consistent with information reviewed as part of the Synthesis Study (W&AR-5) which showed a relationship between springtime flows and subsequent adult escapement (TID/MID 1992, Volume 2; Speed 1993; TID/MID 1997, Report 96-5; Mesick and Marston 2007; Mesick et al. 2008) as well as in variations of annual smolt passage (Mesick et al. 2008). The patterns of smolt productivity and subsequent adult escapement with discharge are consistent with predation as a primary mortality source, with effects upon long-term population levels.

In addition to the direct effects of increasing discharge on smolt productivity (i.e., smolt survival with flow), model results show changes in smolt emigration timing due to water temperature effects upon development rates, as found in monitoring of other river systems (e.g., Rombough 1985, Roper and Scarnecchia 1999). These and other modeled effects upon life history timing (e.g., spawning timing, run sizes) produce results with greater or lower overlap with the scheduled pulse flow period (April 15th though May 15th). Because of the higher smolt survival expected at higher flow rates, pulse flow timing is shown to affect smolt productivity, suggesting that variable pulse flow timing or duration by water year type or other means (e.g., real-time monitoring of fish sizes, shaped pulse flows) could be used to optimize water use and smolt productivity.

6.3.4 Water Temperature

Model sensitivity testing indicates that water temperature is not currently limiting smolt productivity under current conditions, consistent with findings of the Synthesis Study (W&AR-5). Because water temperatures are generally suitable for all in-river life stages in the lower Tuolumne River under both drier and wetter water year types evaluated in sensitivity testing, reductions in mortality threshold parameters (i.e., UUILT) did not result in corresponding changes in smolt productivity. Although water temperature is an important factor controlling egg incubation rates as well as fry and juvenile growth rates, with the exception of issues related to the timing of smoltification and emigration discussed in Section 6.3.3 above, smolt productivity is unaffected by normal seasonal variations in air and water temperatures. More specifically, since the majority of spawning takes place under suitable temperature conditions, modeled egg mortality effects due to potentially unsuitable water temperatures for early arriving spawners during late summer or early fall do not appear to affect subsequent smolt productivity. Further, the majority of smolt emigration occurs prior to periods of potentially unsuitable water temperature occurring in late spring. For this reason, sensitivity to variations in the selected mortality threshold parameter (i.e., UUILT) was low and was not accompanied by large changes in smolt productivity.

6.4 Potential Information Needs

The identified model sensitivity to particular parameters may be used to guide further refinement of the selected parameter values on the basis of future monitoring. For example, simplifying assumptions have been made in the model implementation regarding the uniformity of food resource distribution as well as predator distribution along the river. Although we have used the best available information in making these assumptions, promoting conditions that lead to rearing in particular areas with greater or lower food resources or mortality risks may lead to greater or lower predicted smolt productivity than we have shown in the current model implementation. In order to improve our understanding of the mechanisms represented in the model as well as to confirm the assumptions made in the model implementation, potential information needs are discussed below.

6.4.1 **Fry and Juvenile Movement Data**

In modeling of fry and juvenile movement rates, temporal patterns of historical RST passage data as well as seining density were used to fit parameters to describe movement rates for fry (Section 4.1.3.2) and for juveniles (Section 4.1.4.2). Because smolt productivity is shown to be highly sensitive to these parameter estimates, additional movement data could be used to refine fitted parameters and improve the resulting juvenile passage estimates. Movement data could be collected using dye marked fish with existing seine and RST monitoring efforts, or by use of implanted passive integrated transponder (PIT) tags with passage monitoring by deployment of antenna loops at particular locations.

6.4.2 **Floodplain Water Temperature**

In modeling of growth rates in overbank locations, floodplain water temperatures are assumed to be the same as at nearby in-channel locations on the basis of temperature monitoring conducted during 2011 as part of the *Pulse Flow Study* (Stillwater Sciences 2012). Monitoring data collected for the pulse flow study showed that average water temperatures at in-channel sites were actually slightly above the nearby overbank sites during winter/spring, with overbank sites exhibiting both higher daily maximum and lower daily minimum water temperatures, respectively. Since water temperatures affect growth rates promoting conditions that lead to rearing in particular areas with greater or lower access to in-channel and floodplain habitats may lead to greater or lower smolt productivity than we have shown under the current model implementation. Additional water temperature monitoring at paired overbank and in-channel sites during high flow periods would help confirm use of this assumption in the population model.

6.4.3 **Predation**

For fry, juvenile, and smolt life stages, the model currently attributes changes in relative passage between the two RST locations at Waterford (RM 29.5) and Grayson (RM 5.2) to predation related mortality. Although the current model implementation is capable of representing differing rates of mortality probability to various sub-reaches in the lower Tuolumne River, parameter fitting in the calibrated model has assumed a uniform distribution of predation risk. Additional

Predation Study (W&AR-7) experiments in 2014 may help identify particular reaches with greater and lower smolt survival due to mining pits or flow variability. Additional data on this issue (e.g., predator abundance, smolt survival) would be combined with the existing RST based estimates to develop reach-by-reach variations in juvenile survival/mortality, with additional fitting of model parameters to achieve model calibration. For any future smolt-survival experiments conducted during pulse flows, marked smolts should be used to estimate daily capture efficiencies for each RST site during each pulse flow period. Additional RST efficiency experiments on marked releases of smaller life-stages would also help improve resulting passage estimates that could be used to either refine fitted parameters for fry and juvenile mortality or to develop direct survival relationships with flow for these life stages.

6.4.4 Smolt Emigration Cues

Early RST monitoring conducted in the lower Tuolumne River (1998–2000) at multiple locations from RM 42–24.7 identified several potential emigration cues for smolt-sized fish (TID/MID 2005). In particular, abrupt flow changes appeared to be associated with peaks in smolt emigration, as were releases of large numbers of hatchery-reared CWT salmon in smolt survival studies.

The possibility that flow pulses actively stimulate or concentrate emigration, rather than simply supporting the survival of migrating fish, has implications for the design of spring flows—in particular, for the duration (and perhaps frequency) of flow pulses. Accordingly, exploratory analyses were conducted into the temporal response of emigration to the onset of a spring pulse (Attachment C). Out of six years examined (2007–2012), daily passage was estimated for three years (2007, 2009, and 2012)[1] in which pulse flows were scheduled following steady antecedent flows. Based upon the limited data evaluations to date, emigration cues resulting from pulse flows are suggested, with a greater proportion of fish moving on the first day following flow changes than on subsequent days (Attachment C).

These results suggest that in addition to the overall developmental patterns of smoltification and emigration with broad environmental patterns (e.g., temperature, photo-period), smolt emigration may be temporarily stimulated through the use of variable pulse flows. Because of the increased smolt survival with discharge, overall smolt productivity may be expected to increase for years in which emigration timing is closely matched with scheduled pulse flows. Additional study of pulse flow allocation (e.g., multiple steps, flow increases, flow decreases) using marked fish may confirm if this effect is large enough to be meaningful with regards to promoting smolt emigration during periods while higher flow and survival conditions are being maintained.

[1] Although flow conditions were suitable to evaluate smolt passage during the spring pulse of 2008, a data gap in the RST sampling occurred on the second day of the pulse because of the trap shifted out of the channel thalweg.

7.0 STUDY VARIANCES AND MODIFICATIONS

There are no study variances for W&AR-6.

8.0 REFERENCES

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Attachment A

Conceptual models for in-river life stages of Chinook salmon in the Tuolumne River

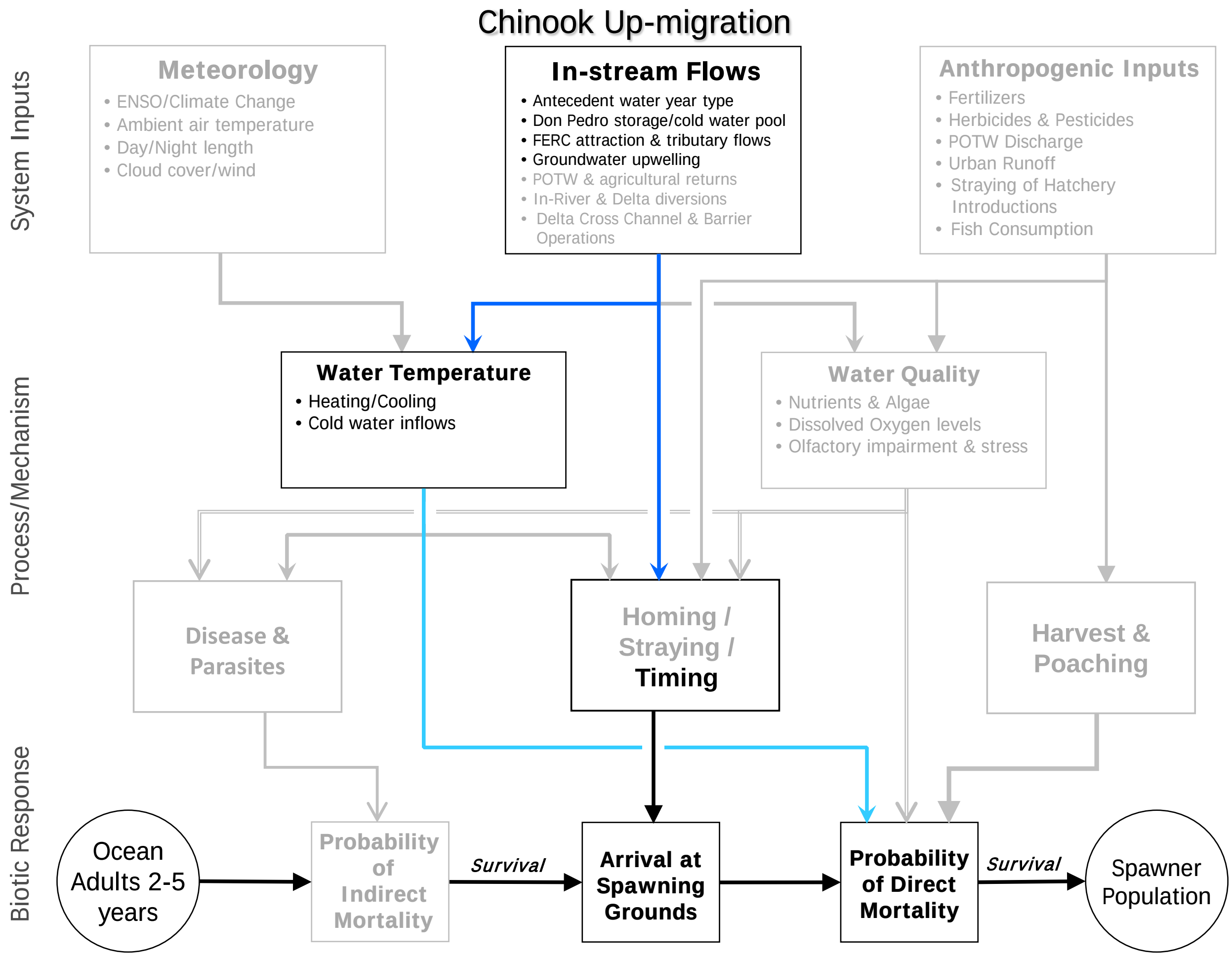
Chinook Up-migration
System Inputs
Process/Mechanism
Biotic Response
Meteorology
• ENSO/Climate Change
• Ambient air temperature
• Day/Night length
• Cloud cover/wind
In-stream Flows
• Antecedent water year type
• Don Pedro storage/cold water pool
• FERC attraction & tributary flows
• Groundwater upwelling
• POTW & agricultural returns
• In-River & Delta diversions
• Delta Cross Channel & Barrier Operations
Anthropogenic Inputs
• Fertilizers
• Herbicides & Pesticides
• POTW Discharge
• Urban Runoff
• Straying of Hatchery Introductions
• Fish Consumption
Water Temperature
• Heating/Cooling
• Cold water inflows
Water Quality
• Nutrients & Algae
• Dissolved Oxygen levels
• Olfactory impairment & stress
Disease & Parasites
Homing / Straying / Timing
Harvest & Poaching
Ocean Adults 2-5 years
Probability of Indirect Mortality
Survival
Arrival at Spawning Grounds
Probability of Direct Mortality
Survival
Spawner Population

Figure A-1.

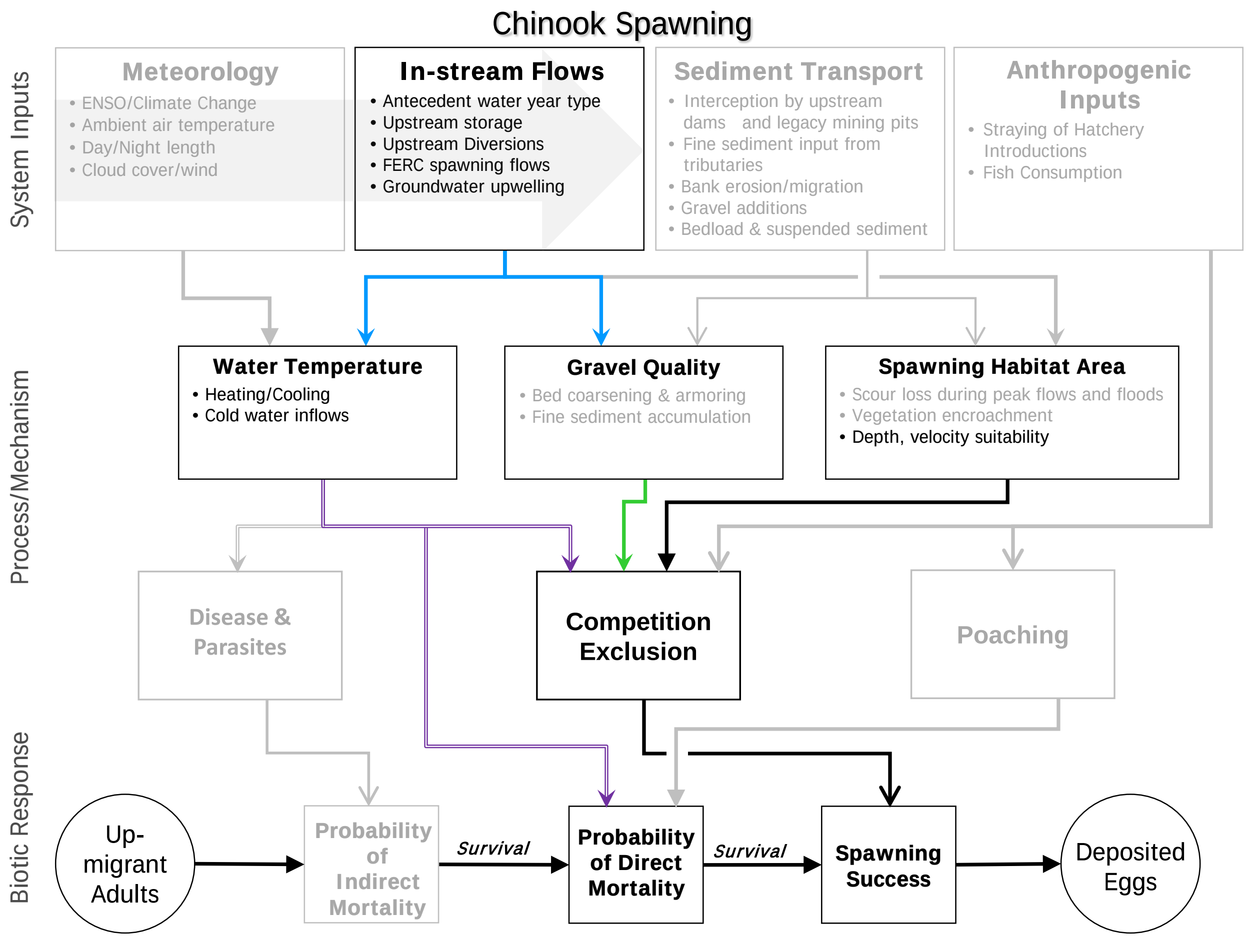
Chinook Spawning
System Inputs
Meteorology
• ENSO/Climate Change
• Ambient air temperature
• Day/Night length
• Cloud cover/wind
In-stream Flows
• Antecedent water year type
• Upstream storage
• Upstream Diversions
• FERC spawning flows
• Groundwater upwelling
Sediment Transport
• Interception by upstream dams and legacy mining pits
• Fine sediment input from tributaries
• Bank erosion/migration
• Gravel additions
• Bedload & suspended sediment
Anthropogenic Inputs
• Straying of Hatchery Introductions
• Fish Consumption
Process/Mechanism
Water Temperature
• Heating/Cooling
• Cold water inflows
Gravel Quality
• Bed coarsening & armoring
• Fine sediment accumulation
Spawning Habitat Area
• Scour loss during peak flows and floods
• Vegetation encroachment
• Depth, velocity suitability
Disease & Parasites
Competition Exclusion
Poaching
Biotic Response
Up-migrant Adults
Probability of Indirect Mortality
Survival
Probability of Direct Mortality
Survival
Spawning Success
Deposited Eggs

Figure A-2.

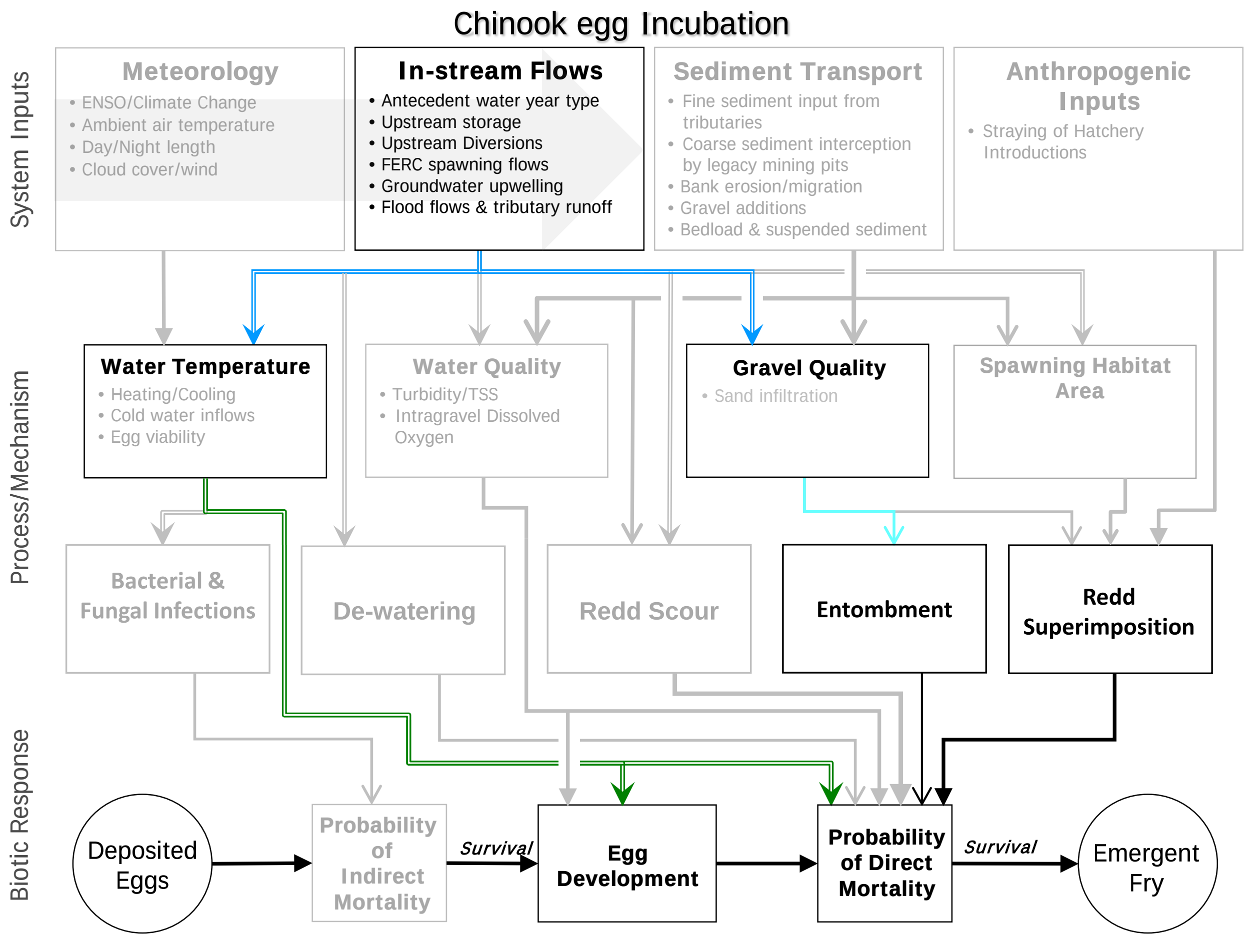
Chinook egg Incubation
System Inputs
Meteorology
• ENSO/Climate Change
• Ambient air temperature
• Day/Night length
• Cloud cover/wind
In-stream Flows
• Antecedent water year type
• Upstream storage
• Upstream Diversions
• FERC spawning flows
• Groundwater upwelling
• Flood flows & tributary runoff
Sediment Transport
• Fine sediment input from tributaries
• Coarse sediment interception by legacy mining pits
• Bank erosion/migration
• Gravel additions
• Bedload & suspended sediment
Anthropogenic Inputs
• Straying of Hatchery Introductions
Process/Mechanism
Water Temperature
• Heating/Cooling
• Cold water inflows
• Egg viability
Water Quality
• Turbidity/TSS
• Intragravel Dissolved Oxygen
Gravel Quality
• Sand infiltration
Spawning Habitat Area
Bacterial & Fungal Infections
De-watering
Redd Scour
Entombment
Redd Superimposition
Biotic Response
Deposited Eggs
Probability of Indirect Mortality
Survival
Egg Development
Probability of Direct Mortality
Survival
Emergent Fry

Figure A-3.

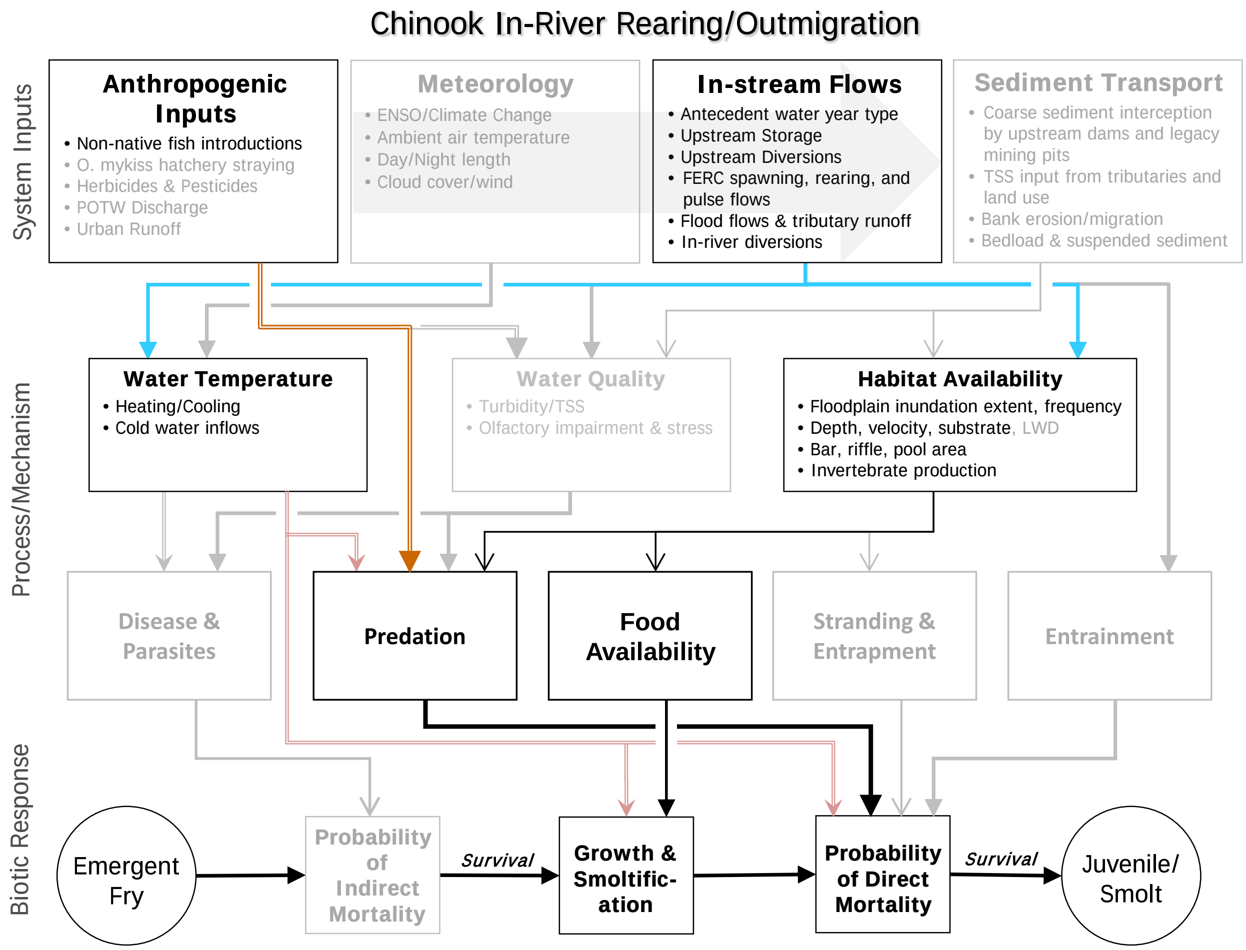
Chinook In-River Rearing/Outmigration
System Inputs
Anthropogenic Inputs
• Non-native fish introductions
• O. mykiss hatchery straying
• Herbicides & Pesticides
• POTW Discharge
• Urban Runoff
Meteorology
• ENSO/Climate Change
• Ambient air temperature
• Day/Night length
• Cloud cover/wind
In-stream Flows
• Antecedent water year type
• Upstream Storage
• Upstream Diversions
• FERC spawning, rearing, and pulse flows
• Flood flows & tributary runoff
• In-river diversions
Sediment Transport
• Coarse sediment interception by upstream dams and legacy mining pits
• TSS input from tributaries and land use
• Bank erosion/migration
• Bedload & suspended sediment
Process/Mechanism
Water Temperature
• Heating/Cooling
• Cold water inflows
Water Quality
• Turbidity/TSS
• Olfactory impairment & stress
Habitat Availability
• Floodplain inundation extent, frequency
• Depth, velocity, substrate, LWD
• Bar, riffle, pool area
• Invertebrate production
Disease & Parasites
Predation
Food Availability
Stranding & Entrapment
Entrainment
Biotic Response
Emergent Fry
Probability of Indirect Mortality
Survival
Growth & Smoltific-ation
Probability of Direct Mortality
Survival
Juvenile/ Smolt

Figure A-4.

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Attachment B

Juvenile Chinook Salmon Seining Density in the Tuolumne River (1999–2012)

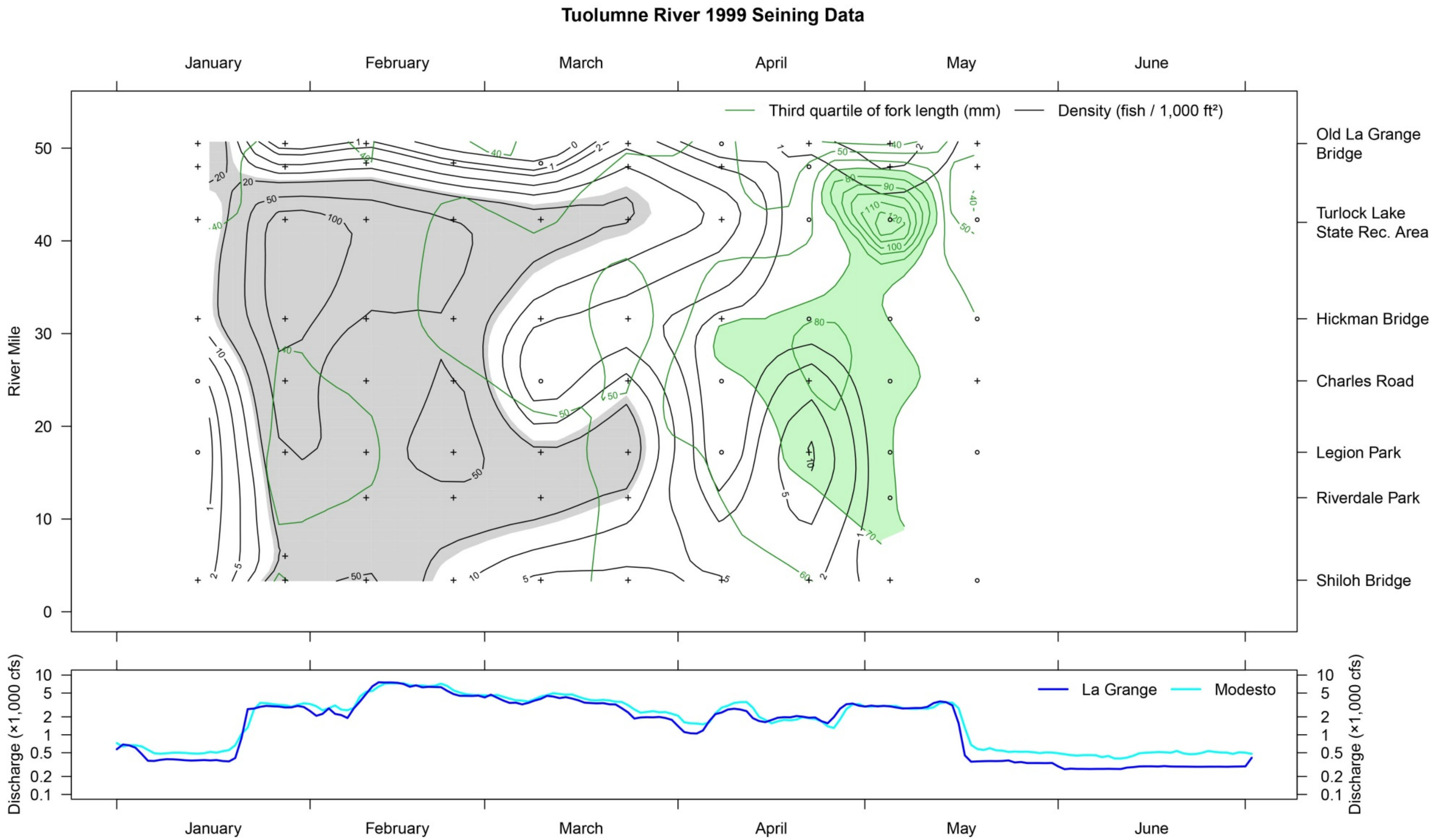

Figure B-1. 1999 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

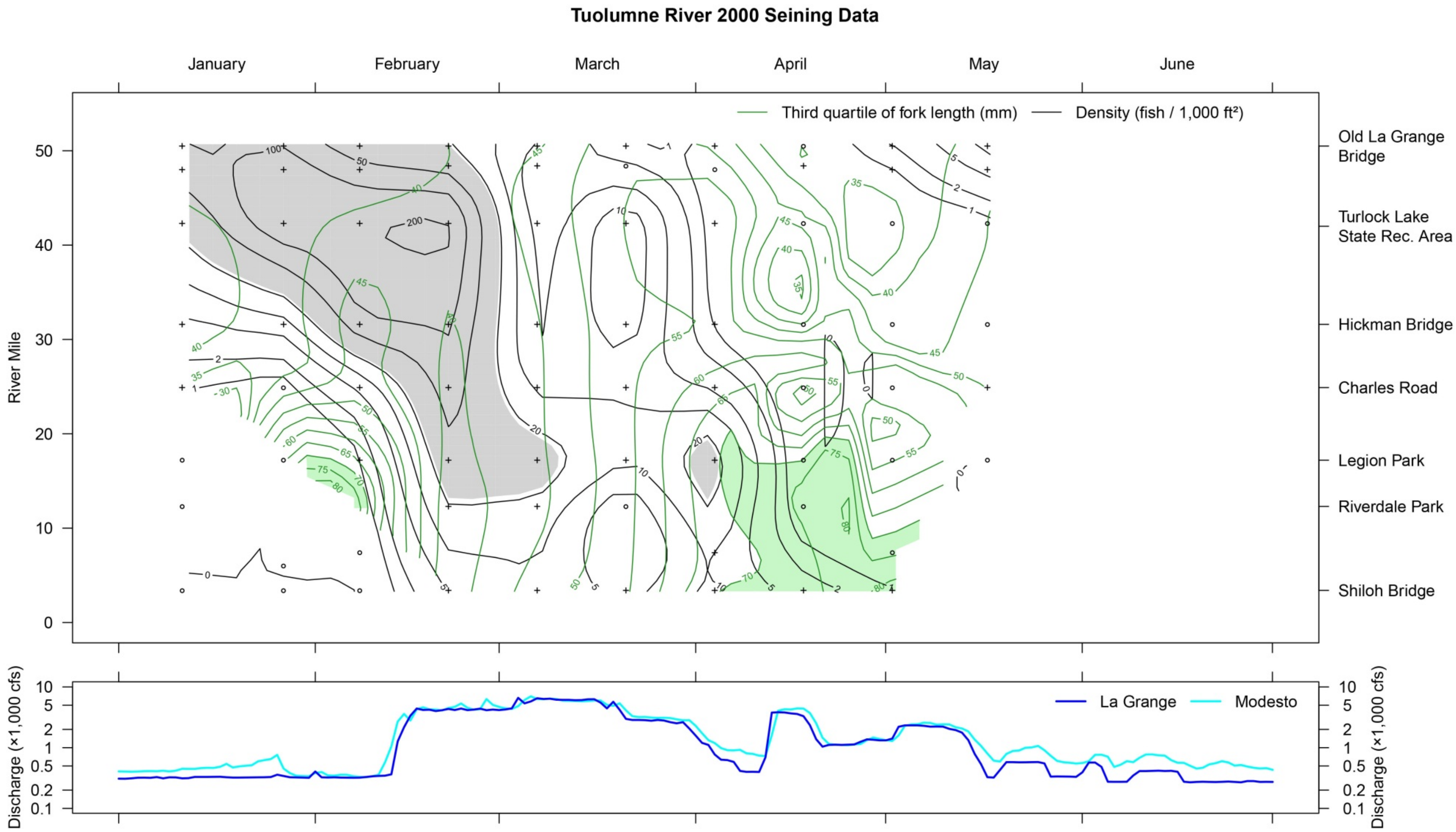

Figure B-2. 2000 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River
(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

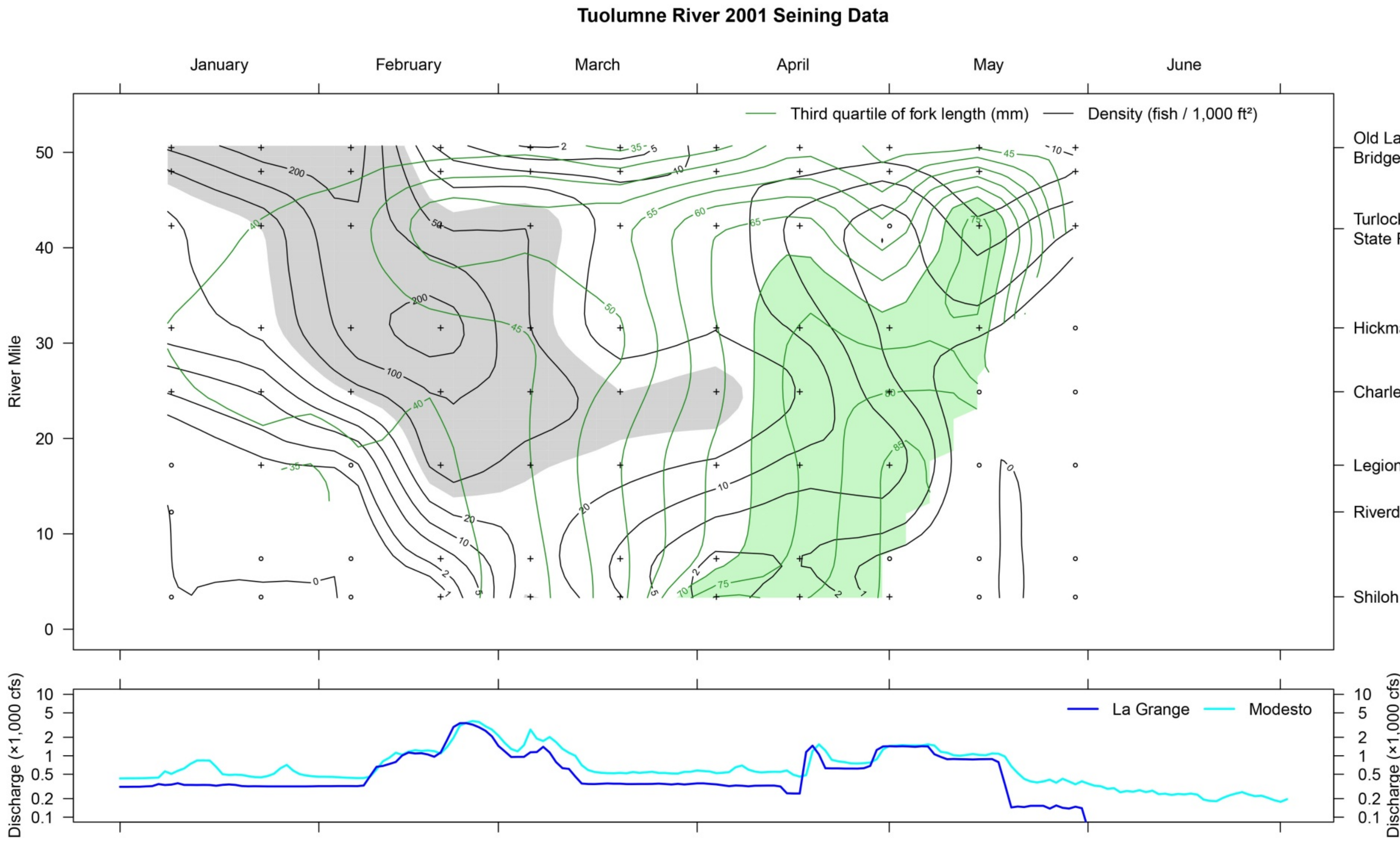

Figure B-3. 2001 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

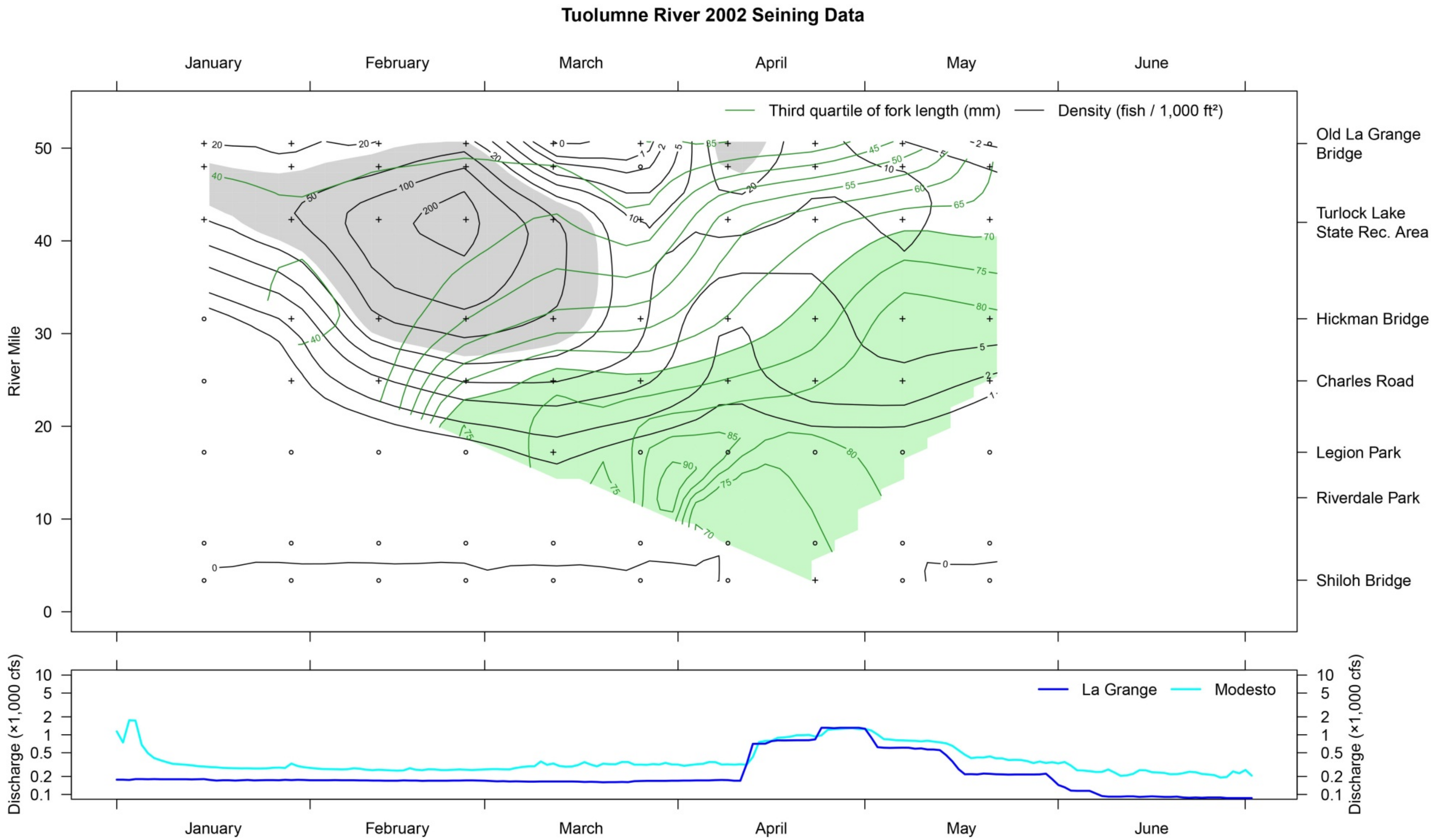

Figure B-4. 2002 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

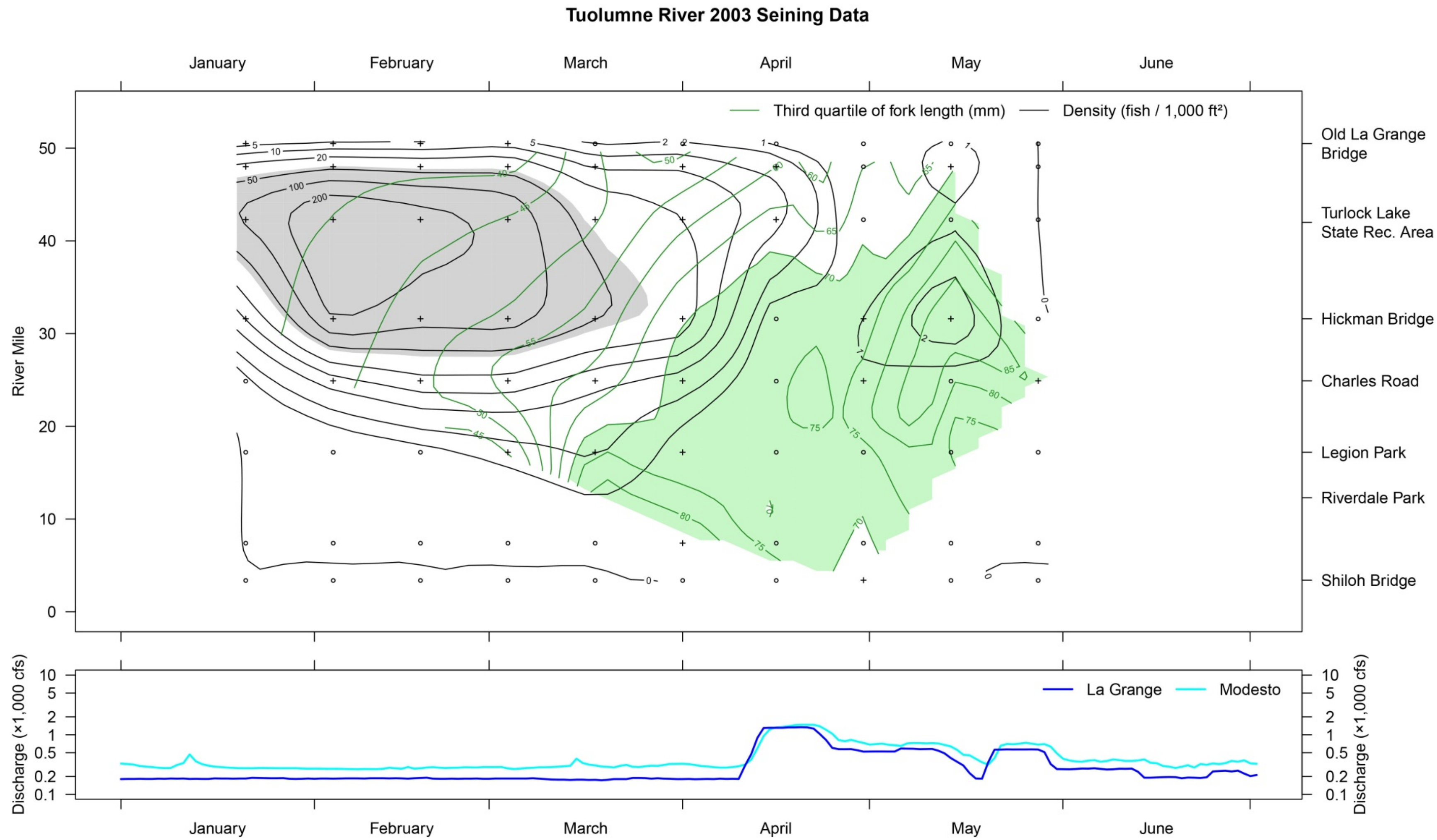

Figure B-5. 2003 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

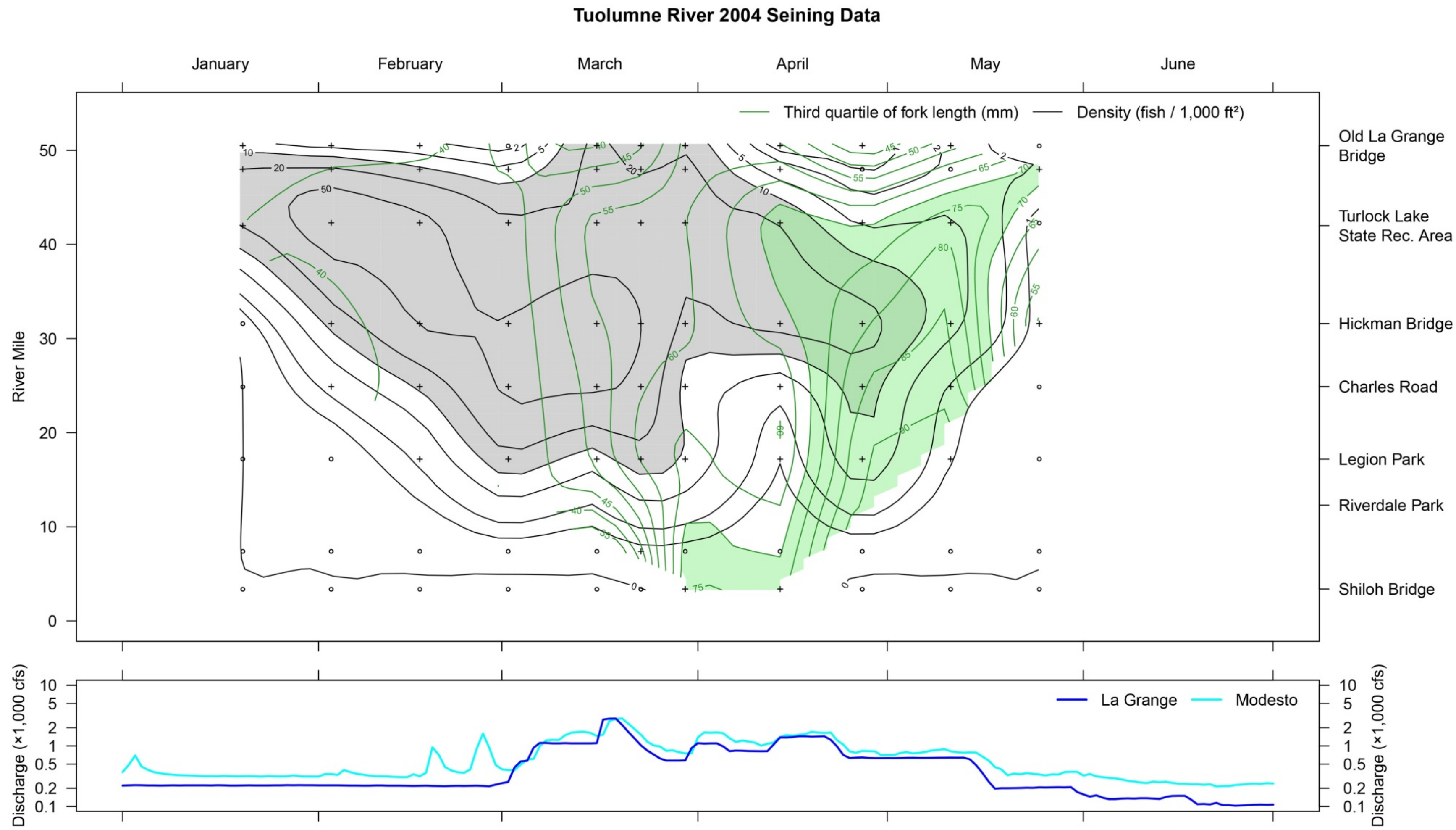

Figure B-6. 2004 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

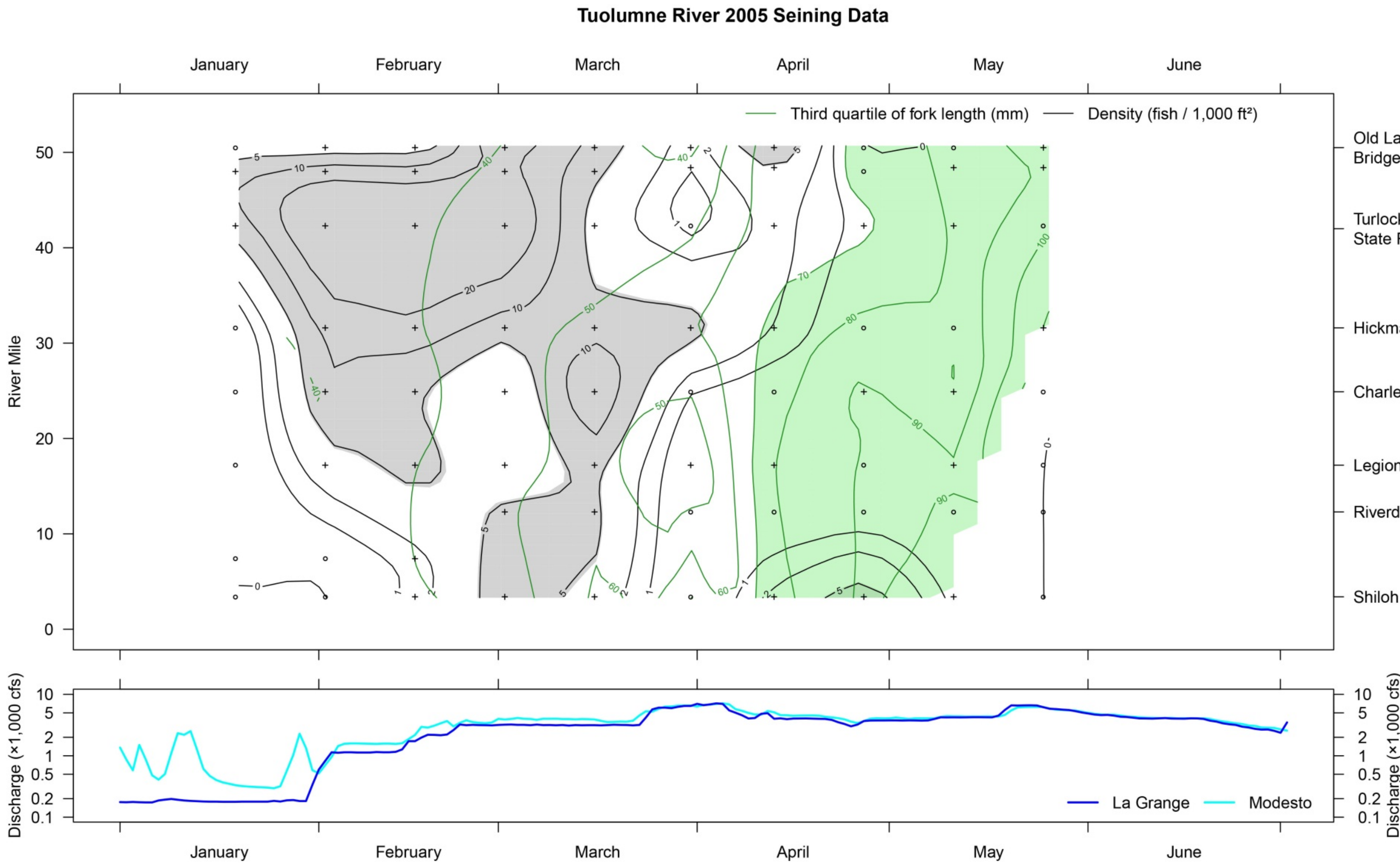

Figure B-7. 2005 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

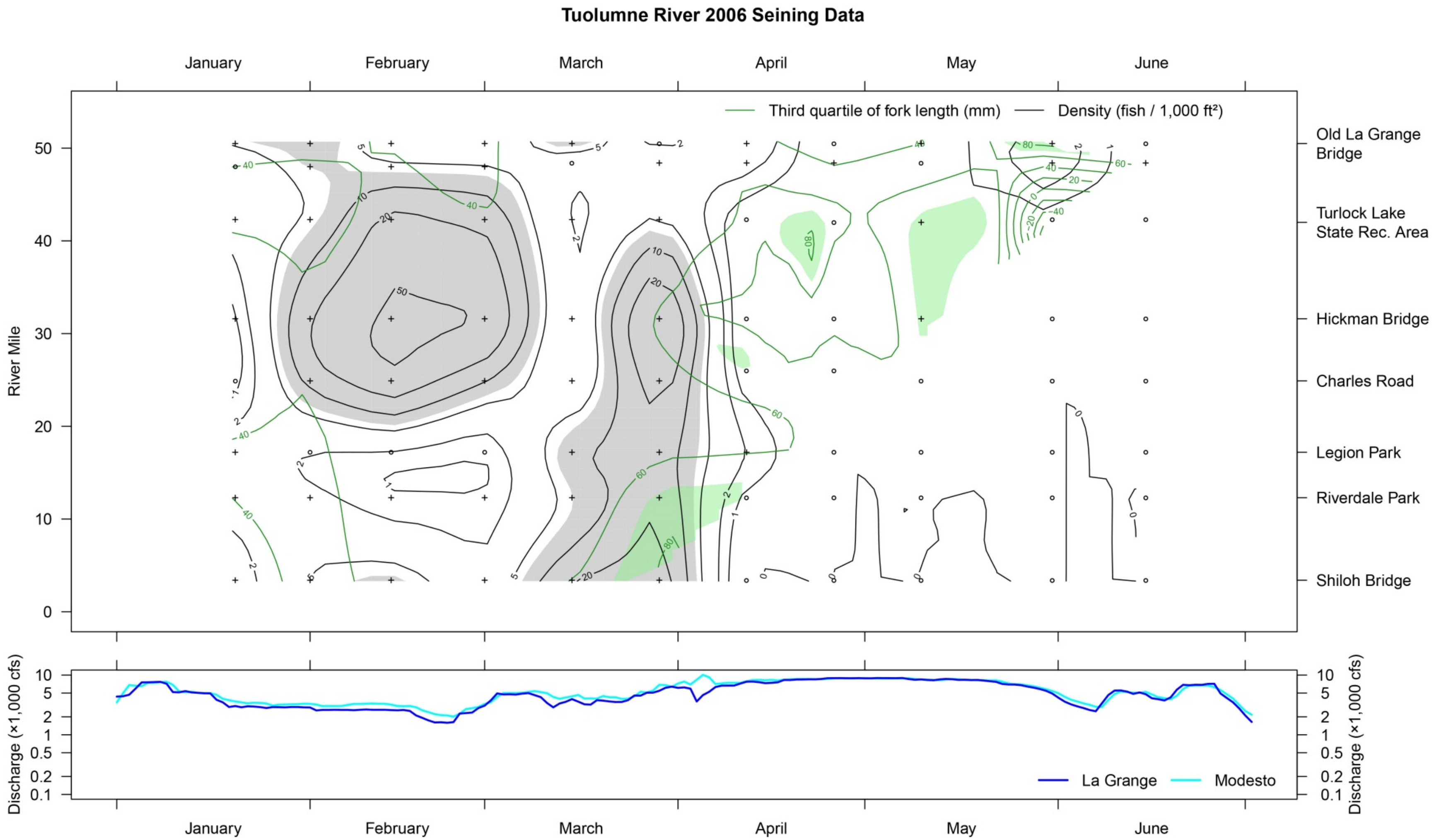

Figure B-8. 2006 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

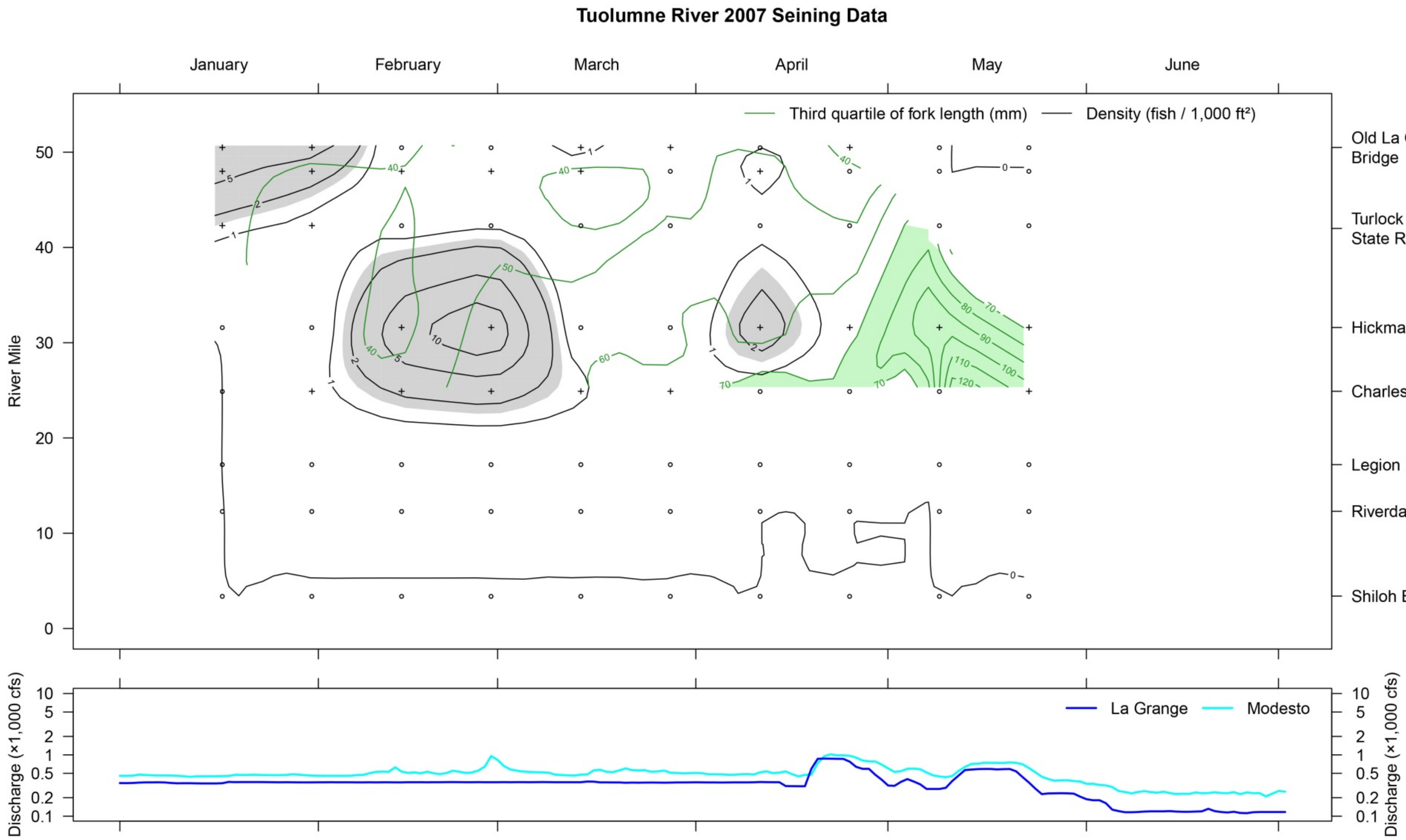

Figure B-9. 2007 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

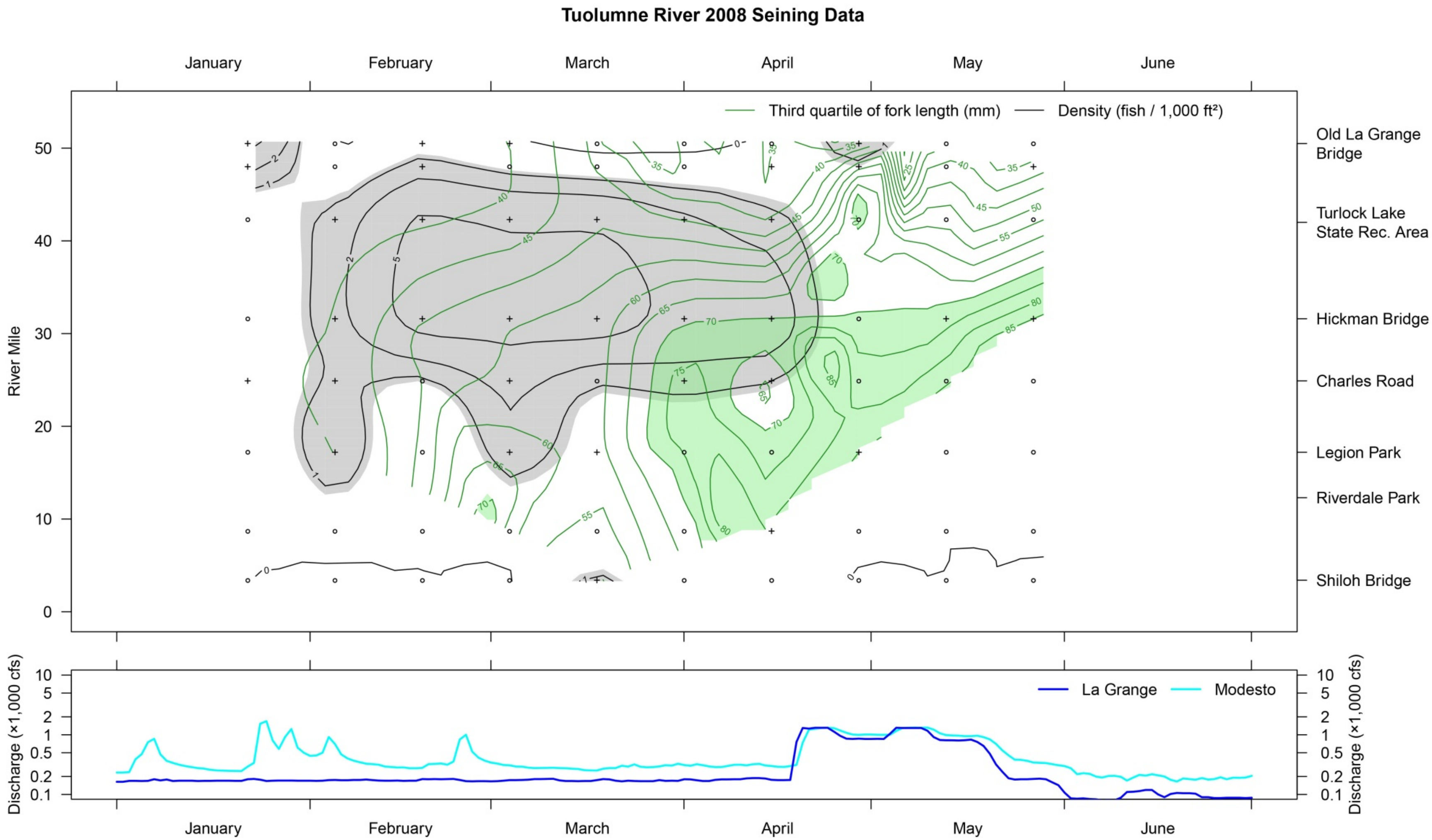

Figure B-10. 2008 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

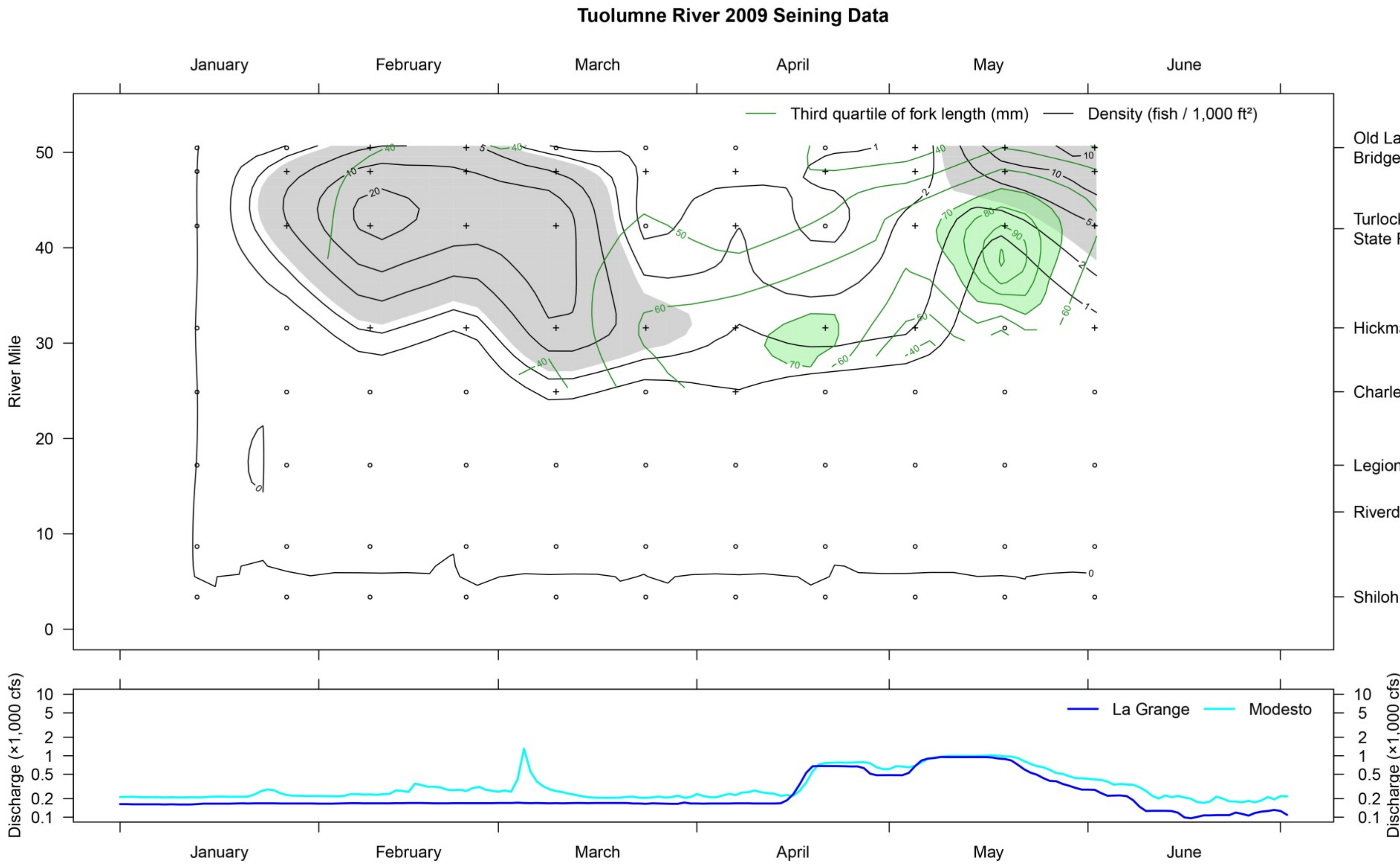

Figure B-11. 2009 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

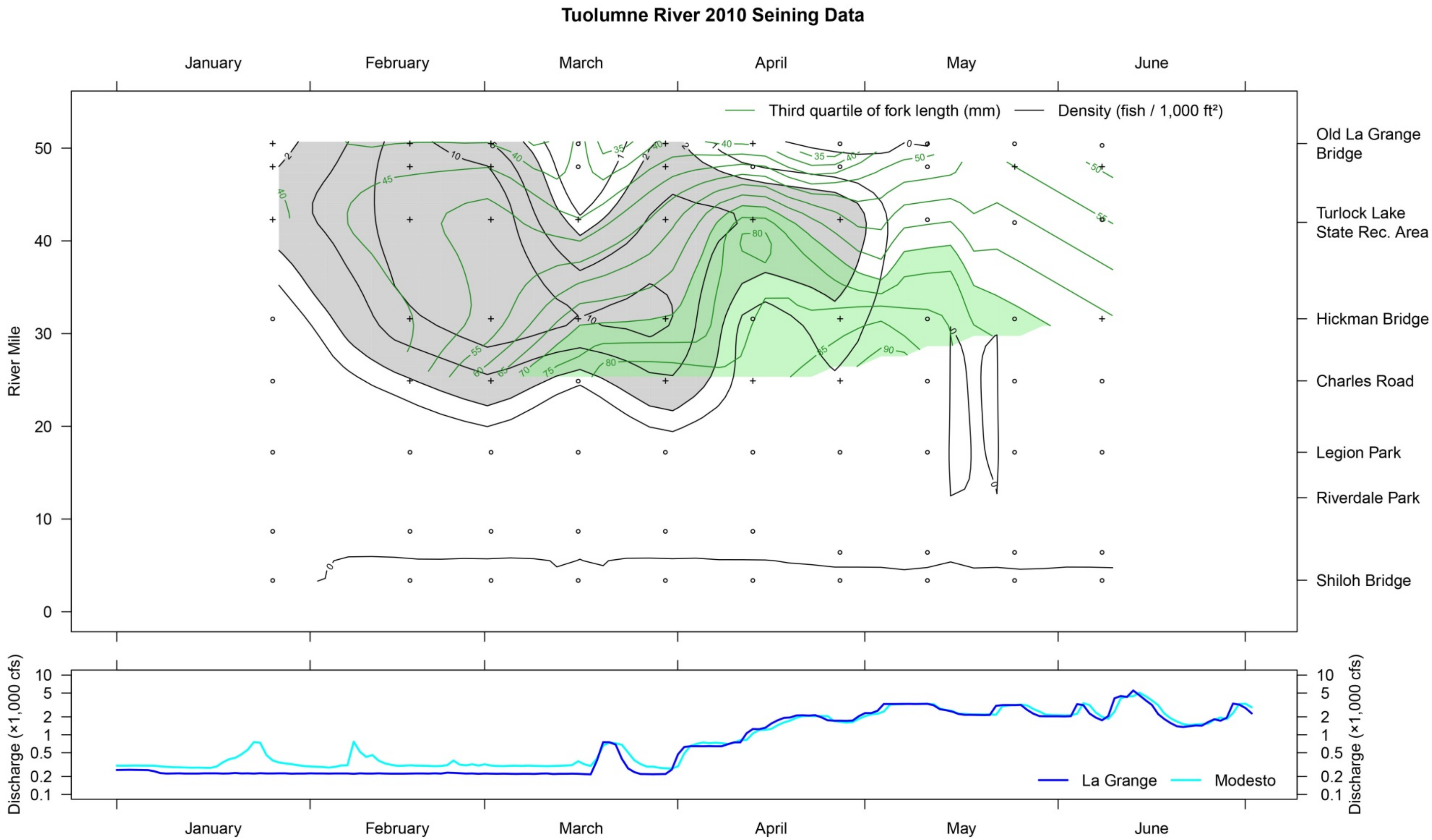

Figure B-12. 2010 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

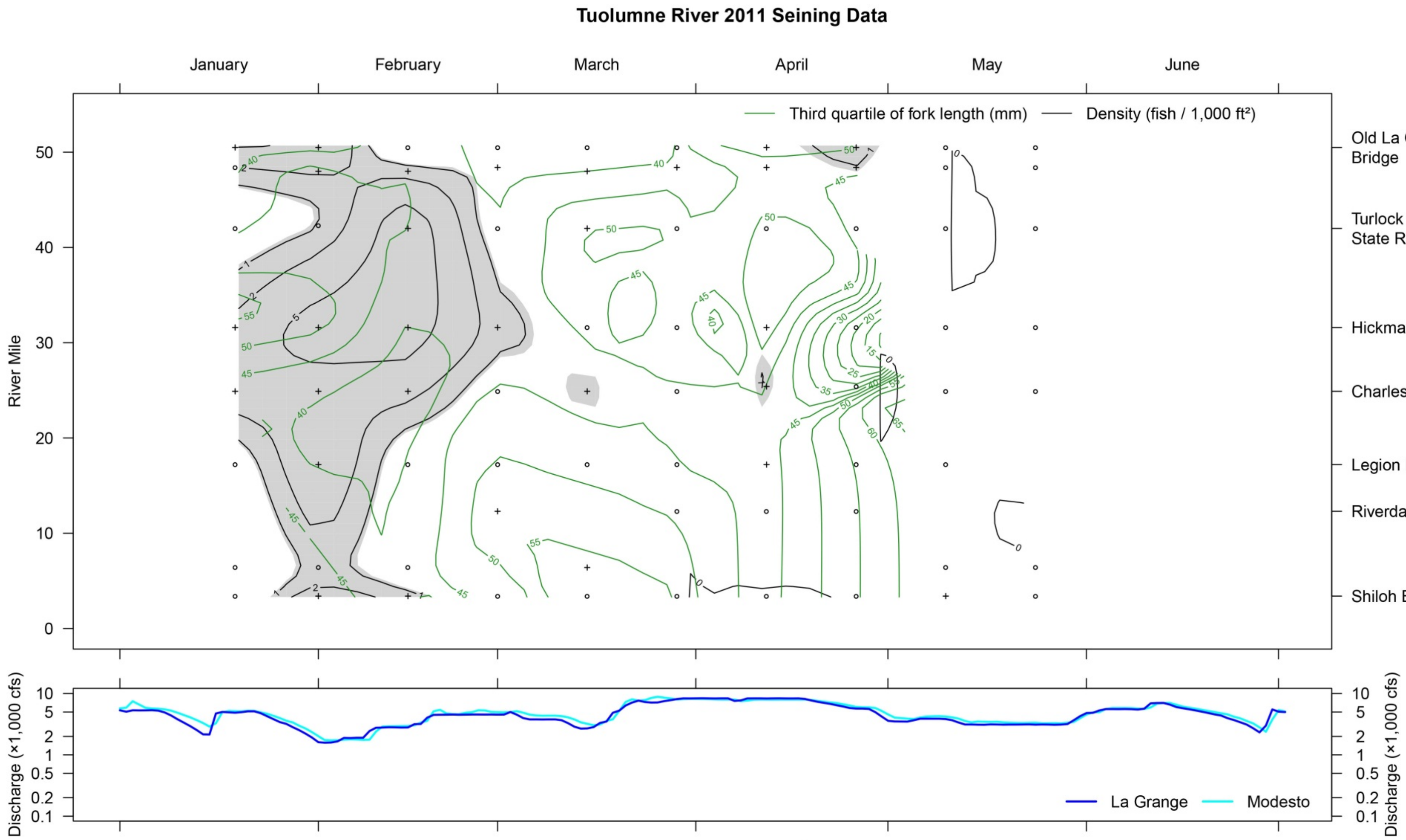

Figure B-13. 2011 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

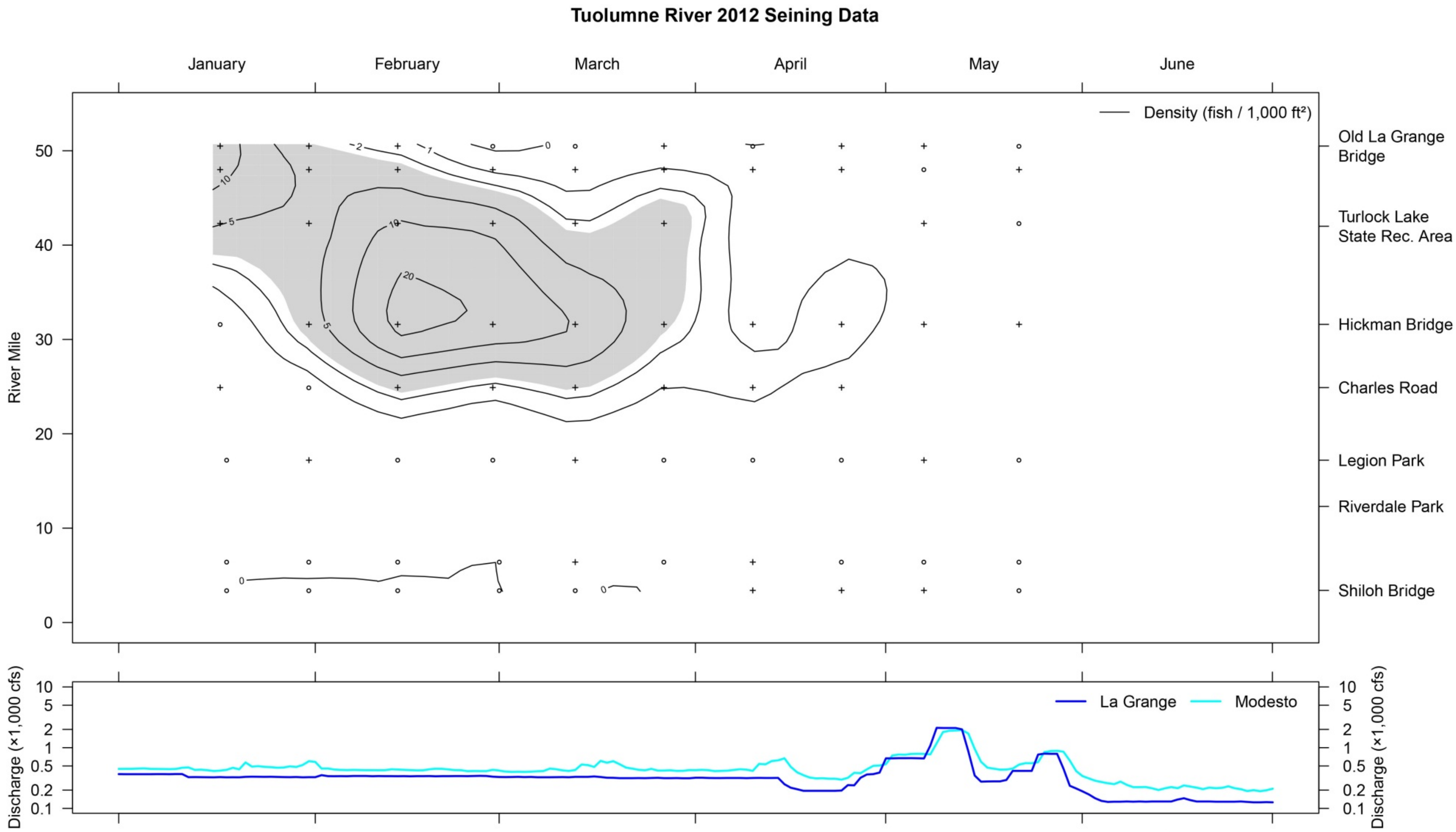

Figure B-14. 2012 Seining Density and Fork Lengths of Chinook Salmon by location and Date with Discharge in the Tuolumne River

(Note: Upper quartiles shaded for juvenile density [grey] and fork length [green])

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Attachment C

Analysis of Tuolumne River rotary screw trap data to examine the relationship between river flow and survival rates for smolts migrating between Waterford and Grayson (2006–2012)

Analysis of Tuolumne River Rotary Screw Trap Data to examine the relationship between river flow and survival rates for Chinook smolts migrating between Waterford and Grayson (2006-12)

Prepared by

Dave Robichaud and Karl English

LGL Limited

9768 Second Street, Sidney, BC, Canada, V8L 3Y8

Introduction

The completion of the *Chinook Salmon Population Model Study* for the Tuolumne River requires an estimate of the survival rate for Chinook salmon smolts as they migrate from upstream rearing areas to the mouth of the Tuolumne River. A preliminary examination of the Waterford and Grayson rotary screw trap (RST) catch and river flow data suggested a more detailed data review and analysis should be conducted to examine seasonal passage estimates as well as to provide a RST-based relationship between apparent smolt survival and river flow. The following data were provided to LGL for these analyses:

1) The number of Chinook fry, parr and smolts caught each day by the Waterford (2006-2012) and Grayson (1999-2012) RSTs;
2) Daily estimates of the river flow at Waterford and Grayson in cubic feet per second (cfs);
3) Daily instantaneous river velocity measurements at Waterford and Grayson in feet per second;
4) Daily estimates of the % of flow sampled by each trap at Waterford (n=1) and Grayson (n=2);
5) All available mark-recapture estimates of trap efficiency and % flow sampled for the Waterford and Grayson RSTs; and
6) Daily instantaneous turbidity measurements and daily average water temperatures at the Waterford and Grayson RST locations.

All of these data were provided by FISHBIO (Andrea Fuller, FISHBIO, pers. comm.). The methods used to collect these data are described in annual reports prepared by FISHBIO (e.g., Sonke and Fuller 2013).

Methods

Catchability vs. Flow Relationships

From 1999 to 2012, 159 separate mark-and-recapture trials were conducted, including 81 at Waterford and 78 at Grayson (Appendix Tables 1 and 2). In each trial, Chinook salmon fry, parr, and smolts were collected from the RSTs or obtained from Merced River Hatchery, and were marked and released upstream of the rotary screw trap. The total numbers of marked fish released were adjusted for dye retention rates to produce an estimate of the effective number of marks released that would be available for recapture in the RSTs. The catch in the trap was examined for several subsequent days, and all marked individuals were counted and at least a sub-sample were measured.

Daily average flow values for the Tuolumne River at La Grange were obtained from a USGS website[1], and were used to represent river flow at the Waterford RST. Daily average flow data for the Tuolumne River at Modesto were obtained from another USGS website[2], and were used to represent river flow at the Grayson RSTs. The Modesto flow station was below Dry Creek, the largest seasonal tributary entering the river downstream of La Grange Dam. As a result, that site includes flow associated with major winter runoff events.

For each experimental trial, the mean fish length at release and recapture were calculated. For each trial (i) at each trap (t), the percent of flow sampled (Φ_{ti}) was calculated as the ratio of flow through the RST ($F_{RST_{ti}}$) to that of whole-river flow ($F_{RIVER_{ti}}$):

$$(\Phi_{ti}) = F_{RST_{ti}} / F_{RIVER_{ti}} \quad \text{(Eq. 1)}$$

Flow through each RST was calculated by multiplying the water velocity at the RST by the surface area of the trap. Catchability was calculated as the proportion of the total adjusted number of individuals released that were recaptured. The mean length at release was used to separate the trials into those that indicated catchability of fry (mean length at release < 50 mm), parr (50 ≥ length < 65 mm) or smolts (≥ 65 mm). Length thresholds were determined by plotting the polymodal distribution of mean lengths over the 159 trials, and selecting break-points where natural breaks (i.e., 'troughs') occurred in the distribution. A decision was made to use 65 mm as the threshold for the 'parr to smolt' transition instead of the more typical size threshold of 70 mm because few migrants occurred in the 65-70 mm size class interval, and because use of the 70 mm threshold would have limited the number of smolt experimental trials by 1 at Waterford, and by 8 at Grayson.

For each life stage (s) at each trap (t), if sample-size sufficed, catchability (C_{tsi}) was regressed against percent of flow sampled (Φ_{ti}) during trial i. Both linear and non-linear curve-fitting procedures were used. Linear regression was used to estimate the slope of the line (m_{ts}), with the intercept forced through 0, as

$$C_{tsi} = (m_{ts} \cdot \Phi_{ti}) \ . \quad \text{(Eq. 2)}$$

For non-linear fitting procedures, cumulative Weibull curves,

$$C_{tsi} = 1 - e^{-(\frac{\Phi_{ti}}{\lambda_{ts}})^{k_{ts}}} \ , \quad \text{(Eq. 3)}$$

were fit to the data by estimating the parameters λ_{ts} (scale) and k_{ts} (shape) using an iterative least squares algorithm. For each life stage at each trap, ANOVA was used to compare the residual sum of squares between linear and non-linear model fits. Alternative analyses were performed to examine the effects of flow or turbidity on catchability, but these analyses were not further pursued since some non-linear fits failed to converge, and some independent variable distributions were highly skewed.

[1] http://waterdata.usgs.gov/ca/nwis/dv/?site_no=11265000&agency_cd=USGS
[2] http://waterdata.usgs.gov/ca/nwis/dv/?site_no=11290000&agency_cd=USGS

Passage Estimation

During 2006 and from 2008 to 2012, , RSTs were operated at Waterford and Grayson from at least January 29 through May 29, and in many years sampling extended earlier or later. During 2007, sampling at Waterford began in January, but was not initiated at Grayson until March. Daily counts of fry, parr, and smolts were tallied at each trap for all days sampled in each year. The percent of the flow sampled was estimated for each day at each trap as described above. Missing velocity observations were interpolated from adjacent values (except during two long data gaps in 2010: linear regressions were performed on the available 2010 data to estimate missing velocity values from flow). Instantaneous measurements of turbidity were also recorded daily at the traps, and daily average water temperatures were obtained from hourly recording thermographs deployed at or near each trap site.

On any given day, catchability was not expected to be 100%, and fish certainly passed the traps without being counted. Life-stage-specific catchability was to be used to calculate total passage from the numbers counted, but scaling was not possible when zero catches were recorded on a particular day. Since catchability was relatively low throughout the study, zero catches of certain life stages were not uncommon. Moreover, total catch could not be taken at face value, as each life stage was expected to have differing catchability.

To account for varying catchability, a four-stage process was used to estimate total fish passage (N) from catch numbers, as follows. First, proportional catch contributions (ρ_{jw}) were calculated for the three life stages for each week (w) as:

$$\rho_{tsw} = \frac{A_{tsw}}{\sum_s^3 A_{tsw}} \qquad \text{(Eq. 4)}$$

where

$$A_{tsw} = \frac{\sum_d^7 O_{tswd}}{\left(m_{ts} \cdot \frac{\sum_d^7 \Phi_{twd}}{7}\right)} \qquad \text{(Eq. 5)}$$

and where O_{tswd} was the observed catch of life stage s at trap t on day d in week w, and Φ_{twd} was the percent flow sampled by trap t on day d in week w. Then, average catchability was calculated for each day at each trap, weighted by the proportional life-stage-specific catch contributions, as:

$$\overline{C_{twd}} = \sum_s^3 \left[\rho_{tsw} \cdot (m_{ts} \cdot \Phi_{td}) \right] \ . \qquad \text{(Eq. 6)}$$

Third, daily total Chinook passage was calculated by dividing total observed catch (of all life stages combined) by the weighted average catchability:

$$N_{twd} = \frac{\sum_s^3 O_{tswd}}{\overline{C_{twd}}} \ . \qquad \text{(Eq. 7)}$$

Lastly, the daily total Chinook passage was partitioned into the three life stages, based on the proportional catch rates from Equation 4:

$$N_{tswd} = N_{twd} \cdot \rho_{tsw} \ . \qquad \text{(Eq. 8)}$$

If total fish passage on a given day was below the level of measurement error (i.e., the inverse of catchability for that day), this method produced passage estimates of zero fish.

Smolt Survival Estimation

Using daily smolt passage estimates, as calculated above, the proportion of smolts that passed Waterford and subsequently survived to pass Grayson were used to provide RST-based smolt survival estimates. The 2006 data were excluded because of a substantial gap in sampling at Waterford near the peak of the smolt migration period (12-21 April). The 2010 and 2011 data were included to allow construction of survival estimates across a broader flow range. However, since substantial numbers of fry appeared to rear at locations downstream of Waterford, the resulting survival estimates may be biased high by smolts originating in the Waterford to Grayson reach. Based upon the relative timing of apparent peaks in daily smolt counts at the two traps, the Grayson data were lagged by two days to account for the timing of fish passing Waterford that are expected at Grayson. Total smolts at Grayson were then divided by the number that passed Waterford to calculate survival in that stretch of river.

To analyze the apparent smolt survival as a function of flow, daily average flow data from each year were plotted, and changes in flow rate were used to divide each year into periods of relatively uniform flow (Figure 1). During each flow period, the total number of smolts passing each trap site was calculated. Flow periods prior to March were excluded because the sample sizes for these periods were very small and the smolts migrating downstream during these periods were often much larger than those migrating during the primary migration period of April- May. During each flow period, the average turbidity, and average flow at LaGrange were calculated.

Survival was modeled as a function of average flow using several different methods. Linear regressions were performed on the untransformed and on arcsine transformed survival data. The data were also fitted with general linear models (GLMs) that assume a binomial error structure and that use a logit link function (Crawley 2007). The S-shaped curves that are fit by GLM and the arcsine transformed linear model are desirable since survival values are bounded by 0 and 1. Also, since each fish could either survive or not survive, the binomial error structure was the most appropriate for the GLM. We originally proposed to use the methods described in Schnute and Richards (1990) for fitting survival data to a family of six curves. However, further examination of the data showed that there was not sufficient range in the survival and flow estimates to distinguish among the six alternative survival curves.

Multivariate general linear models with binomial error structure and logit link function were used to fit survival as a function of flow (from LaGrange), temperature and turbidity (both from Waterford), and abundance (numbers of smolts estimated past Waterford).

Passage During First Pulse Flow Event

Changes in flow in the Tuolumne River have been hypothesized to provide an environmental cue to initiate downstream movement of salmon smolts. Regulated flows may include ‘pulse flow events’ where flows increase suddenly and are sustained at an elevated level over several days to stimulate downstream movements. To examine whether there were consistent numbers of fish travelling throughout each pulse flow event or whether the majority passed at the start of the pulse, we calculated fish responses to pulse flows. For this analysis, the first pulse flow event that occurred during the smolt emigration period of each year was examined. Figure 1 shows that there were identifiable pulse flows in 2007 (Flow Period b), 2008 (Period d), 2009 (Period c) and 2012 (Period g). Data from

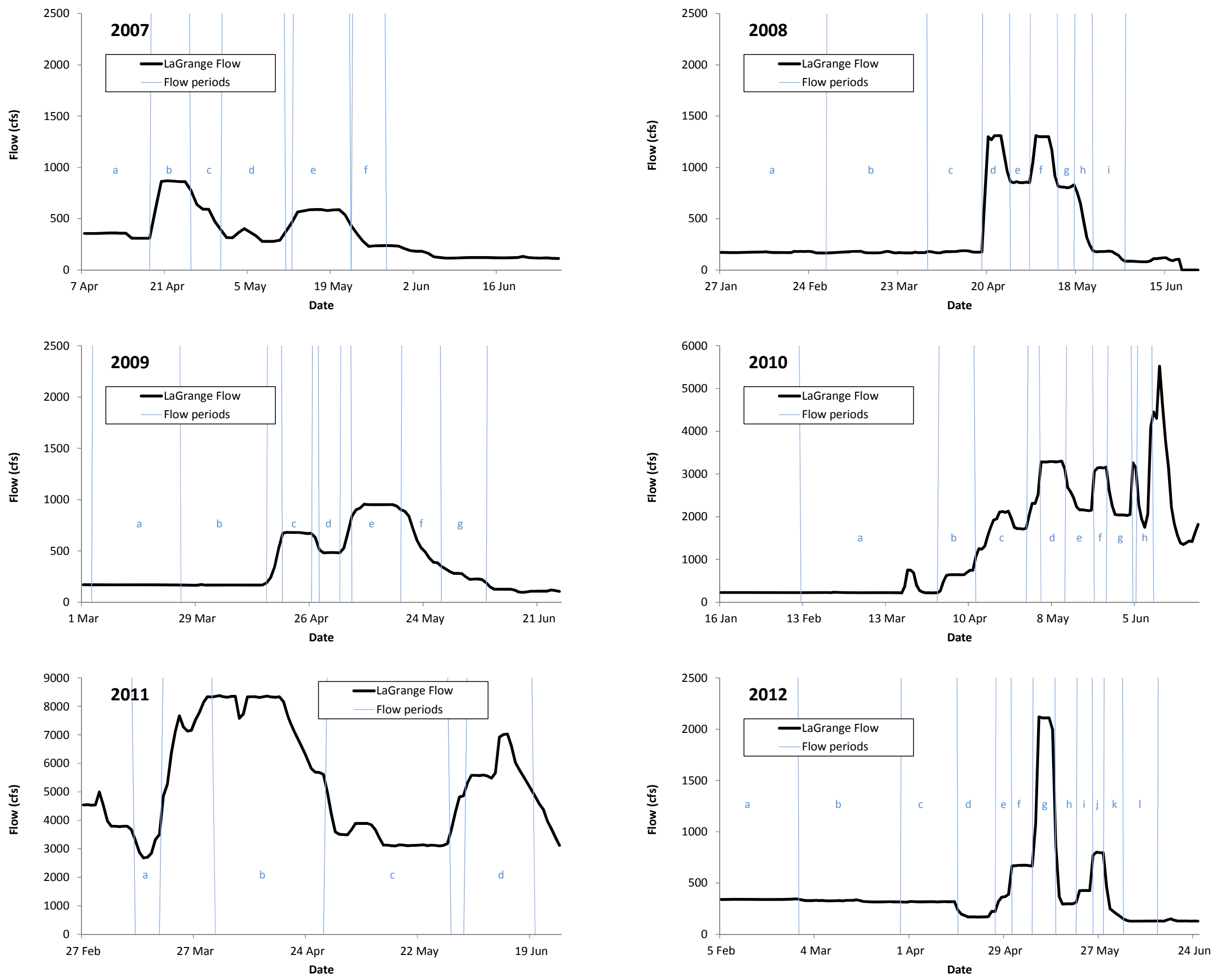


Figure 1. **Daily Flow (cfs) measured at LaGrange during the smolting periods in 2007-2012. Each study year has been divided into periods (labelled with letters) based on flow characteristics. Data periods without labels were not included in the analyses. The X and Y axis scales vary among figure panels.**

other years were excluded from the analysis. The numbers of fish that passed Waterford on each day from the start of the pulse flow event until the end of the pulse event were tallied. The daily percent of total-event-passage was calculated for each pulse, and presented as daily cumulative proportions.

Statistical Methods

For GLMs, data were considered overdispersed when the residual deviance was much greater than the degrees of freedom. In such cases, GLMs were recalculated, using the 'quasibinomial' error distribution, which fits an additional 'dispersion' parameter, allowing for more accurate model output. R^2 approximations were calculated for GLMs as the squared correlation between the predicted and observed values. All statistical analyses were carried out using R (R Core Team 2013).

Results

Catchability vs. Percent Flow Relationships

The total number of experimental trials for which percent flow and catchability could be calculated was 143 (Appendix Tables 1 and 2). This included 60 fry, 3 parr, and 17 smolt trials at Waterford, and 15 fry, 8 parr, and 40 smolt trials at Grayson. Sample sizes for parr were considered inadequate for robust curve fitting

Curve fits and parameter estimates for each trap, life stage and model are shown in Figure 2 and Table 1, respectively. In no case was there a significant difference between linear and non-linear model fits, thus the simpler (linear) model was selected as the more parsimonious (slopes for parr were set as the mean of those of fry and smolts). Despite the two curves being very similar within the observed range data (Figure 2), the predicted values differed more widely at higher percent flows. Thus, blind extrapolation of these curves beyond the range of the currently available percent flow data is not advisable; and more work will be needed to determine the shape of the curves in high percent flow conditions.

Table 1. **Parameter estimates from linear and non-linear models fitting fry and smolt catchability to percent flow at two RST sites (Waterford and Grayson). For each site and life stage, ANOVA (df = 1) was used to compare residual sum of squares between the two model fits. See text for parameter definitions.**

Rotary Screw Trap, t	Chinook Life Stage, s	Non-linear Model Parameters		Linear Model Parameter	ANOVA (Non-linear vs. Linear)	
		k_{ts}	λ_{ts}	m_{ts}	F	P
Waterford	Fry	0.68	4.37	0.60	1.65	0.204
	Smolt	0.75	9.72	0.28	0.32	0.578
Grayson	Fry	0.40	78.65	0.53	4.18	0.062
	Smolt	1.31	1.77	0.28	1.26	0.270

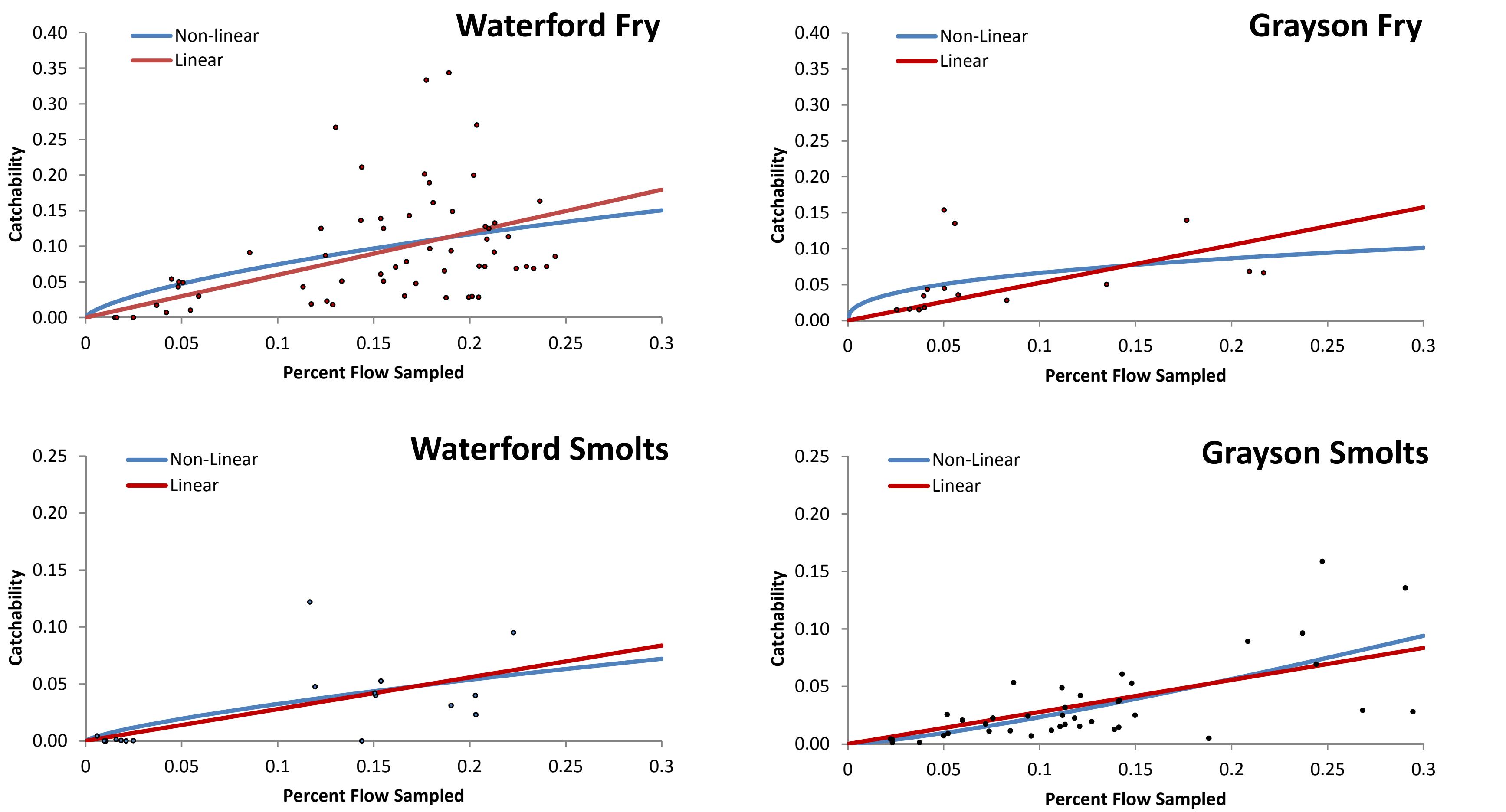


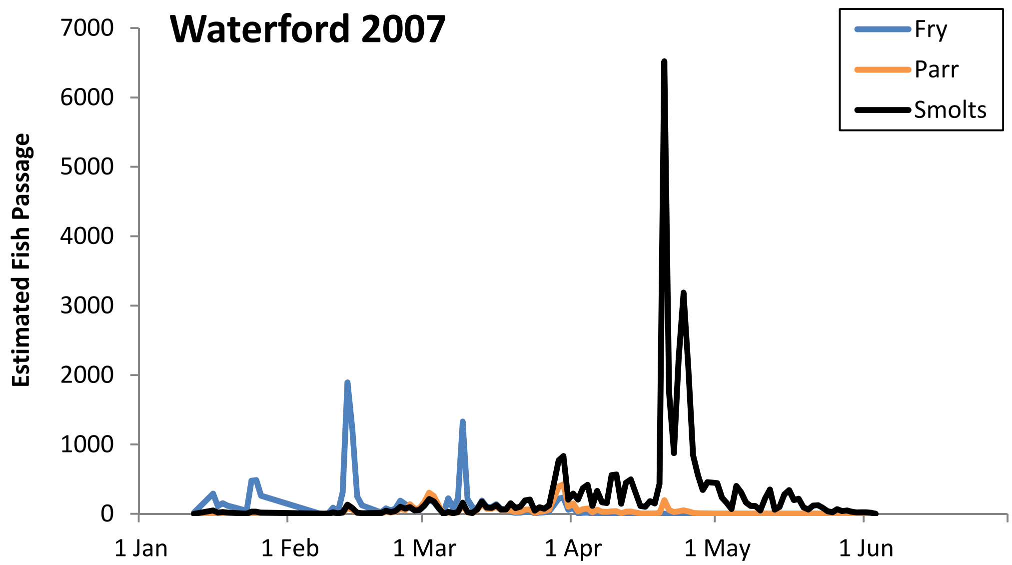
Figure 2. **Fry and smolt catchability as a function of the percent flow sampled at two RST sites (Waterford and Grayson). Linear (no intercept) and non-linear (cumulative Weibull) models were fit to each of the datasets. The Y axis scale varies among the figure panels.**

Estimated Passage

Daily total numbers of fry, parr and smolts that were estimated to have passed Waterford and Grayson from 2006 to 2012 are shown in Figure 3 to Figure 8. Total annual passage tallies are shown in Table 2. Daily and annual tallies differ from those presented previously (e.g., Sonke and Fuller 2013) primarily due to differences in the methods used to estimate catchability from the available data.

Table 2. Annual passage estimates for fry, parr and smolts at Waterford and Grayson (survey periods varied among traps years and between traps).

	Waterford				Grayson			
Year	Survey Period	Fry	Parr	Smolts	Survey Period	Fry	Parr	Smolts
2007	1/12 - 6/5	11,090	4,911	34,572	3/24 - 5/29	0	0	952
2008	1/8 - 6/2	17,806	1,921	29,800	1/29 - 6/4	1,251	25	1,744
2009	1/7 - 6/9	17,492	7,306	29,719	1/8 - 6/11	57	138	3,877
2010	1/5 - 6/10	10,595	1,049	62,876	1/6 - 6/17	92	0	1,964
2011	12/4/'10 - 6/30	284,444	5,689	74,494	1/6 - 6/30	71,071	2,130	21,955
2012	1/3 - 6/15	29,907	7,568	24,601	1/3 - 6/15	72	10	2,186



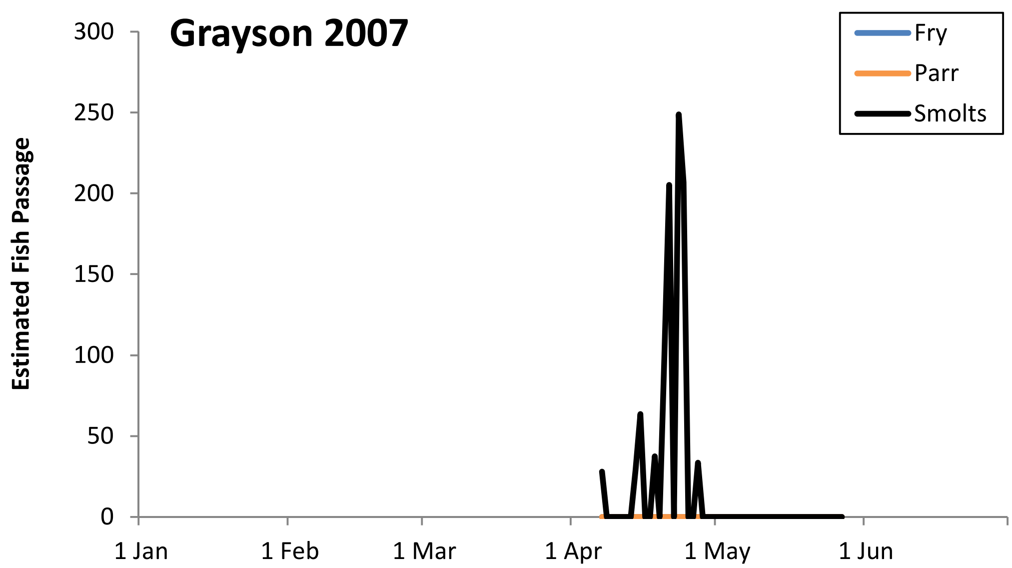
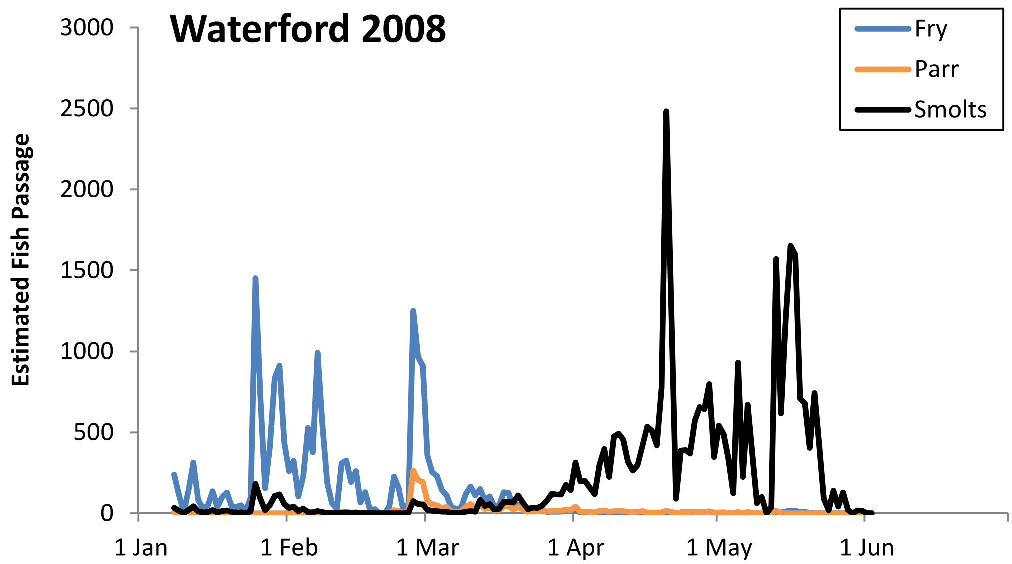


Figure 3. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2007. Grayson data are lagged by two days.**



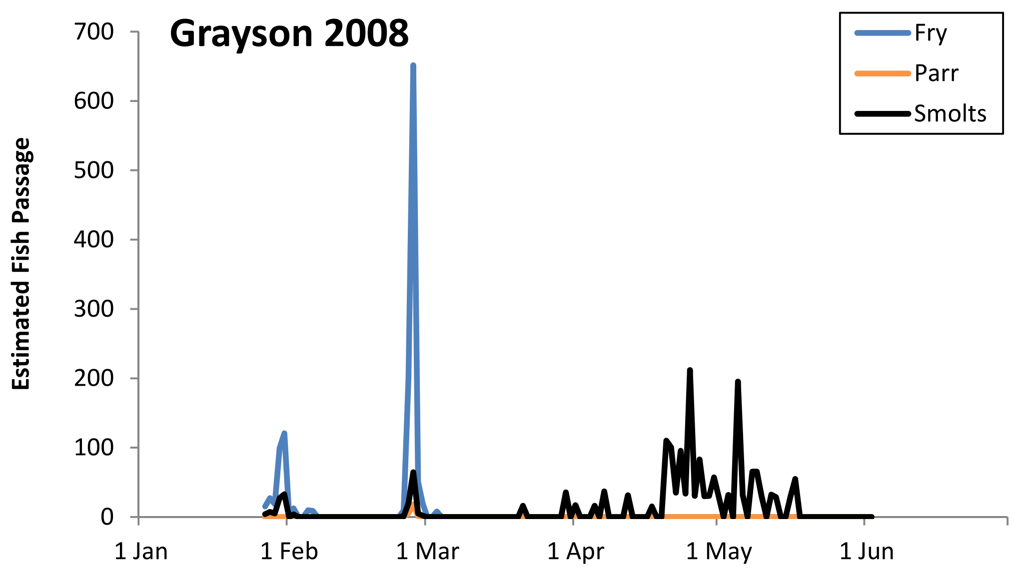
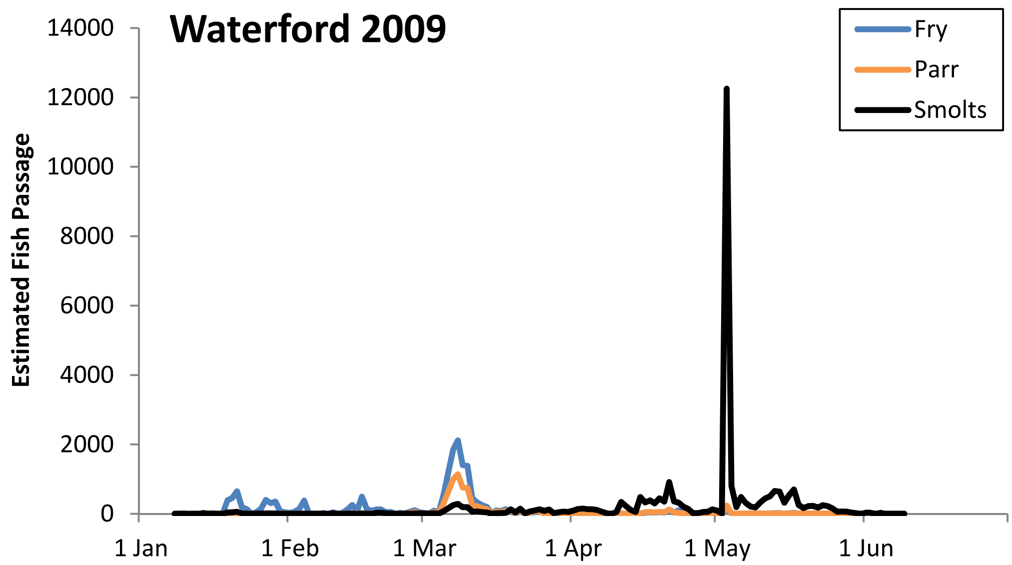


Figure 4. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2008. Grayson data are lagged by two days.**



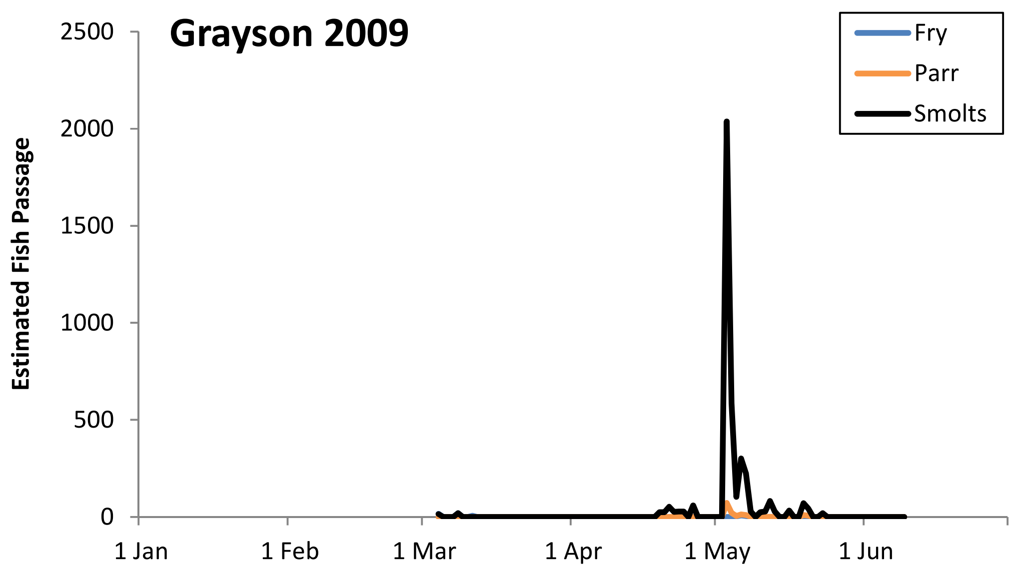
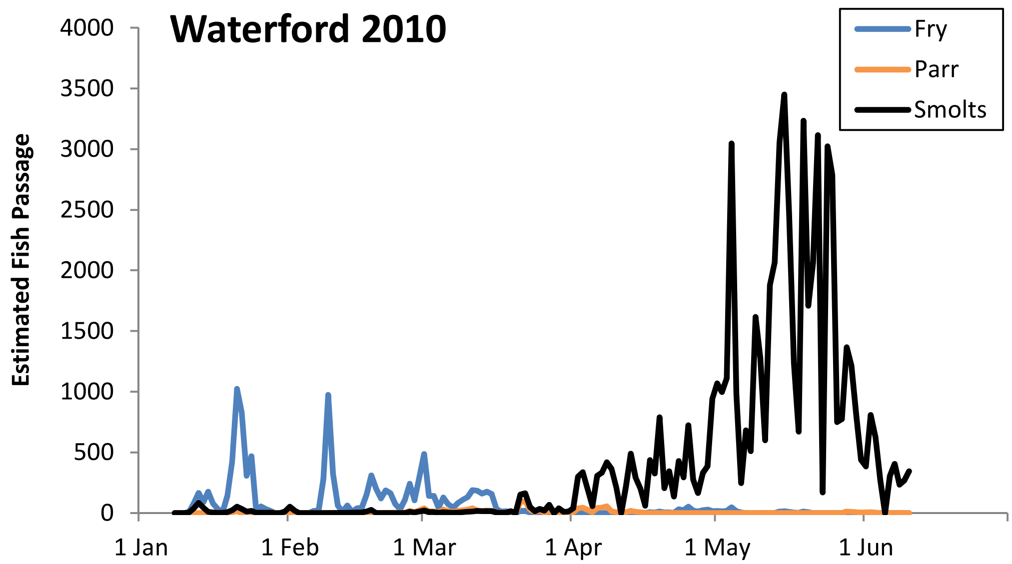


Figure 5. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2009. Grayson data are lagged by two days.**



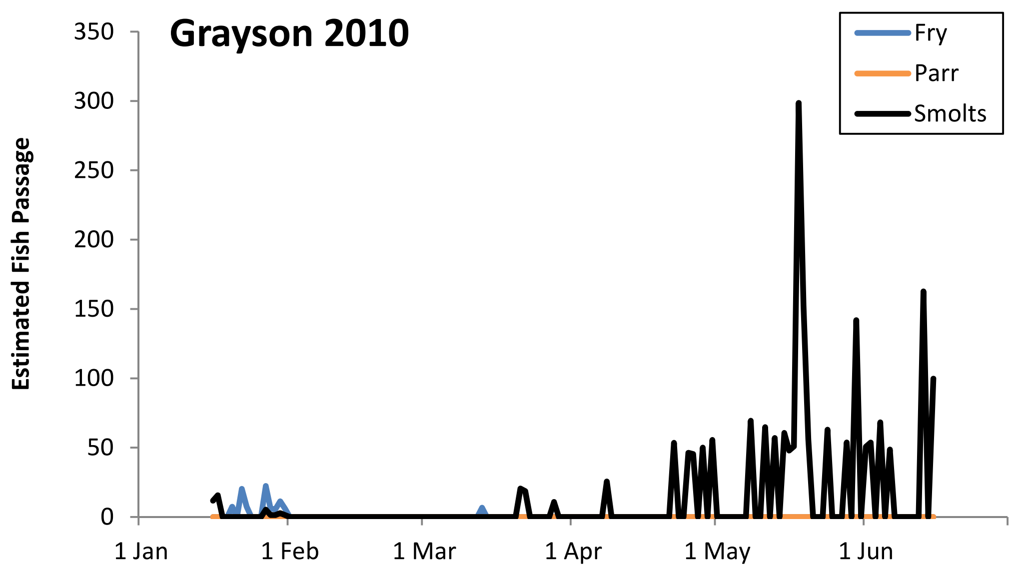
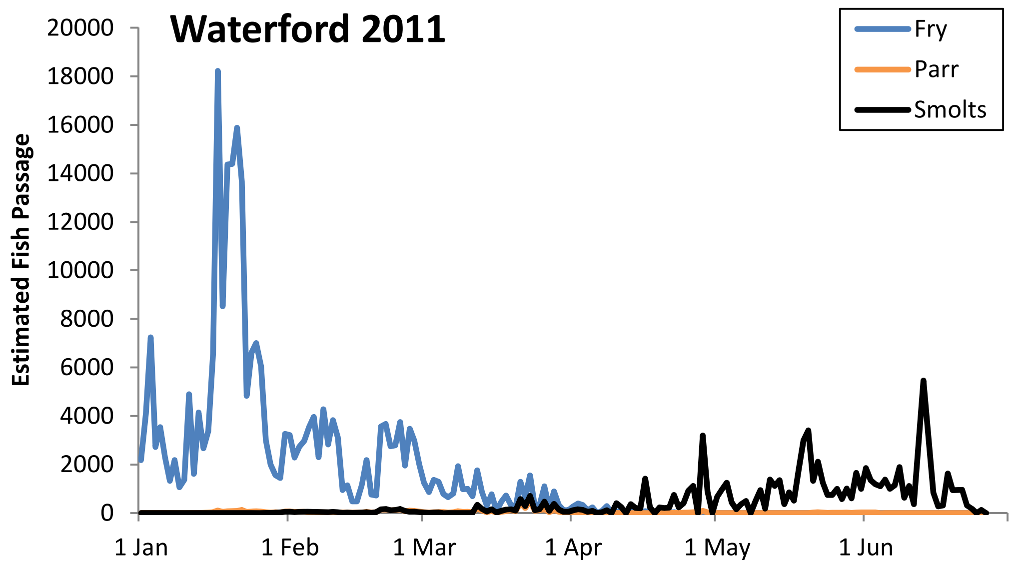


Figure 6. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2010. Grayson data are lagged by two days.**



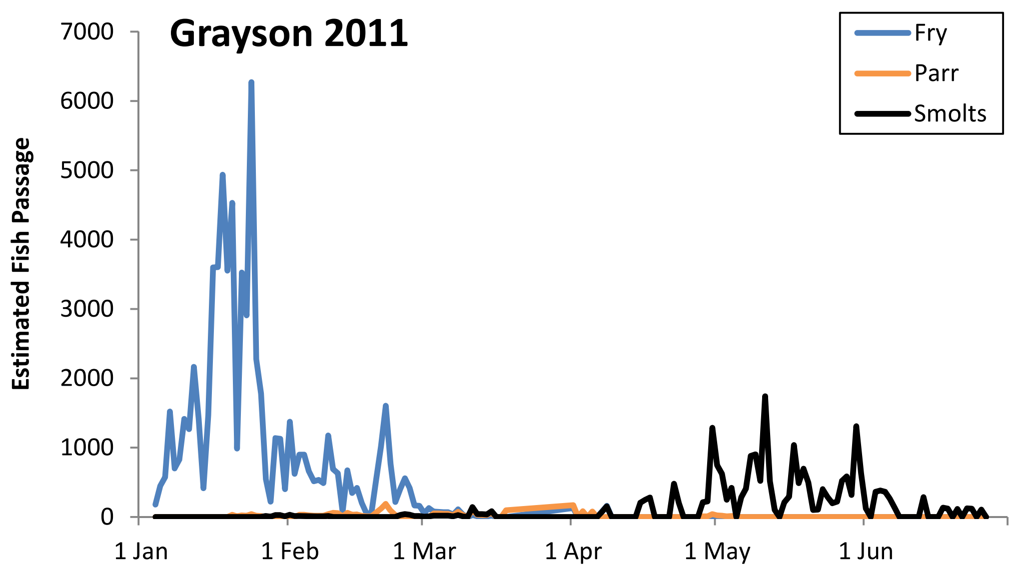
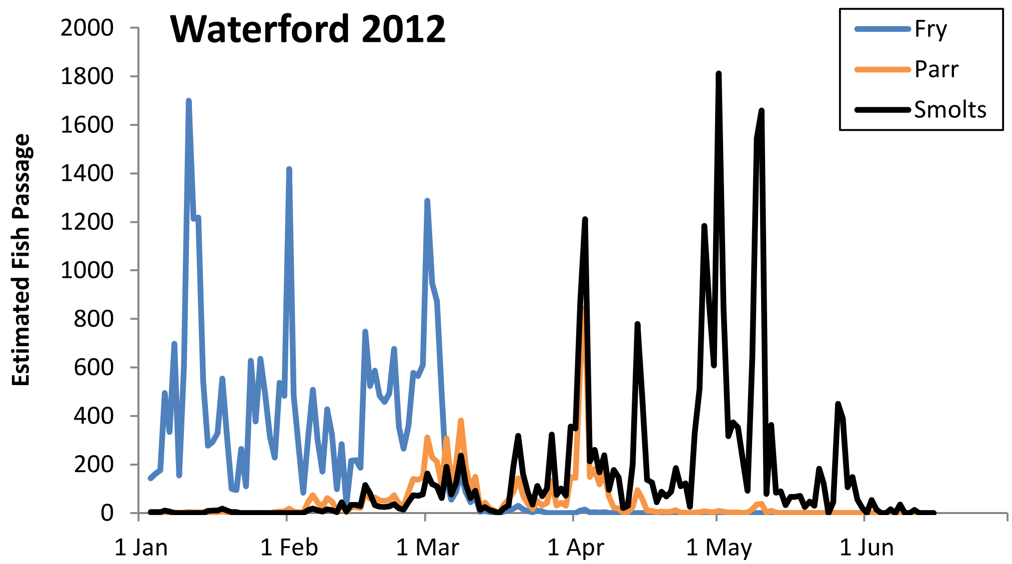


Figure 7. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2011. Grayson data are lagged by two days.**



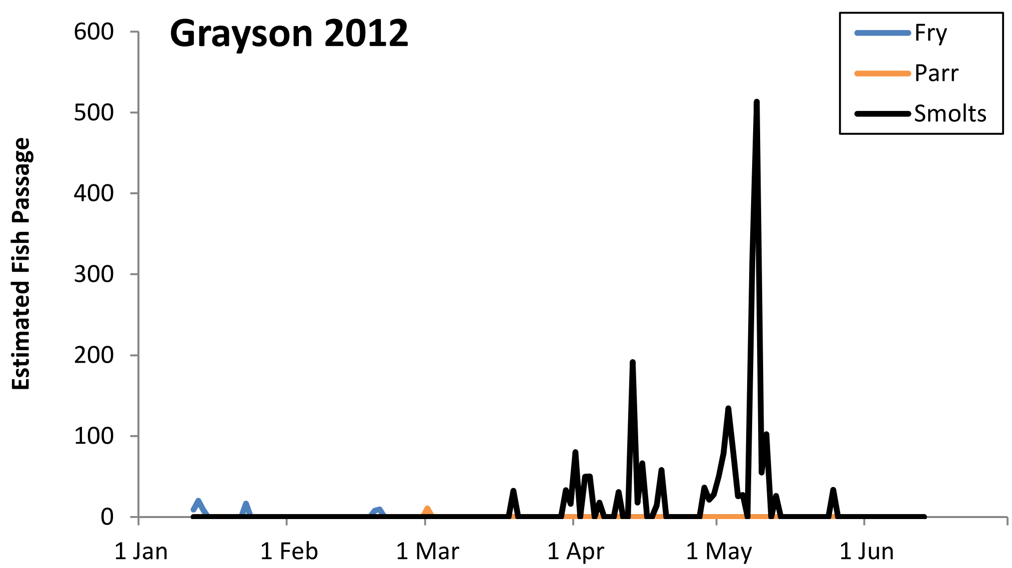


Figure 8. **Estimates of daily passage numbers for fry, parr and smolts at Waterford and Grayson in 2012. Grayson data are lagged by two days.**

Smolt Survival Estimation

Table 3 shows the total number of smolts that passed each trap, along with estimated survival from Waterford to Grayson, and mean flow, water temperature, and turbidity during each of the flow periods in 2007 to 2012. Survival ranged from 0% during many of the flow periods, to a high of 49.4% at a flow of 3,435 cfs during 29 April to 29 May 2011 (Table 3).

The linear relationship between survival and mean flow had a slope of 2.38 x10^{-5} (P = 0.002; R^2 = 0.20). The slope of the arcsine-transformed model was (in transformed units) 4.90 x10^{-5} (P = 0.001; approximate R^2 = 0.16). For the univariate GLM, the survival data were originally fitted to the mean flow data using a binomial error structure. However, the data were overdispersed, so the GLMs were recalculated using a 'quasibinomial' fit. The univariate GLM showed that flow was a statistically significant factor predicting survival (P = 0.015; Figure 9). The predictive equation for the univariate GLM was

$$Survival = \frac{1}{1 + e^{-(-2.551 + (0.000229 \cdot Mean\ Flow))}} \,. \qquad \text{(Eq. 10)}$$

The approximate R^2 of the univariate model was 0.16. The effect of the exclusion of the single highest survival point (49.4% in 2011) resulted in improved fits (linear R^2 = 0.21; arcsine approximate R^2 = 0.19; GLM approximate R^2 = 0.20) and shallower slopes (i.e., lower predicted survival values; linear slope = 1.66 x10^{-5}; arcsine slope = 4.00 x10^{-5}; GLM coefficients: -2.96 and 0.000148).

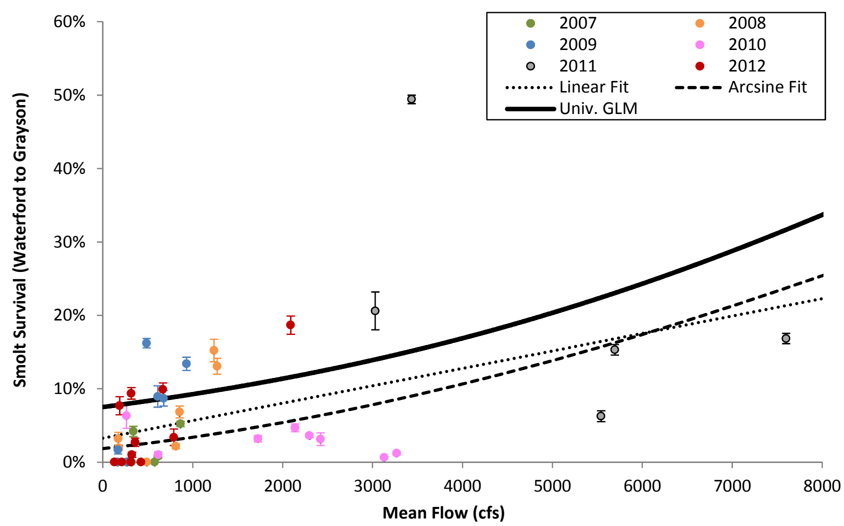


Figure 9. **Survival from Waterford to Grayson, as a function of mean flow (discharge measured at LaGrange). Linear regressions on the raw (R^2 = 0.20) and arcsine transformed (approximate R^2 = 0.16) survival data are shown, along with the results of the univariate quasibinomial general linear model, with approximate R^2 = 0.16.**

The multivariate quasibinomial GLM showed that abundance was the most important factor (P < 0.0001) predicting survival. No other predictors improved the model (turbidity: P = 0.18; flow: P = 0.56; temperature: P = 0.84). The predictive equation for the final GLM was

$$Survival = \frac{1}{1 + e^{-(-3.51 + (0.000107 \cdot Smolt\ Adundance))}}\ . \qquad \text{(Eq. 11)}$$

The approximate R^2 of the multivariate model was 0.49. However, this model fit was highly sensitive to one data-point with very high abundance and very high survival (Figure 10). With that point removed, abundance was no longer a significant factor ($P = 0.10$), discharge ($P < 0.001$) and turbidity ($P < 0.001$) were statistically significant, and temperature was not ($P = 0.68$). Figure 11 shows the 3-D plane of the fitted relationship between flow, turbidity and survival (with the high abundance data-point removed). The approximate R^2 of the fitted plane was 0.30.

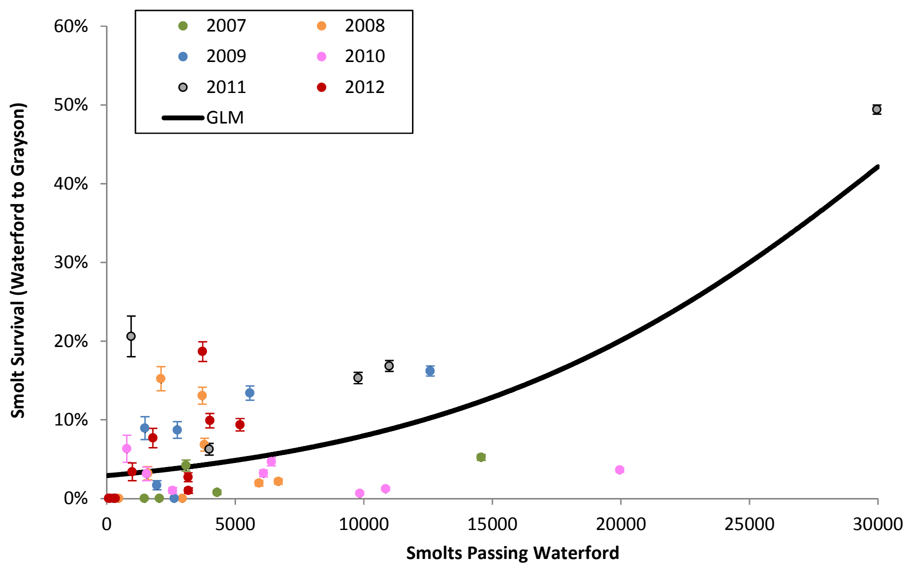


Figure 10. **Survival from Waterford to Grayson, as a function of abundance (number of smolts passing Waterford). Line is the fit from a quasibinomial general linear model, with approximate R^2 = 0.49.**

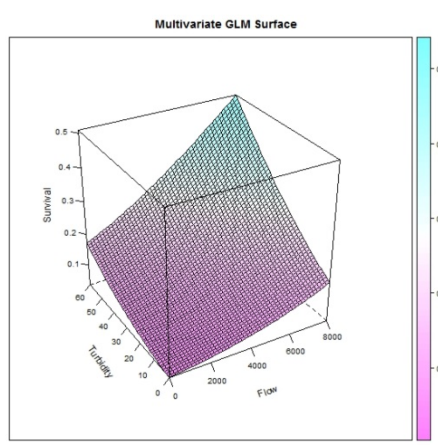


Figure 11. **Survival from Waterford to Grayson, as a function of mean flow (discharge measured in cfs at LaGrange) and turbidity (NTU), as fitted by a multivariate quasibinomial general linear model. One data point with high leverage was removed before fitting this model.**

Table 3. **Total number of smolts estimated to have passed each RST (Waterford and Grayson), survival between the RSTs (with 95% Confidence Intervals), and mean flow, temperature and turbidity during each of the flow periods from 2007 to 2012.**

Interval	Interval Dates (at Waterford)		Estimated Smolt Passage		Survival	Survival (95 % Confedence Interval)		Mean discharge at La Grange	St Dev	Mean Temperature		Mean Turbidity	
	Start	End	Waterford	Grayson	(estimate)	Lower	Upper	(cfs)	(discharge)	Waterford (°F)	Grayson (°F)	Waterford (NTU)	Grayson (NTU)
2007a	7 Apr	18 Apr	3085	129	4.2%	3.5%	4.9%	339.8	24.7	58.7	59.3	0.8	2.8
2007b	20 Apr	24 Apr	14570	760	5.2%	4.9%	5.6%	864.0	3.5	54.8	57.0	1.6	3.1
2007c	25 Apr	29 Apr	4294	33	0.8%	0.5%	1.0%	613.4	108.4	58.4	63.4	1.0	1.9
2007d	1 May	10 May	2049	0	0.0%	0.0%	0.0%	321.7	43.8	60.9	64.2	0.7	2.0
2007e	13 May	21 May	1469	0	0.0%	0.0%	0.0%	577.2	16.7	60.0	64.4	1.0	2.2
2007f	23 May	27 May	252	0	0.0%	0.0%	0.0%	266.8	52.5	64.8	69.6	0.7	1.3
2008b	1 Mar	31 Mar	1606	52	3.2%	2.3%	4.1%	172.0	5.4	58.1	61.2	2.7	4.4
2008c	1 Apr	18 Apr	5923	116	2.0%	1.6%	2.3%	178.8	5.5	61.5	65.4	2.6	4.5
2008d	20 Apr	25 Apr	3719	486	13.1%	12.0%	14.1%	1272.0	79.5	53.8	58.2	2.4	4.2
2008e	27 Apr	3 May	3806	260	6.8%	6.0%	7.6%	854.9	4.9	56.1	61.2	1.4	3.7
2008f	4 May	10 May	2110	321	15.2%	13.7%	16.7%	1236.7	110.0	56.1	61.6	1.4	2.6
2008g	12 May	17 May	6680	144	2.2%	1.8%	2.5%	812.8	9.7	58.4	67.6	1.3	2.4
2008h	18 May	22 May	2945	0	0.0%	0.0%	0.0%	489.8	217.4	60.5	66.1	1.3	3.9
2008i	23 May	2 Jun	465	0	0.0%	0.0%	0.0%	160.6	34.5	65.3	69.6	1.5	3.1
2009a	4 Mar	24 Mar	1953	33	1.7%	1.1%	2.3%	169.1	1.5	57.9	60.5	9.9	16.4
2009b	25 Mar	15 Apr	2627	0	0.0%	0.0%	0.0%	168.2	4.7	60.9	63.9	2.6	5.4
2009c	19 Apr	26 Apr	2746	239	8.7%	7.6%	9.8%	676.3	4.3	57.5	63.5	2.4	7.1
2009d	28 Apr	3 May	12583	2038	16.2%	15.6%	16.8%	487.3	11.1	56.6	62.4	55.4	39.0
2009e	6 May	18 May	5569	746	13.4%	12.5%	14.3%	931.2	34.1	58.1	64.8	3.9	6.7
2009f	19 May	26 May	1486	133	8.9%	7.5%	10.4%	610.9	185.3	60.7	67.9	1.9	4.3
2009g	27 May	8 Jun	266	0	0.0%	0.0%	0.0%	271.5	57.2	66.0	71.8	2.7	6.6
2010a	12 Feb	30 Mar	784	50	6.3%	4.6%	8.0%	263.4	127.6	55.5	57.8	3.0	8.5
2010b	31 Mar	11 Apr	2567	26	1.0%	0.6%	1.4%	616.8	132.0	54.5	56.5	1.1	3.7
2010c	12 Apr	29 Apr	6104	195	3.2%	2.8%	3.6%	1726.7	330.8	53.5	56.3	2.0	3.6
2010d	4 May	12 May	10850	134	1.2%	1.0%	1.4%	3267.8	55.9	53.2	55.4	1.2	1.9
2010e	13 May	21 May	19960	723	3.6%	3.4%	3.9%	2298.9	211.3	54.3	56.5	0.6	1.9
2010f	22 May	26 May	9847	63	0.6%	0.5%	0.8%	3130.0	40.0	53.4	55.7	1.2	2.4
2010g	27 May	3 Jun	6406	300	4.7%	4.2%	5.2%	2138.8	204.0	55.3	60.0	0.5	1.4
2010h	6 Jun	10 Jun	1551	49	3.1%	2.3%	4.0%	2422.0	951.4	56.7	58.9	0.6	3.0
2011a	12 Mar	18 Mar	950	196	20.6%	18.0%	23.2%	3030.0	332.3	50.8	51.5	2.6	3.6
2011b	1 Apr	28 Apr	10991	1850	16.8%	16.1%	17.5%	7600.4	1011.5	51.3	52.3	2.5	3.0
2011c	29 Apr	29 May	29962	14807	49.4%	48.9%	50.0%	3435.5	437.5	52.9	55.2	1.3	2.3
2011d	3 Jun	11 Jun	9778	1497	15.3%	14.6%	16.0%	5695.6	470.0	53.3	55.7	1.5	1.9
2011e	15 Jun	19 Jun	3990	250	6.3%	5.5%	7.0%	5542.0	379.6	54.6	57.2	0.6	2.1
2012b	28 Feb	29 Mar	3181	32	1.0%	0.7%	1.4%	324.6	7.4	55.1	57.6	1.6	3.6
2012c	30 Mar	14 Apr	5186	486	9.4%	8.6%	10.2%	316.8	1.6	57.7	60.8	2.1	5.7
2012d	15 Apr	26 Apr	1798	138	7.7%	6.5%	8.9%	187.2	25.5	66.1	70.6	2.0	4.1
2012e	27 Apr	30 Apr	3168	86	2.7%	2.1%	3.3%	359.5	28.8	62.6	69.6	2.2	4.5
2012f	1 May	7 May	4012	397	9.9%	9.0%	10.8%	669.6	3.0	59.6	65.2	2.7	4.5
2012g	9 May	13 May	3730	696	18.7%	17.4%	19.9%	2090.0	50.5	56.7	60.5	2.2	2.7
2012h	15 May	20 May	307	0	0.0%	0.0%	0.0%	309.8	27.3	64.7	70.6	1.6	4.3
2012i	21 May	24 May	335	0	0.0%	0.00%	0.00%	426.5	0.6	65.0	68.7	1.8	3.2
2012j	25 May	28 May	991	34	3.4%	2.26%	4.51%	790.3	12.4	59.2	65.3	1.5	3.0
2012k	30 May	2 Jun	130	0	0.0%	0.00%	0.00%	210.8	32.4	69.1	74.0	1.4	4.1
2012l	3 Jun	13 Jun	76	0	0.0%	0.00%	0.00%	130.8	6.3	71.9	73.2	1.5	3.3

Passage During First Pulse Flow Event

Four years of data were initially selected for this analysis, however, the first pulse flow peak in 2008 had a data gap on the second day of the pulse (the Waterford RST had shifted out of the thalweg and only fished 424 revs; Andrea Fuller, FISHBIO, pers. comm.), and was excluded. Figure 12 shows the cumulative proportion of fish passing on each day of the first pulse flow event in 2007, 2009 and 2012. On average, 35% of the fish passed on the first day of the event (45% in 2007 and 2012, 16% in 2009). By day three, an average of 66% of the fish had passed (63% in 2007, 62% in 2009, and 74% in 2012). Sample sizes were very limiting for this analysis (i.e., n=3), and results should be interpreted with caution.

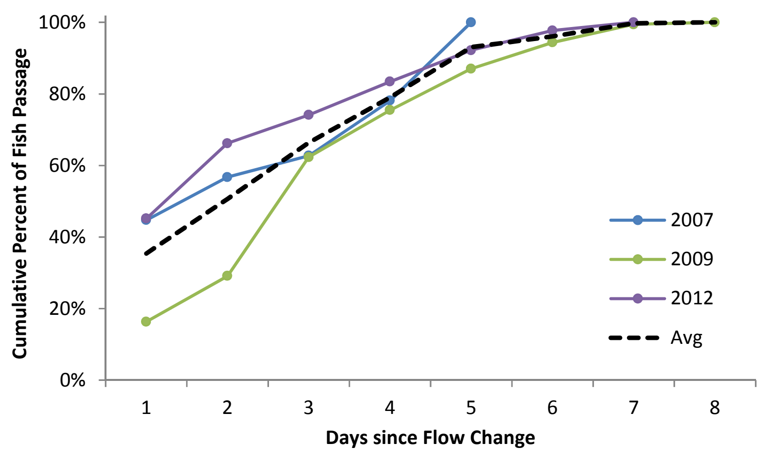


Figure 12. **Cumulative proportion of smolts that passed on each day of the first pulse flow event in 2007, 2009 and 2012, relative to the total number of smolts that passed during the pulse flow event.**

Conclusions

A. There were no significant differences between the linear and non-linear relationships between catchability and % flow, so we used the linear relationship to convert daily estimates of the % flow sampled into daily estimates of RST catchability for each RST site.
B. The relationships between smolt catchability and % flow were very consistent for the Waterford and Grayson RSTs. Catchability of smolts was less than that of fry at all % flow levels, and the effect was more pronounced when greater portions of the total flow were sampled (i.e., the slopes for the smolt relationships (0.28) were lower than those for fry (0.60 at Waterford; 0.53 at Grayson)).
C. There was a positive and significant relationship between survival from Waterford to Grayson and river flow, although the exact relationships were sensitive to outlier values. Abundance of smolts and turbidity also appear to impact survival. Other possible factors, for which we lack adequate data to test, include predator abundance and predation rate.
D. On average, 35% of the fish moved during the first day of increased flows, and 66% moved within the first three days.

Recommendations

1. Further experimentation with flows between 1300 cfs and 8000 cfs (especially between 3500 and 8000 cfs) should be conducted to better define the shape of the 'survival vs flow' relationship above 1300 cfs.
2. To derive more meaningful estimates of the survival rates for pulse flows, additional data are required. To obtain additional survival data, experimental pulse flows should be maintained for 4 days. The available data suggested that, for the first pulse flow event, the daily increment in smolt migration is relatively low after the first 3 to 4 days of elevated flow.
3. For any future smolt-survival experiments conducted during pulse flows, marked smolts should be used to estimated daily capture efficiencies for each RST site during each pulse flow period.
4. Once additional survival estimates have been obtained for periods with flows above 1300 cfs, the curve fitting approach described in Schnute and Richards (1990) may be applied to select between alternative curve forms that best describe the resulting survival versus flow relationship.

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Appendix Table 1. Release and recapture data recorded for each of the 81 catch efficiency experiments conducted at Waterford between 2006 and 2012, along with flow and turbidity data. Experiments with missing %flow data were excluded from analyses.

Release Date	Origin	Size Class	Adjusted Number Released	Number Recaptured	% Recaptured	Length at Release (mm)	Length at Recapture (mm)	Flow (cfs)	% Flow Sampled	Turbidity (NTU)
31 Jan 2006	Wild	Fry	240	13	0.054	35	35	3171	0.045	3.38
8 Feb 2006	Wild	Fry	225	11	0.049	35	35	2940	0.051	2.56
10 Feb 2006	Wild	Fry	120	6	0.050	35	35	3027	0.049	2.29
17 Feb 2006	Wild	Fry	163	7	0.043	34	34	2892	0.048	2.18
6 May 2006	Hatchery	Smolts	778	0	0.000	73	.	8870	0.011	1.35
13 May 2006	Hatchery	Smolts	1581	0	0.000	78	.	8480	0.010	1.31
17 May 2006	Hatchery	Smolts	2442	11	0.005	83	83	8360	0.006	1.67
26 May 2006	Hatchery	Smolts	2326	3	0.001	86	74	6780	0.016	1.41
3 Jun 2006	Hatchery	Smolts	2948	1	0.000	79	80	3243	0.025	1.30
9 Jun 2006	Hatchery	Smolts	2731	0	0.000	85	.	4623	0.021	1.34
15 Jun 2006	Hatchery	Smolts	2163	1	0.000	98	75	4793	0.018	0.59
13 Feb 2007	Wild	Fry	35	1	0.029	35	37	356	0.205	5.13
14 Feb 2007	Wild	Fry	238	23	0.097	35	33	356	0.179	1.48
3 Mar 2007	Wild	Fry	98	7	0.071	46	49	358	0.229	1.41
5 Mar 2007	Wild	Parr	75	3	0.040	56	60	359	0.231	0.62
10 Mar 2007	Wild	Fry	180	13	0.072	38	37	358	0.205	0.35
15 Mar 2007	Wild	Fry	61	4	0.066	36	36	367	0.187	0.75
29 Mar 2007	Wild	Parr	48	3	0.063	57	60	355	0.181	2.88
31 Mar 2007	Wild	Parr	75	3	0.040	58	47	356	0.203	0.52
5 Apr 2007	Wild	Smolts	50	2	0.040	76	75	354	0.203	1.48
11 Apr 2007	Wild	Smolts	63	6	0.095	81	80	361	0.223	0.70
24 Apr 2007	Wild	Smolts	63	3	0.048	82	80	860	0.119	1.42
26 Apr 2007	Wild	Smolts	171	9	0.053	80	79	637	0.154	2.26
13 Jan 2008	Wild	Fry	32	11	0.344	37	37	170	0.189	3.86
26 Jan 2008	Wild	Fry	132	15	0.114	36	36	170	0.220	75.20
27 Jan 2008	Wild	Fry	98	13	0.133	37	37	171	0.213	18.60
31 Jan 2008	Wild	Fry	131	12	0.092	37	38	170	0.213	15.70
1 Feb 2008	Wild	Fry	55	9	0.164	37	37	170	0.236	9.33
6 Feb 2008	Wild	Fry	64	6	0.094	37	37	173	0.190	14.00
13 Feb 2008	Wild	Fry	33	11	0.333	37	37	170	0.177	.
28 Feb 2008	Wild	Fry	140	20	0.143	38	38	167	0.168	13.00
16 May 2008	Wild	Smolts	41	5	0.122	88	88	811	0.117	0.67
20 Jan 2009	Wild	Fry	42	2	0.048	43	35	168	0.172	0.69
22 Jan 2009	Wild	Fry	70	5	0.071	36	36	168	0.208	1.28
28 Jan 2009	Wild	Fry	47	7	0.149	35	35	167	0.191	1.89
30 Jan 2009	Wild	Fry	37	7	0.189	37	36	167	0.179	1.18
6 Feb 2009	Wild	Fry	47	6	0.128	37	37	169	0.208	1.08
16 Feb 2009	Wild	Fry	36	1	0.028	36	36	170	0.188	7.67
21 Feb 2009	Wild	Fry	31	5	0.161	37	37	168	0.181	2.05
6 Mar 2009	Wild	Fry	74	20	0.270	44	44	169	0.204	48.70
9 Mar 2009	Wild	Fry	263	53	0.202	40	45	168	0.176	6.07
13 Mar 2009	Wild	Fry	51	4	0.078	49	49	170	0.167	2.47
20 Mar 2009	Wild	Fry	35	1	0.029	50	34	170	0.199	2.82
21 Jan 2010	Wild	Fry	110	22	0.200	35	35	225	0.202	33.30
22 Jan 2010	Wild	Fry	82	9	0.110	35	35	226	0.209	21.20
9 Feb 2010	Wild	Fry	34	1	0.029	37	40	226	0.201	7.99
10 Feb 2010	Wild	Fry	116	8	0.069	37	37	224	0.233	1.16
19 Feb 2010	Wild	Fry	42	3	0.071	35	32	225	0.240	1.66
20 Feb 2010	Wild	Fry	33	1	0.030	36	35	224	0.166	1.14
23 Feb 2010	Wild	Fry	29	2	0.069	36	37	232	0.224	0.20
1 Mar 2010	Wild	Fry	36	5	0.139	35	36	224	0.154	15.50
2 Mar 2010	Wild	Fry	44	8	0.182	36	36	223	.	5.50
11 Mar 2010	Wild	Fry	32	4	0.125	36	35	225	0.210	1.68
14 Mar 2010	Wild	Fry	35	3	0.086	36	36	222	0.244	1.99

…continued

Appendix Table 1 continued.

Release Date	Origin	Size Class	Adjusted Number Released	Number Recaptured	% Recaptured	Length at Release (mm)	Length at Recapture (mm)	Flow (cfs)	% Flow Sampled	Turbidity (NTU)
12 Jan 2011	Wild	Fry	22	0	0.000	35	.	2940	0.025	2.23
15 Jan 2011	Wild	Fry	142	1	0.007	35	35	2150	0.042	2.57
20 Jan 2011	Wild	Fry	116	0	0.000	35	.	4970	0.015	2.45
21 Jan 2011	Wild	Fry	120	0	0.000	35	.	5130	0.016	2.24
1 Feb 2011	Wild	Fry	96	1	0.010	35	35	1610	0.055	1.71
2 Feb 2011	Wild	Fry	100	3	0.030	38	38	1580	0.059	1.84
9 Feb 2011	Wild	Fry	116	2	0.017	36	36	2450	0.037	1.66
7 Jan 2012	Wild	Fry	38	8	0.211	33.8	33.0	367	0.144	1.16
11 Jan 2012	Wild	Fry	44	6	0.136	36	36.3	368	0.143	0.91
14 Jan 2012	Wild	Fry	66	4	0.061	34.7	35.3	327	0.154	1.09
25 Jan 2012	Wild	Fry	55	1	0.018	34.5	37.0	332	0.129	1.99
27 Jan 2012	Wild	Fry	30	8	0.267	34.5	34.8	328	0.130	2.00
31 Jan 2012	Wild	Fry	42	3	0.071	33.5	34.7	327	0.161	0.25
2 Feb 2012	Wild	Fry	66	6	0.091	36.2	35.2	353	0.085	0.95
7 Feb 2012	Wild	Fry	46	4	0.087	42.3	36.8	342	0.125	1.08
10 Feb 2012	Wild	Fry	39	2	0.051	41.5	29.5	339	0.133	1.03
18 Feb 2012	Wild	Fry	80	10	0.125	42.1	36.2	340	0.155	1.72
21 Feb 2012	Wild	Fry	39	2	0.051	35.4	33.0	340	0.155	0.82
22 Feb 2012	Wild	Fry	43	1	0.023	40.3	31.0	340	0.126	1.28
28 Feb 2012	Wild	Fry	53	1	0.019	44.4	35.0	342	0.118	1.11
29 Feb 2012	Wild	Fry	47	2	0.043	40.3	34.5	333	0.113	1.07
5 Mar 2012	Wild	Fry	32	4	0.125	34.1	34.8	328	0.123	0.25
3 Apr 2012	Wild	Smolts	96	4	0.042	71.3	69.3	317	0.151	0.75
4 Apr 2012	Wild	Smolts	50	2	0.040	67.4	62.0	316	0.151	0.45
15 Apr 2012	Wild	Smolts	43	1	0.023	82.6	75.0	235	0.203	3.77
16 Apr 2012	Wild	Smolts	32	1	0.031	78.4	71.0	198	0.190	0.77
29 Apr 2012	Wild	Smolts	43	0	0.000	82.6	.	367	0.144	1.86

Appendix Table 2. Release and recapture data recorded for each of the 78 catch efficiency experiments conducted at Grayson between 1999 and 2012, along with flow and turbidity data. Experiments with missing %flow data were excluded from analyses.

Release Date	Origin	Size Class	Adjusted Number Released	Number Recaptured	% Recaptured	Length at Release (mm)	Length at Recapture (mm)	Flow (cfs)	% Flow Sampled	Turbidity (NTU)
11 Mar 1999	Hatchery	Medium	1946.465	28	0.014	54	53	4620	0.040	9.10
24 Mar 1999	Hatchery	Medium	1938.48	67	0.035	61	61	3130	0.051	5.20
31 Mar 1999	Hatchery	Medium	1884.623	73	0.039	65	64	2250	0.059	5.90
7 Apr 1999	Hatchery	Large	1948.849	50	0.026	68	68	2280	0.052	5.00
14 Apr 1999	Hatchery	Large	1953.066	34	0.017	73	72	2000	0.072	3.90
20 Apr 1999	Hatchery	Large	2007	45	0.022	73	75	1800	0.076	4.40
29 Apr 1999	Hatchery	Large	1959.335	14	0.007	79	80	3220	0.050	8.80
4 May 1999	Hatchery	Large	2007.52	18	0.009	83	82	3030	0.052	6.50
18 May 1999	Hatchery	Large	2001	29	0.014	86	84	677	0.141	6.70
26 May 1999	Hatchery	Large	1984	75	0.038	96	92	518	0.142	9.60
1 Mar 2000	Hatchery	Medium	1964	30	0.015	56	53	4690	0.032	16.11
16 Mar 2000	Hatchery	Medium	1548	22	0.014	56	56	5980	0.027	7.48
23 Mar 2000	Hatchery	Medium	1913	55	0.029	59	60	3190	.	7.13
30 Mar 2000	Hatchery	Medium	1942	60	0.031	62	63	2820	0.051	6.30
29 Apr 2000	Hatchery	Large	1931	22	0.011	81	82	1470	0.085	9.16
6 May 2000	Hatchery	Large	1987	41	0.021	85	85	2430	0.060	14.23
24 May 2000	Hatchery	Large	2010	24	0.012	85	85	1010	0.106	9.09
18 Jan 2001	Hatchery	Small	1810	120	0.066	37	.	487	0.217	4.30
8 Feb 2001	Hatchery	Small	1980	276	0.139	47	.	434	0.177	3.20
1 Mar 2001	Hatchery	Small	2017	57	0.028	41	.	2130	0.083	4.20
14 Mar 2001	Hatchery	Small	1487	75	0.050	46	.	703	0.135	7.90
21 Mar 2001	Hatchery	Medium	3025	207	0.068	61	.	519	0.162	7.50
28 Mar 2001	Hatchery	Medium	1954	219	0.112	51	.	515	0.182	6.80
11 Apr 2001	Hatchery	Large	2021	141	0.070	66	.	535	.	5.20
18 Apr 2001	Hatchery	Large	2060	95	0.046	68	.	483	.	7.90
25 Apr 2001	Hatchery	Large	1515	34	0.022	71	.	753	0.118	7.20
2 May 2001	Hatchery	Large	3053	163	0.053	72	.	1460	0.086	7.00
9 May 2001	Hatchery	Large	3002	147	0.049	75	.	1160	0.112	6.20
16 May 2001	Hatchery	Large	2942	93	0.032	76	.	1020	0.113	9.20
20 Feb 2002	Hatchery	Medium	2094	444	0.212	57	.	265	.	5.90
6 Mar 2002	Hatchery	Large	2331	316	0.136	68	.	278	0.291	5.30
13 Mar 2002	Hatchery	Large	2042	324	0.159	65	.	300	0.247	10.10
20 Mar 2002	Hatchery	Large	2105	242	0.115	68	.	328	.	8.40
27 Mar 2002	Hatchery	Large	2121	147	0.069	68	.	314	0.244	10.00
3 Apr 2002	Hatchery	Large	1962	130	0.066	76	.	312	.	8.90
9 Apr 2002	Hatchery	Large	1995	56	0.028	79	.	319	0.295	13.30
17 Apr 2002	Hatchery	Large	2048	40	0.020	84	.	889	0.127	12.90
25 Apr 2002	Hatchery	Large	2001	22	0.011	86	.	1210	0.074	12.60
1 May 2002	Hatchery	Large	2033	14	0.007	89	.	1250	0.096	9.20
8 May 2002	Hatchery	Large	2021	31	0.015	95	.	798	0.12084	9.80
15 May 2002	Hatchery	Large	2047	26	0.013	97	.	653	0.139	8.00
22 May 2002	Hatchery	Large	2043	10	0.005	94	.	403	0.188	11.30

…continued

Appendix Table 2 continued.

Release Date	Origin	Size Class	Adjusted Number Released	Number Recaptured	% Recaptured	Length at Release (mm)	Length at Recapture (mm)	Flow (cfs)	% Flow Sampled	Turbidity (NTU)
10 Apr 2003	Hatchery	Large	1956	138	0.071	77	.	297	.	.
17 Apr 2003	Hatchery	Large	2047	65	0.032	77	.	1350	.	.
24 Apr 2003	Hatchery	Large	1979	31	0.016	88	.	1210	.	.
1 May 2003	Hatchery	Large	2044	113	0.055	96	.	685	.	.
8 May 2003	Hatchery	Large	2078	206	0.099	83	.	726	.	.
15 May 2003	Hatchery	Large	1996	125	0.063	83	.	559	.	.
20 May 2003	Hatchery	Large	1989	60	0.030	89	.	317	.	.
28 May 2003	Hatchery	Large	1950	125	0.064	94	.	685	.	.
13 Apr 2004	Hatchery	Large	1991.88	84	0.042	79	74	1140	0.121	4.80
20 Apr 2004	Hatchery	Large	1979.802	48	0.024	81	79	1660	0.094	2.97
27 Apr 2004	Hatchery	Large	1941.006	118	0.061	86	85	826	0.143	4.67
4 May 2004	Hatchery	Large	2007.91	50	0.025	90	87	789	0.150	4.75
11 May 2004	Hatchery	Large	1971.52	104	0.053	86	79	815	0.148	4.05
18 May 2004	Hatchery	Large	1996	178	0.089	88	77	446	0.208	4.29
25 May 2004	Hatchery	Large	2013	59	0.029	92	90	337	0.268	3.94
9 Feb 2006	Wild	Small	37	5	0.135	35	35	3290	0.056	4.30
11 Feb 2006	Wild	Small	26	4	0.154	35	37	3340	0.050	3.15
12 Feb 2006	Wild	Small	23	1	0.043	36.09	37.0	3310	0.041	2.65
13 Feb 2006	Wild	Small	28	1	0.036	35.5	33.0	3310	0.058	3.37
3 Mar 2006	Wild	Small	89	4	0.045	34.78	35.3	4300	0.050	4.97
5 May 2006	Hatchery	Large	949	4	0.004	73.18	74.3	8770	0.022	3.05
12 May 2006	Hatchery	Large	1286	5	0.004	81.76	76.6	8280	0.023	2.07
25 May 2006	Hatchery	Large	1532	2	0.001	83.7	69.5	7070	0.023	1.82
1 Jun 2006	Hatchery	Large	1694	0	0.000	91.87	.	4960	.	2.79
14 Jun 2006	Hatchery	Large	1507	2	0.001	85.42	83.0	5050	0.037	1.78
1 Mar 2008	Wild	Small	73	5	0.068	37.78	37.6	342	0.209	25.90
15 Apr 2008	Hatchery	Large	1131	109	0.096	77.12	75.7	300	0.237	4.24
25 Apr 2008	Hatchery	Large	1005	17	0.017	86.3	84.5	1290	0.113	2.66
7 May 2008	Hatchery	Large	526	8	0.015	95.62	95.5	1310	0.111	2.85
14 May 2008	Hatchery	Large	519	13	0.025	92.66	90.8	973	0.112	3.98
21 May 2008	Hatchery	Large	515	19	0.037	91.64	90.9	703	0.141	2.75
14 Jan 2011	Wild	Small	87	3	0.034	36	35.0	3300	0.040	2.50
20 Jan 2011	Wild	Small	51	1	0.015	36	32.0	5130	0.025	2.24
21 Jan 2011	Wild	Small	63	1	0.016	36	30.0	5230	0.032	4.28
25 Jan 2011	Wild	Small	62	1	0.015	36	36.0	4330	0.037	2.13
26 Jan 2011	Wild	Small	45	1	0.018	36	29.0	3970	0.040	2.15

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Attachment D

Chinook salmon stock production model data structure

Table D - 1. Output Data Frame Fields Produced by the Stock-Production Models

Attribute	Description	Date type
Spawner Lifestage		
rm	location (as river-mile) at which fish enters the inventory	numeric
date	date at which fish enters the inventory	POSIXct
sex	female or male	factor, levels=c("F", "M")
age	age in years (by usual convention)	integer
Redd Lifestage		
feature	location of redd (as a gravel feature)	text
rm	location of redd (as river-mile)	numeric
construct.date	date redd is complete	POSIXct
abandon.date	date spawner stops defending redd	POSIXct
area.defend	area of gravels from which spawner excludes other females	numeric
area.disturb	area of gravels reworked during redd construction	numeric
eggs	number of eggs initially deposited in redd	numeric
gravel.qual	expected survival-to-emergence of eggs deposited in this redd	numeric, between 0 and 1
superimposal	fraction of existing undefended redd area in the feature destroyed by the construction of this one	numeric, between 0 and 1
Carcass Lifestage		
feature	location of death (as a gravel feature)	text
rm	location of death (as river-mile)	numeric
date	date of death	POSIXct
sex	female or male	factor, levels=c("F", "M")
age	age in years (by usual convention)	integer
eggs	number of unspawned eggs	numeric
Swim-up Lifestage		
count	number of swimup-fry represented by this record	numeric
feature	location of emergence (as a gravel feature)	text
rm	location of redd (as river-mile)	numeric
date	date of emergence	POSIXct
Parr Lifestage		
count	number of parr represented by this record	numeric
date	date of promotion to parr	POSIXct
rm	location of promotion (rm)	numeric
length	fork length at promotion (mm)	numeric
Dead Fry Lifestage		
count	number of fry represented by this record	numeric
date	date of death or exit from river	POSIXct
rm	location of death or exit (rm)	numeric
length	fork length at death or exit (mm)	numeric
Passage Fry Lifestage		
count	number of fry represented by this record	numeric
date	date of passage of landmark	POSIXct
m	location of landmark (rm)	numeric
length	fork length at passage (mm)	numeric
Smolt Ready Lifestage		
count	number of parr represented by this record	numeric
date	date of promotion to parr	POSIXct
rm	location of promotion (rm)	numeric
length	fork length at promotion (mm)	numeric
Dead Juvenile Lifestage		
count	number of juveniles represented by this record	numeric
date	date of death or exit from river	POSIXct
rm	location of death or exit (rm)	numeric
length	fork length at death or exit (mm)	numeric
Passage Juvenile Lifestage		

Attribute	Description	Date type
count	number of juveniles represented by this record	numeric
date	date of passage of landmark	POSIXct
rm	location of landmark (rm)	numeric
length	fork length at passage (mm)	numeric

Table D - 2. Output Data Frame Fields Produced by each Habitat Generator

Attribute	Description	Date type
Spawning Habitat		
feature	name of feature (e.g., a patch name or reach label)	text
rm	location (as river-mile) of feature	numeric
gravel.qual	expected survival-to-emergence of eggs deposited in this feature	numeric, between 0 and 1
preference	feature preference at requested time	numeric
area	usable spawning area at requested time (square feet)	numeric
Fry Habitat		
reach	name of reach	text
us	upstream extent of reach (rm)	numeric
ds	downstream extent of reach (rm)	numeric
rm	reference location for feature (rm)	numeric
LD50	exposure time over which 50% of migrating fry would be lost (days)	numeric
R	ration level (dimensionless)	numeric
density	maximum fish per unit wua (fish/ft²)	numeric
wua	weighted usable area of fry habitat (square feet)	numeric
Juvenile Habitat		
reach	name of reach	text
us	upstream extent of reach (rm)	numeric
ds	downstream extent of reach (rm)	numeric
rm	reference location for feature (rm)	numeric
LD50	exposure time over which 50% of migrating fry would be lost (days)	numeric
R	ration level (dimensionless)	numeric
density	maximum fish per unit wua (fish/ft²)	numeric
wua	weighted usable area of fry habitat (square feet)	numeric

From: Staples, Rose
Sent: Monday, August 05, 2013 11:48 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Chinook Salmon Population Model Workshop No 2 Reminder-August 6 - HDR Offices Sacramento

Chinook salmon Population Model Workshop No. 2 is being held tomorrow, August 6th, in the HDR Offices in Sacramento at 2379 GATEWAY OAKS DRIVE, Suite 200 (916-679-8700).

AGENDA for the meeting is below—link to the LiveMeeting (and audio call-in number) is also below for those who cannot attend in person. In addition, later today (early evening), I will be posting on the relicensing website (www.donpedro-relicensing) a copy of the PowerPoint presentation that will be used in the meeting. I will post it both as an attachment to the meeting date and as an announcement. I will notify you all when it has been posted. Thank you.

Chinook salmon Population Model Workshop No. 2
Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994
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Join online meeting
https://meet.hdrinc.com/carin.loy/HM5F42M3
First online meeting?
[!OC([1033])!]
....
Agenda
9:00 a.m. – 9:15 a.m. Introductions and Background
9:15 a.m. – 10:30 a.m. Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production

1. Relationship to W&AR-5 Synthesis Study
2. General assumptions and model structure
3. Key Sub Model Relationships by Life-Stage

10:30 a.m. – 11:00 a.m. Model Calibration and Validation Results
11:00 a.m. – 12:00 p.m. Modeling Sensitivity Testing
12:00 p.m. – 1:00 p.m. Lunch (on your own)
1:00 p.m. – 2:00 p.m. Discussion of Base Case (1971–2009) Scenario Results
2:00 p.m. – 3:00 p.m. Discussion of Factors Affecting Chinook Production
3:00 p.m. – 3:45 p.m. Discussion of Modeling Scenarios

- 300 cfs Test Case Run
- Requests for Additional Scenarios

3:45 p.m. – 4:00 p.m. Next Steps

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Tuolumne River Chinook salmon (W&AR-6) study

Modeling Workshop No. 2

August 6, 2013

Don Pedro Project Relicensing
FERC No. 2299

Agenda/Overview

Introductions and Background

1. Purpose of Meeting
2. Relationship to Other Studies

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Salmon Juvenile Production

1. Relationship to W&AR-5 Synthesis
2. General Assumptions and Model Structure
3. Key Sub Model Relationships by Life-Stage

Modeling Calibration and Validation

1. Upmigration and Spawning
2. Fry and Juvenile Rearing
3. RST passage of Fry and Smolts

Agenda/Overview

Sensitivity Testing of Parameters by Life Stage

1. Upmigration and Spawning
2. Egg Incubation
3. Fry Rearing
4. Juvenile Rearing
5. Smolt Emigration

Base Case Scenario Results

Factors Affecting Chinook Production

Discussion of Modeling Scenarios

1. 300 cfs Test Case (Example Scenario) Run
2. Requests for Additional Scenarios

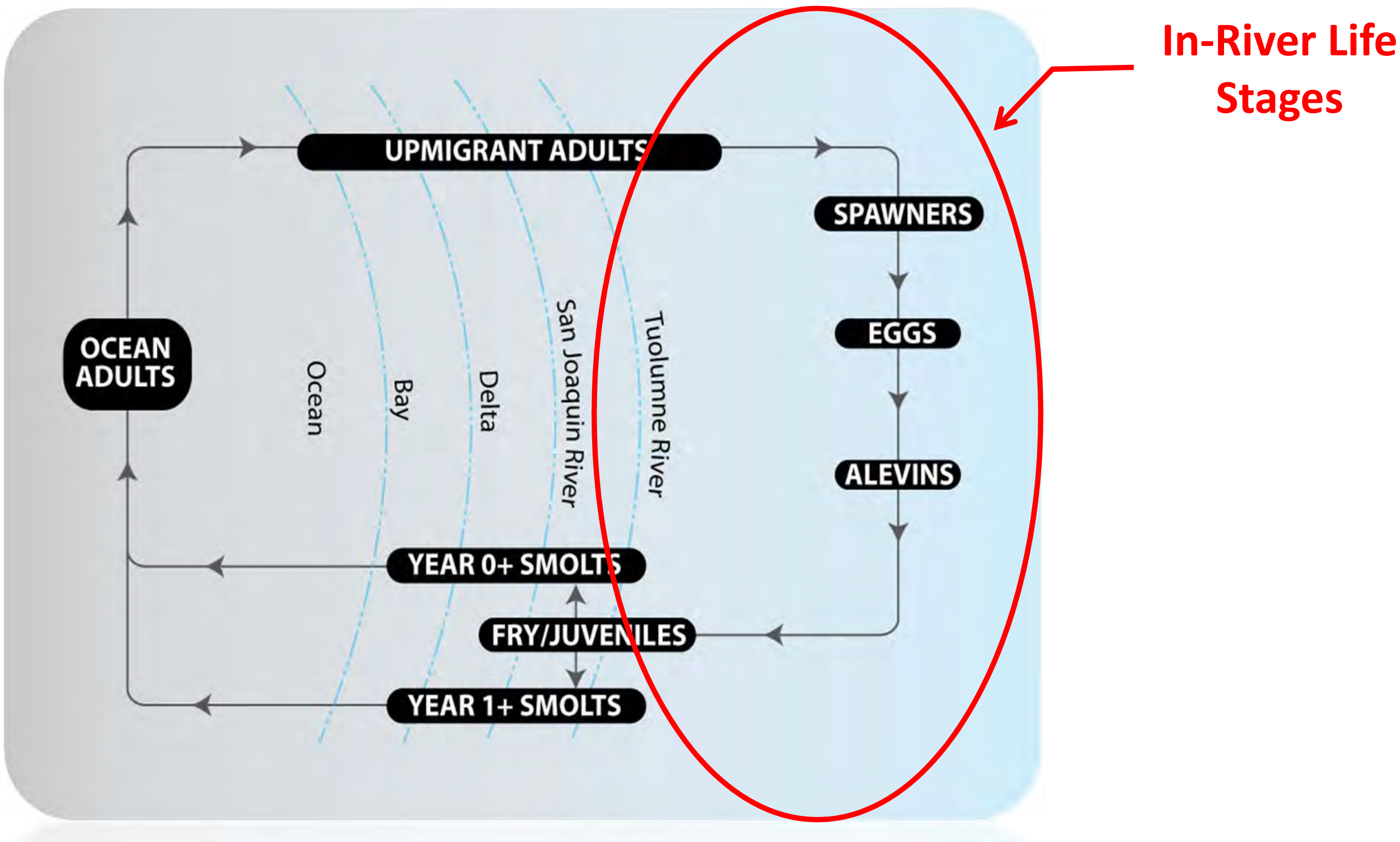
Next Steps

Relationship to W&AR-5 Synthesis

- Literature Review
- Initial assessment of in-river and out-of-basin factors affecting overall population levels
- Production models intended to examine relative importance of identified ***in-river factors upon juvenile production***
- Inclusion of some factors for modeling not recognized as important in initial W&AR-5 assessment
- Recognition that some factors may not be feasibly modeled

General Assumptions and Model Structure

- Independent sub-models separate life-history transitions
  - calibration and verification (e.g., weir counts, redd counts, egg-survival, RST passage)



Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Events	Life stages	Life stanzas	Processes (Parameters)
arrival at weir location	spawner →	upstream migration, habitat selection, redd construction	gravel area (flow, water temp.) gravel preference redd dimensions, redd defense times
burial of fertilized eggs	redd →	embryo development	development rate (water temp.) acute mortality (water temp.) superimposition mortality gravel quality-related mortality
emergence from gravels	swimup →	fry rearing	displacement (flow) migration mortality habitat area (flow, water temp.) development rate (water temp.)
arrival at RST locations	passage fry →		
exit from Tuolumne River	emigrant fry →		
attainment of dev. threshold (fork length = 50 mm)	parr →	juvenile rearing	habitat area (flow, water temp.) development rate (water temp.) acute mortality (water temp.) background mortality smoltification criteria
arrival at RST locations	passage juvenile →		
exit from Tuolumne River	emigrant juvenile →		
smoltification	smolt →		
remaining after the spring outmigration	summer →		

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Events	Life stages	Life stanzas	Processes/Parameters
	smolt	smolt emigration	acute mortality (water temp.) background mortality (flow)
arrival at RST locations	passage smolt		
exit from Tuolumne River	emigrant smolt		

Model Structure

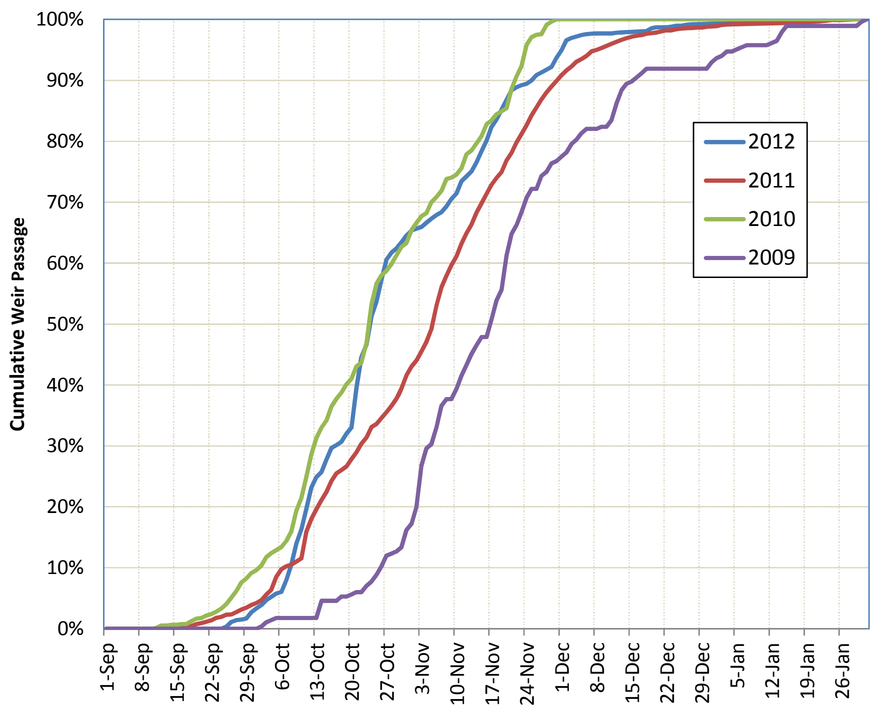
- Subdivision of river into smaller sub-reaches
  – longitudinal variation in habitat composition and availability
- Sub-reach resolution may be altered by sub-model
  – (e.g., spawning vs. rearing, temperature variations, etc.)

W&AR-6 Model Reaches

La Grange dam to OLGB	52.0-50.7
OLGB to TLSRA	50.7-42.0
TLSRA to Hickman Bridge	42.0-31.6
Hickman Bridge to Charles Road	31.6-24.8
Charles Road to Legion Park	24.8-17.6
Legion Park to Riverdale Park	17.6-12.4
Riverdale Park to Shiloh Bridge	12.4-3.5
Shiloh Bridge to mouth	3.5-0.0

Key Sub Model Relationships by Life-Stage

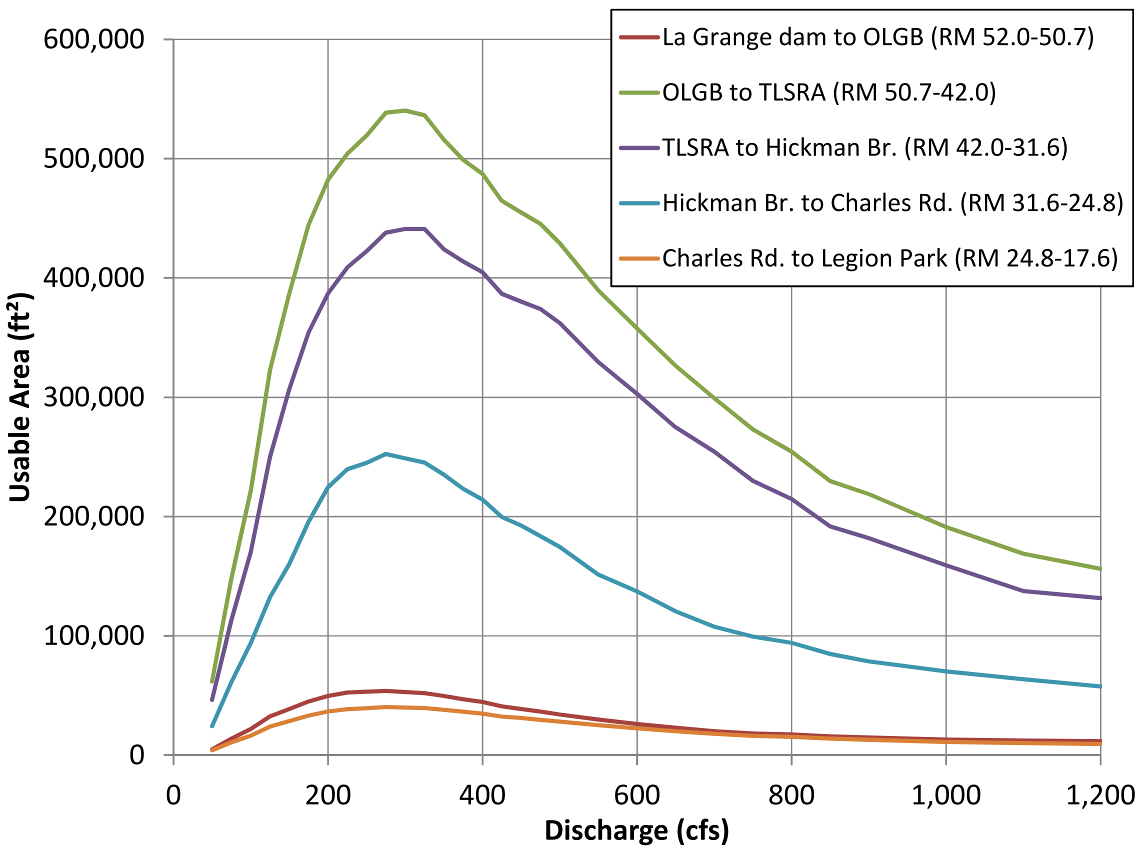
- Upmigration and Spawning (Timing)
  - Migration timing and spawner movement from weir counts
  - Historical spawner survey statistics (e.g., run size, age composition, sex ratio by age, arrival times mean and standard deviation)



Tuolumne River weir passage
2009–2012

Key Sub Model Relationships by Life-Stage

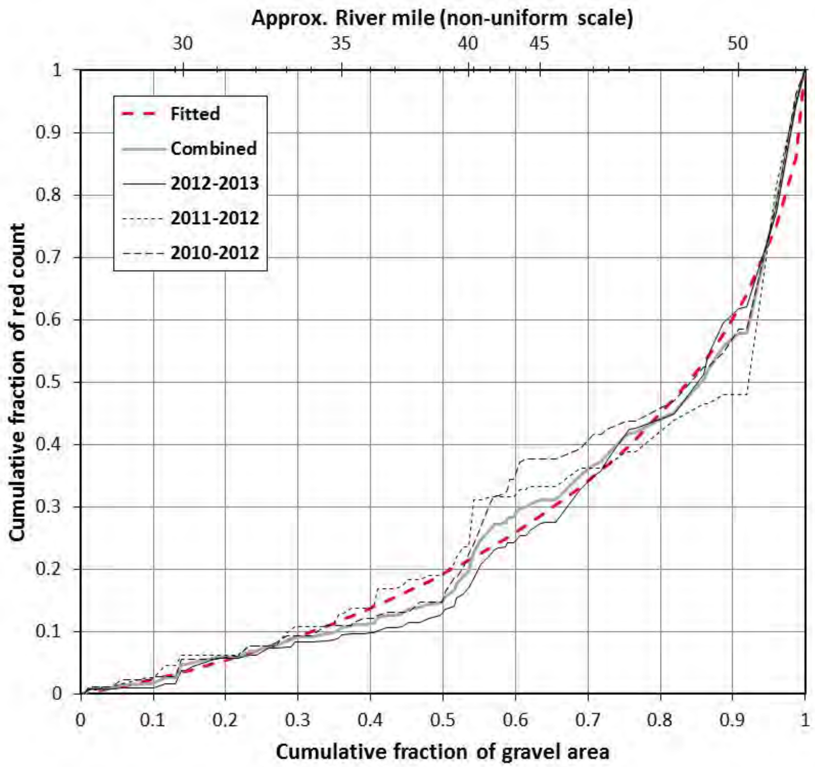
- Upmigration and Spawning (Habitat Suitability)
  - Spawning habitat suitability combines gravel suitability (W&AR-4) with hydraulic suitability (depth, velocity) from IFIM Study.



Weighted usable area estimates for Chinook salmon spawning in sub-reaches of the lower Tuolumne River

Key Sub Model Relationships by Life-Stage

- Spawning (Habitat Suitability)
  - Habitat use of suitable spawning areas as a “preference” function of RM based upon recent redd mapping (W&AR-8)
  - Superimposition onto undefended redds allowed



$$\Phi^{-1}\big(G(i)\big) = b_0 + b_1\Phi^{-1}\big(F(i)\big),$$
$$\Phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} e^{-t^2/2}\,dt$$

$\Phi(z)$ = probit transform

Φ^{-1} = inverse of the probit transform

$F(i)$ = cumulative fraction of gravel area within and downstream of a mapped riffle number (i)

$G(i)$ = cumulative fraction of the female spawners expected to spawn within and downstream of riffle number (i)

Key Sub Model Relationships by Life-Stage

- Upmigration and Spawning (Fecundity)
  - Egg deposition based upon historical fecundity relationships

$$Eggs = 158.45 \times L - 6138.91$$

L = fork length

- Upmigration and Spawning (Mortality)
  - No pre-spawn mortality applied due to high water temperature (W&AR-5).

Key Sub Model Relationships by Life-Stage

- Egg Incubation
  - Embryo development based upon temperature and incubation time (Rombough 1985)
  - Mortality due to superimposition, excess fines, and water temperature

$$\sum_{i=1}^{D} \mathrm{WTU}_i \geq 1, \text{ with}$$

$$WTU_i = \exp(-5.88 - 0.000513W + 0.152T_i)$$

WTU_i = weighted thermal units on day (i)

D = days after fertilization that fry hatching occurs

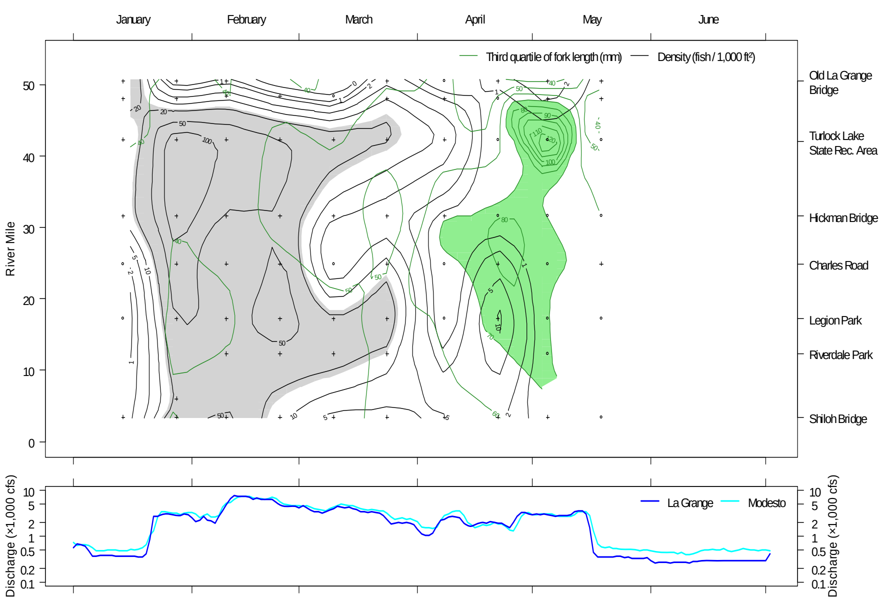
W = estimate of initial egg weight

T = temperature on day (i)

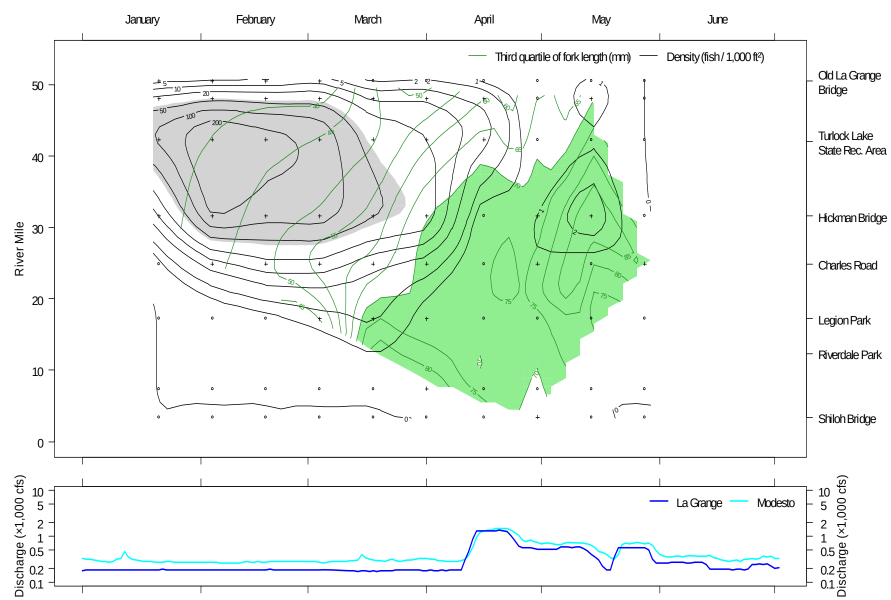
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Movement)
  - Downstream (volitional) movement of fry shortly after emergence (RST data)
  - Riverwide distribution at high/low flows (seine data)

1999 Seine Density



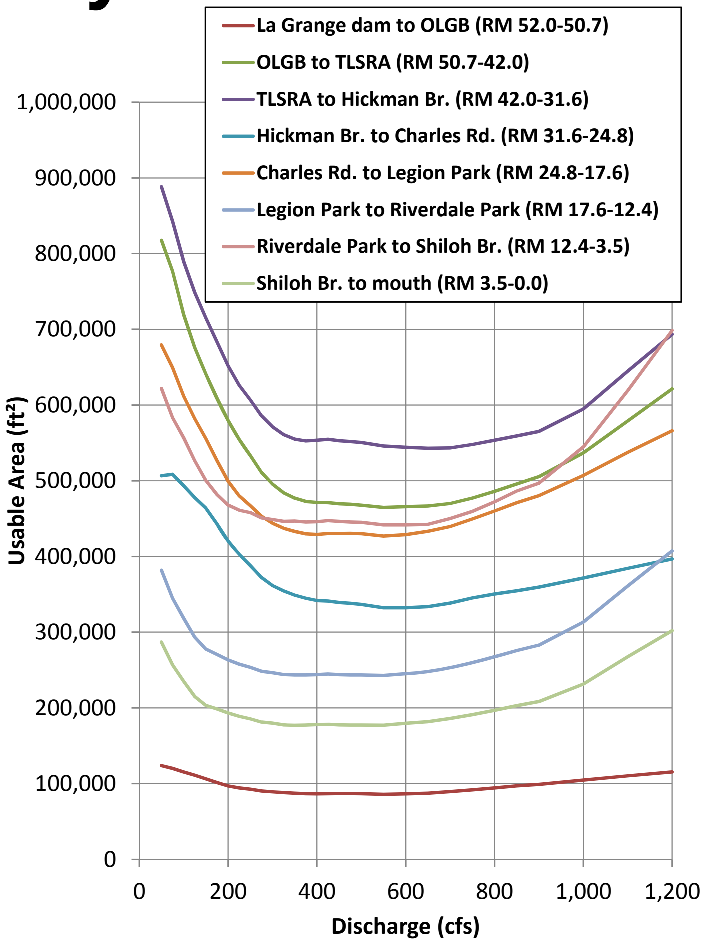
2003 Seine Density



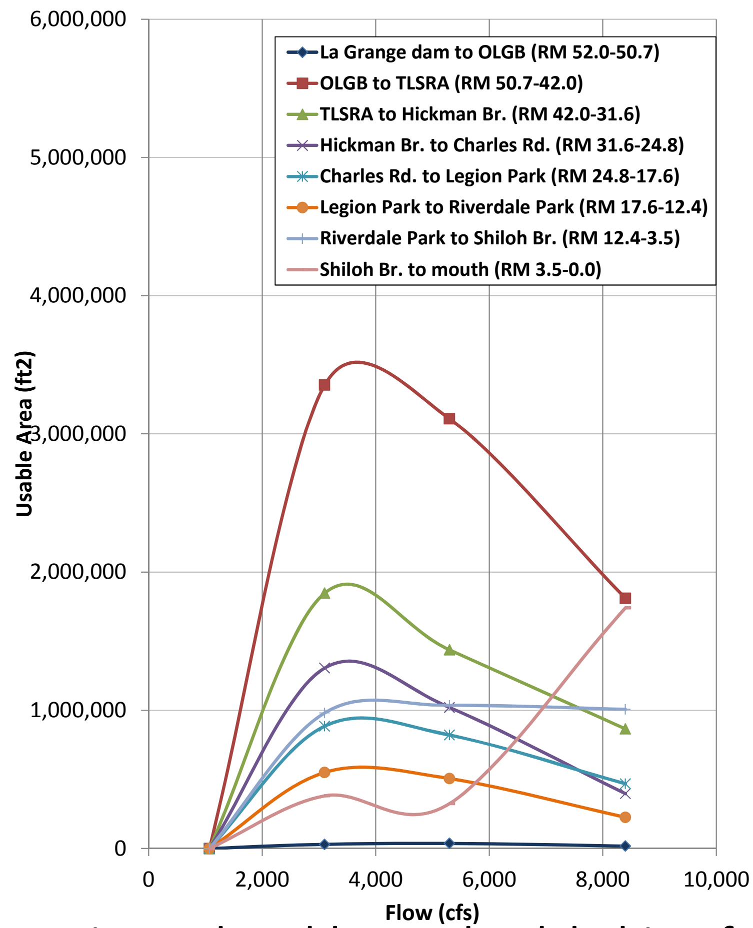
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping (TID/MID 1997) scaled by WUA vs flow relationships from 2D Pulse Flow study .
  - Overbank rearing density in proportion to in-channel and overbank usable area estimates by sub-reach
  - Displacement of resident fry when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon fry rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon fry

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Growth)
  - Growth based upon fish size, ration, and water temperature

$$W^{+} = W e^{g\Delta t}, \text{ where} \qquad g = \text{GMAX} \sin\left(\frac{\pi}{2} \frac{R - \text{RMAINT}}{\text{RMAX} - \text{RMAINT}}\right)$$

$$\text{GMAX} = (a_1 + a_2 T + a_3 T^2 + a_4 T^3 + a_5 T^4)(a_6 W^{-a_7})$$
$$\text{RMAINT} = (l_1 10^{l_2 T})(l_3 W^{-l_4})$$
$$\text{RMAX} = (-l_5 + l_6 \ln T)(l_7 W^{-l_8})$$

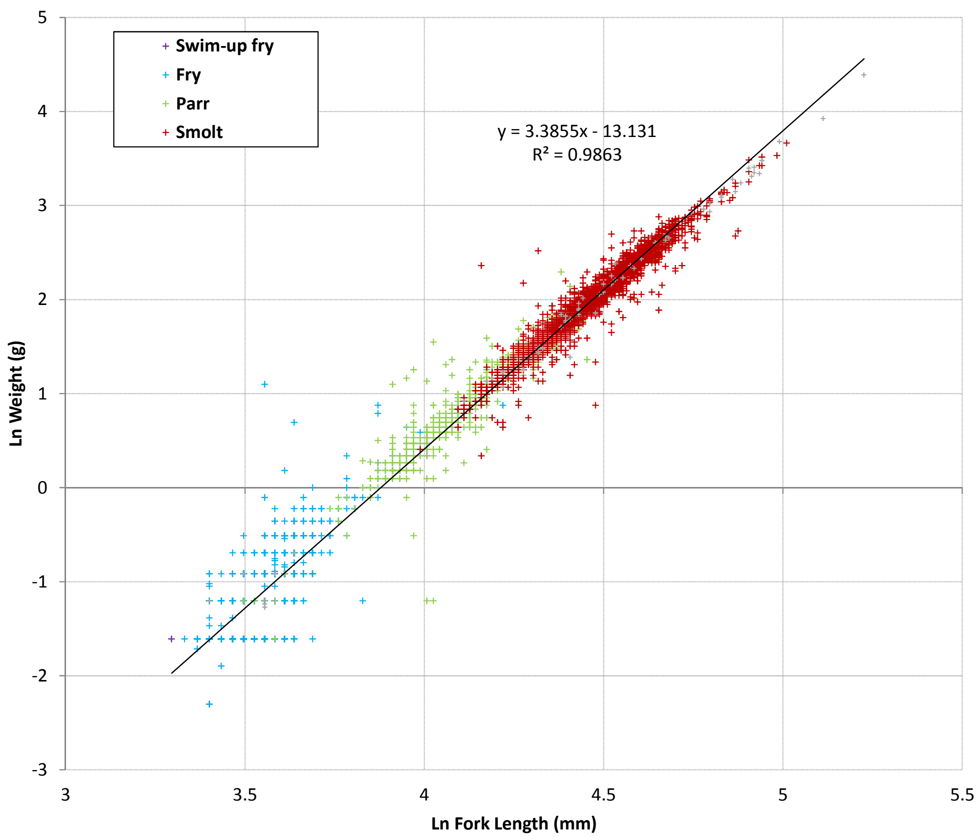
W = starting weight

T = water temperature

R = ration level

weight-length conversions obtained by linear regression of log-weight and log-length of fish from RST sampling

Key Sub Model Relationships by Life-Stage



Length vs. Weight relationship for juvenile Chinook salmon in the Tuolumne River (2004–2010)

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Mortality) sources
  - Background (fixed) daily mortality
  - Movement mortality (e.g., predation, other factors) represented as exposure time (distance)

$$Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt}$$

Survival = the probability of fry survival for any incremental exposure time from t_1 to t_2

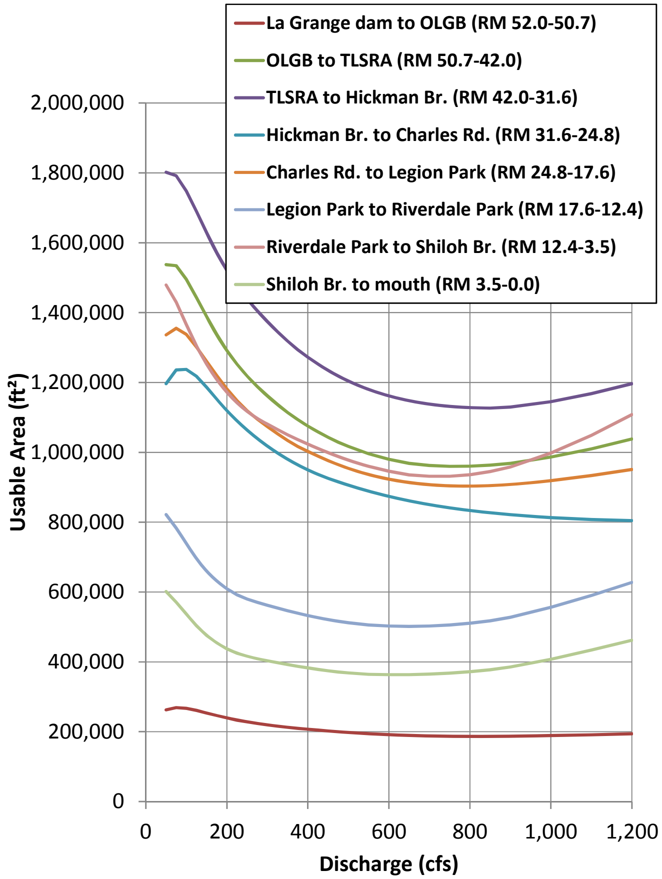
m(t)dt = instantaneous mortality in the main channel

  - Acute mortality due to daily average water temperature exceedance UUILT (T >25^{o}C)

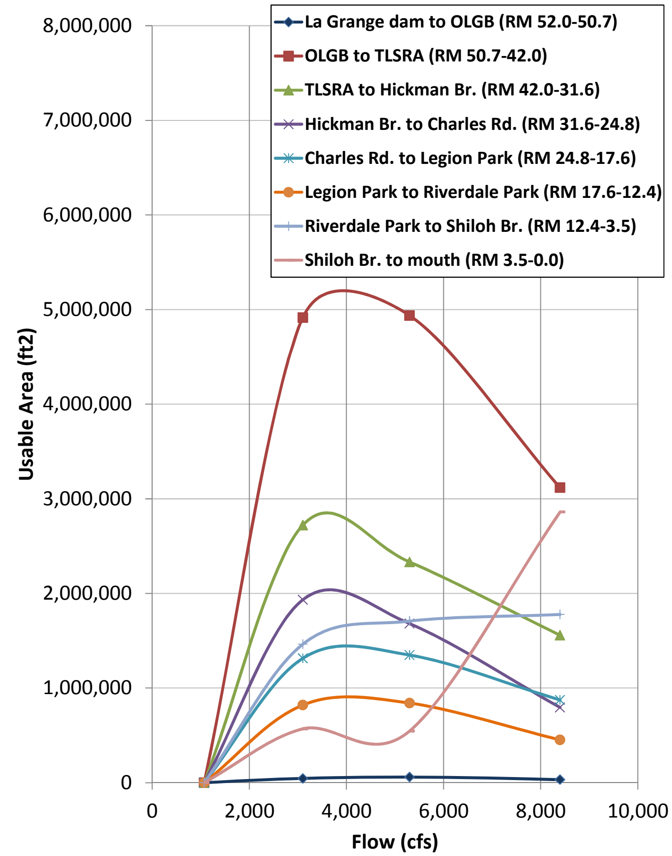
Key Sub Model Relationships by Life-Stage

- Juvenile Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping scaled by WUA vs flow relationships from 2D Pulse Flow study.
  - In-channel and Overbank rearing density in proportion to usable area estimates by sub-reach
  - Displacement of juveniles when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon juvenile rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon juveniles

Key Sub Model Relationships by Life-Stage

- Juvenile growth (same as for Fry)
- Juvenile mortality (same as for Fry):
  - Background mortality
  - Exposure Time $Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt}$
  - UUILT Exceedance (T > 25^{o}C)

Key Sub Model Relationships by Life-Stage

- Smolt Emigration (Size)
  - Emigration of smolt-ready juveniles based upon suitable water temperatures, exceedance of minimum size threshold and probability around historical median size at emigration

$$P = \frac{\frac{1}{\sqrt{2\pi\sigma^2}} e^{-(L-\mu)^2/2\sigma^2}}{\int_L^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\lambda-\mu)^2/2\sigma^2} d\lambda} \frac{\Delta L}{\sigma}.$$

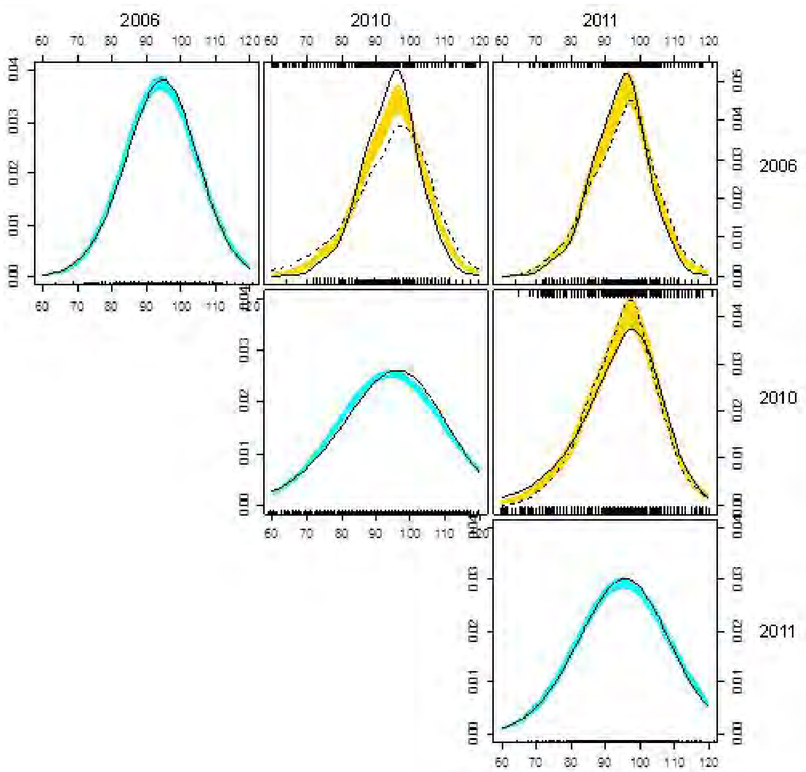
ΔL = the daily growth increment

P = the probability that an individual will smolt at a length between L and $L+\Delta L$

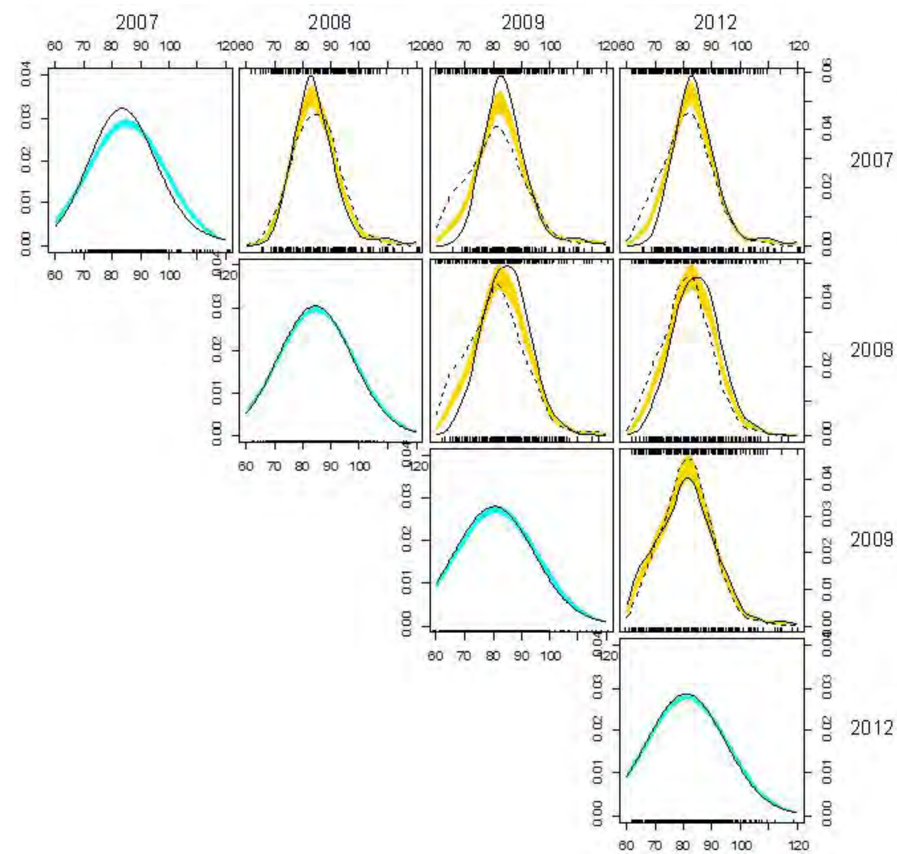
(μ) = mean length

  - Smolt emigration event cues (i.e., pulse flow effects on day-to-day variations in smolt passage) not presently modeled.

Key Sub Model Relationships by Life-Stage



Comparisons of smolt size at emigration in **above average** water year types (2006, 2010, and 2011) in the Tuolumne River



Comparisons of smolt size at emigration in **below average** water year types (2007–2009, and 2012) in the Tuolumne River

Key Sub Model Relationships by Life-Stage

- Smolt Mortality
  - Mortality due to predation and other factors represented as distance travelled (Equation), as well as temperature (T > 25C).
  - Smolt Survival Relationship based upon RST passage data

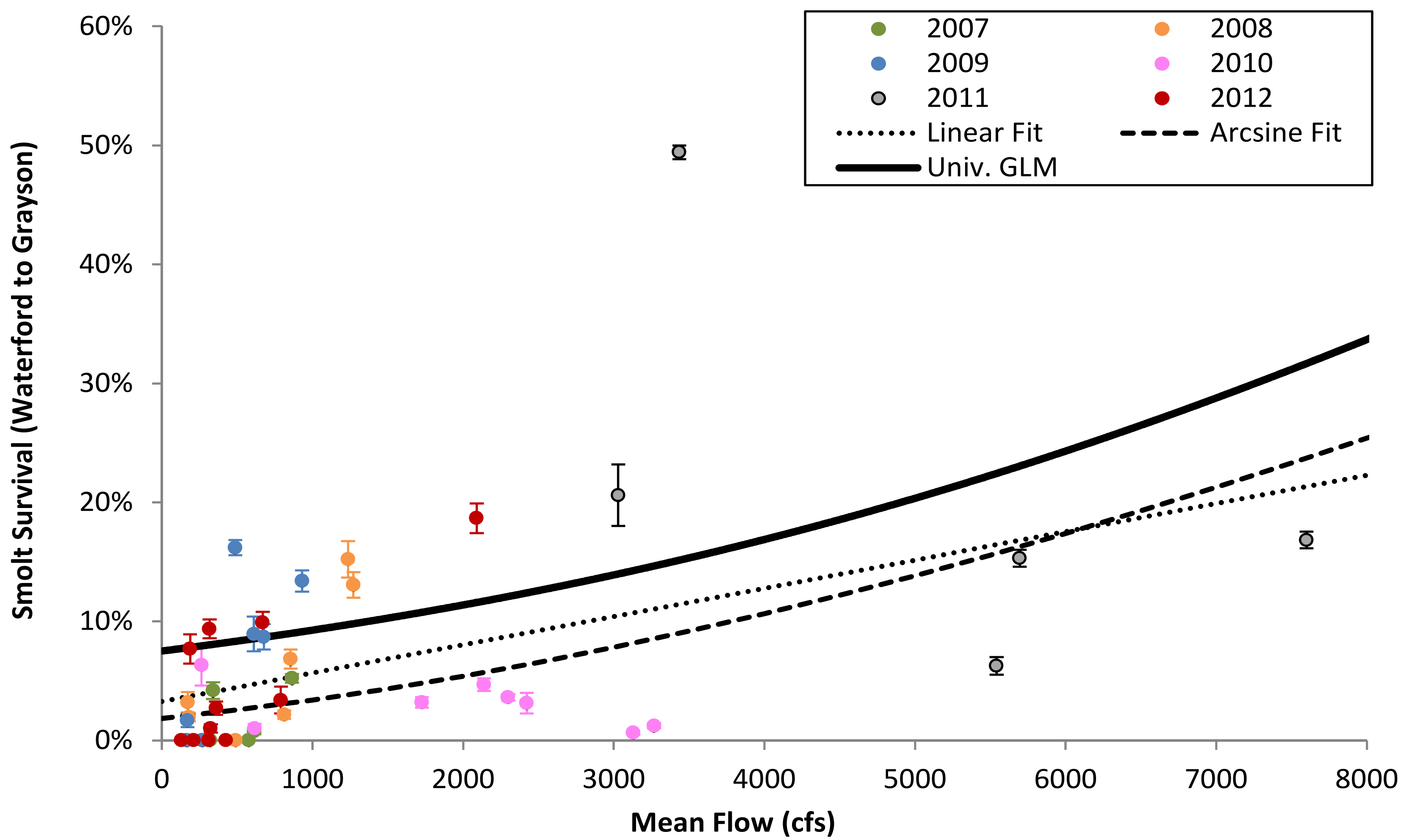
$$S_{RST} = \min(0.03287 + 2.347 \times 10^{-5} \times Q_{LaGrange}\ , 1)$$

$$S_D = e^{-mD}, \text{ where } m = -\frac{\log S_{\mathrm{RST}}}{29.8-5.2}$$

Survival = the probability of smolt survival at flow rate, *Q*

D = Distance (RM)

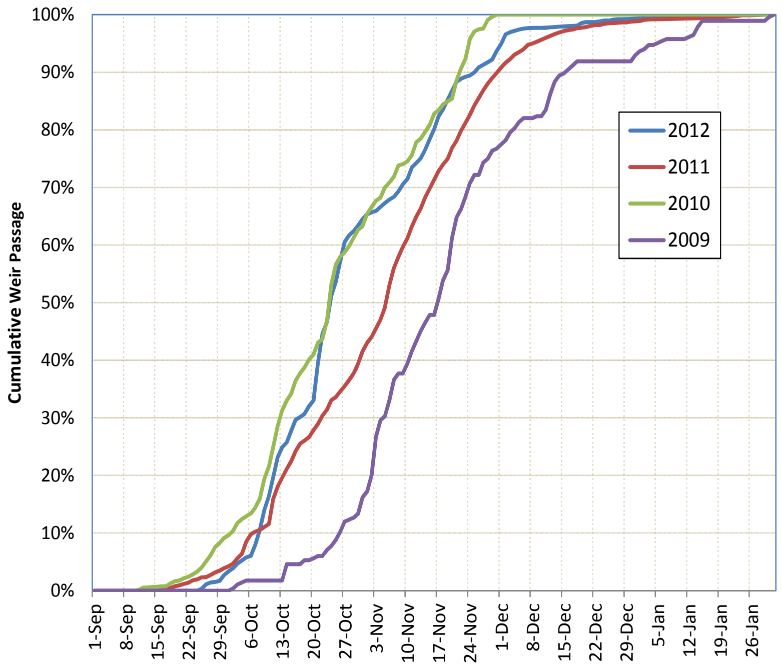
Smolt survival measured by RST passage



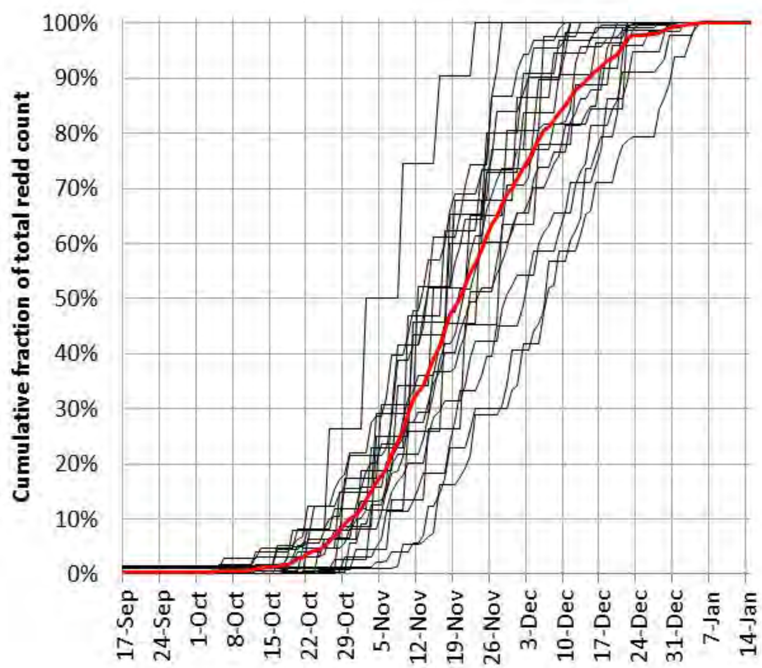
Upmigration and Spawning Timing

- Time lag between weir passage (2009-2012) and spawning activity represented as upmigration speed and not holding

50% weir passage (2009-2012)
Approx. November 5th

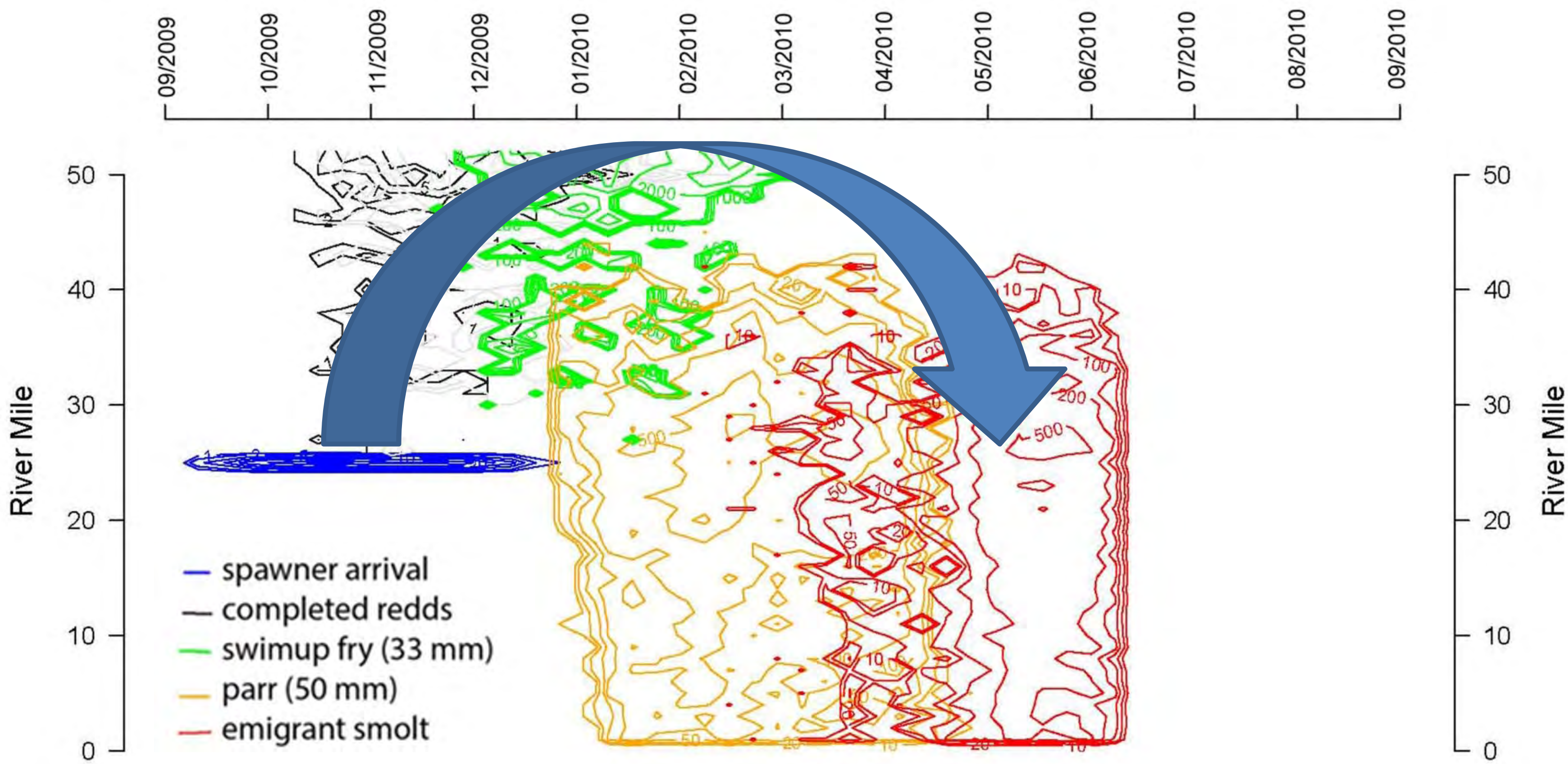


50% redd counts (1992-2010)
Approx. November 20th



Fry and Juvenile Rearing Patterns

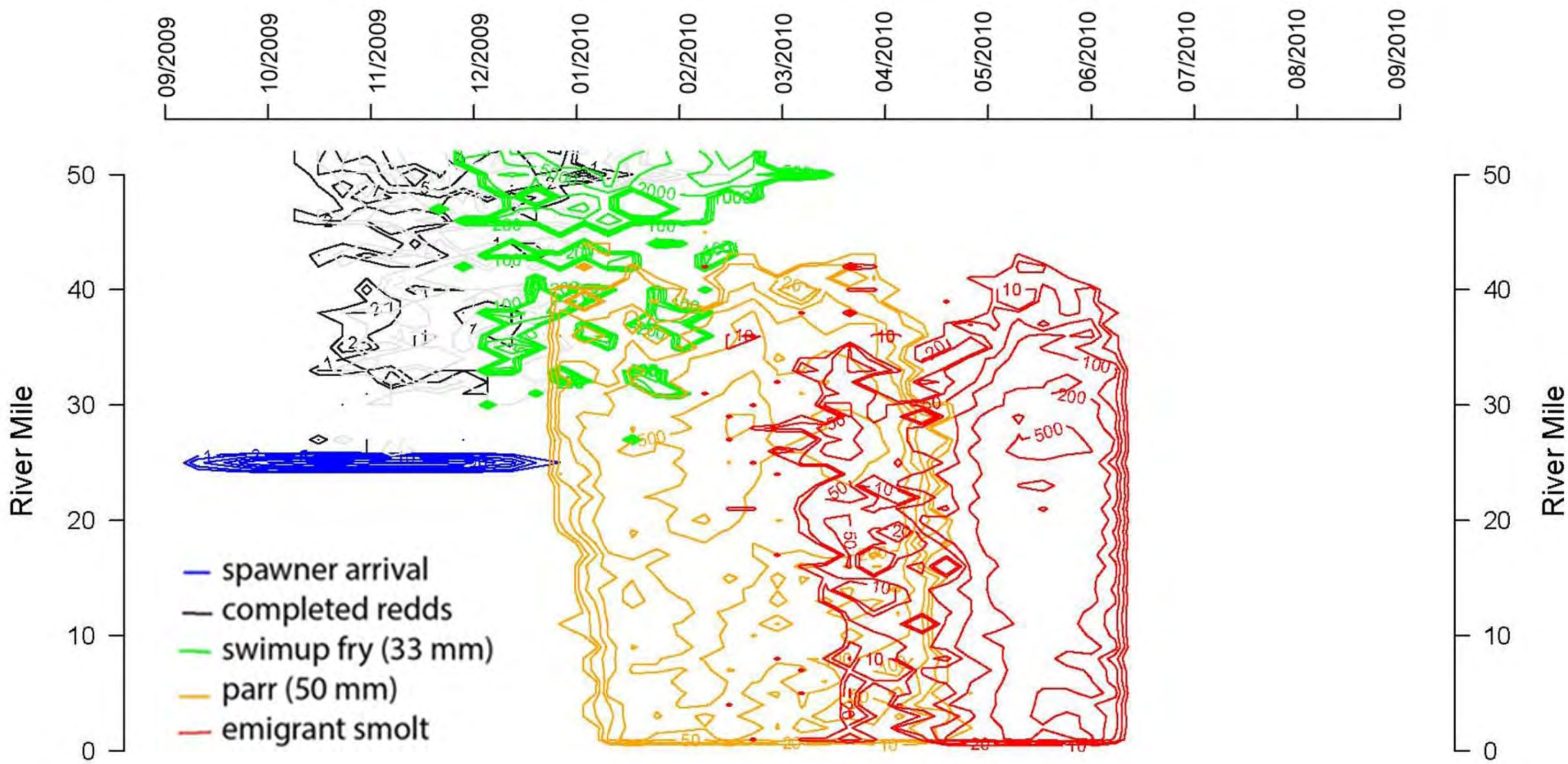
- Matching of life history transition locations and timing



Water Year 2011 (Wet)

Fry and Juvenile Rearing Patterns

- Matching of life history transition locations and timing

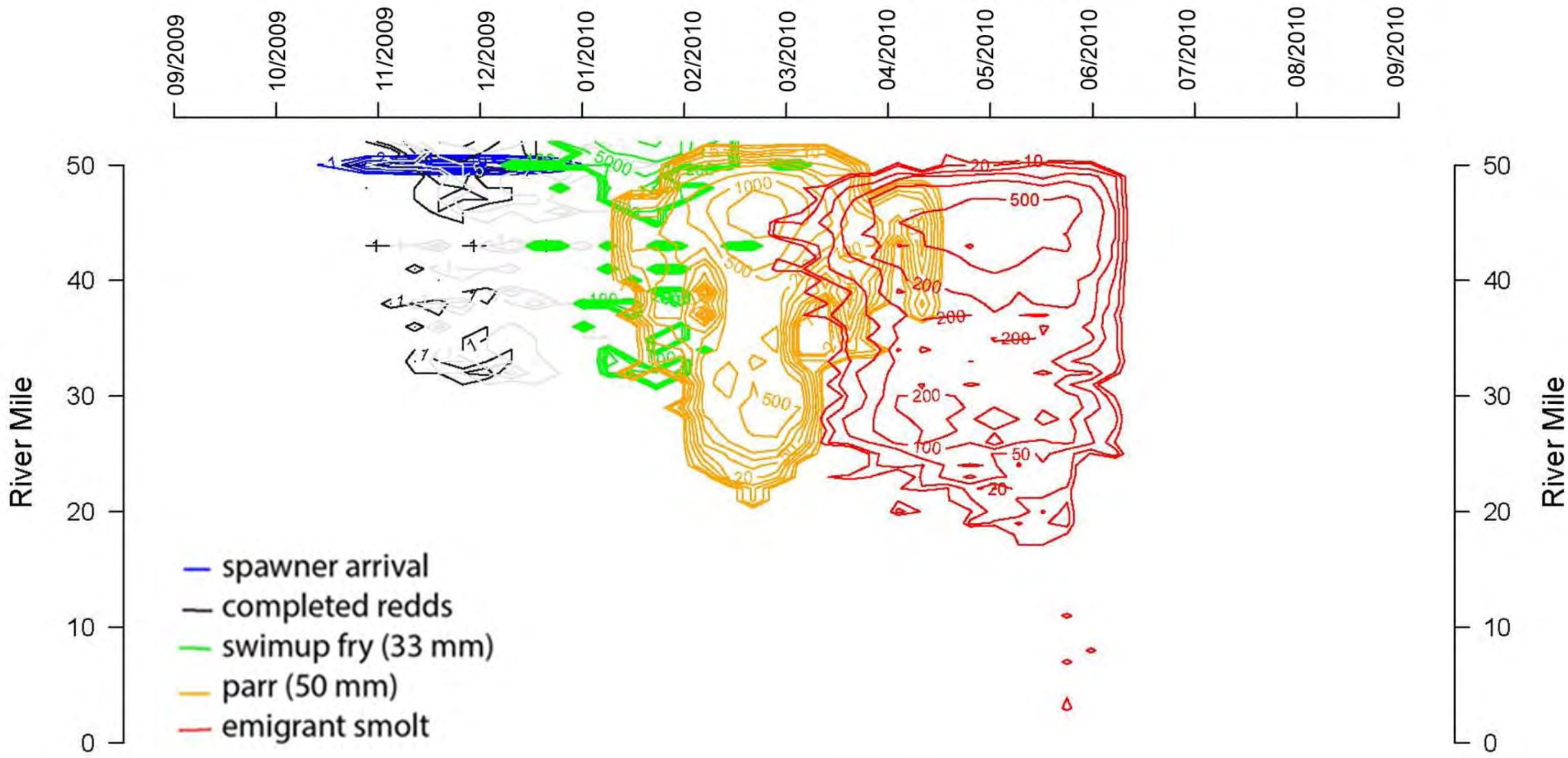


Water Year 2011 (Wet)

Modeling Calibration and Validation

Fry and Juvenile Rearing Patterns

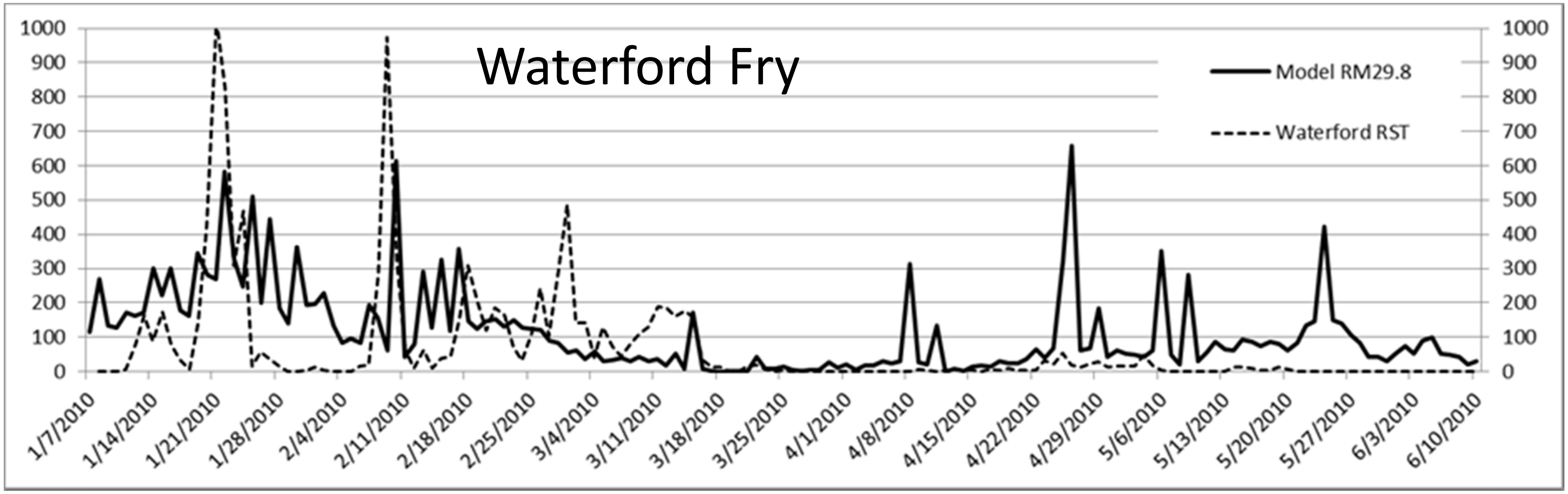
- Matching of life history transition locations and timing

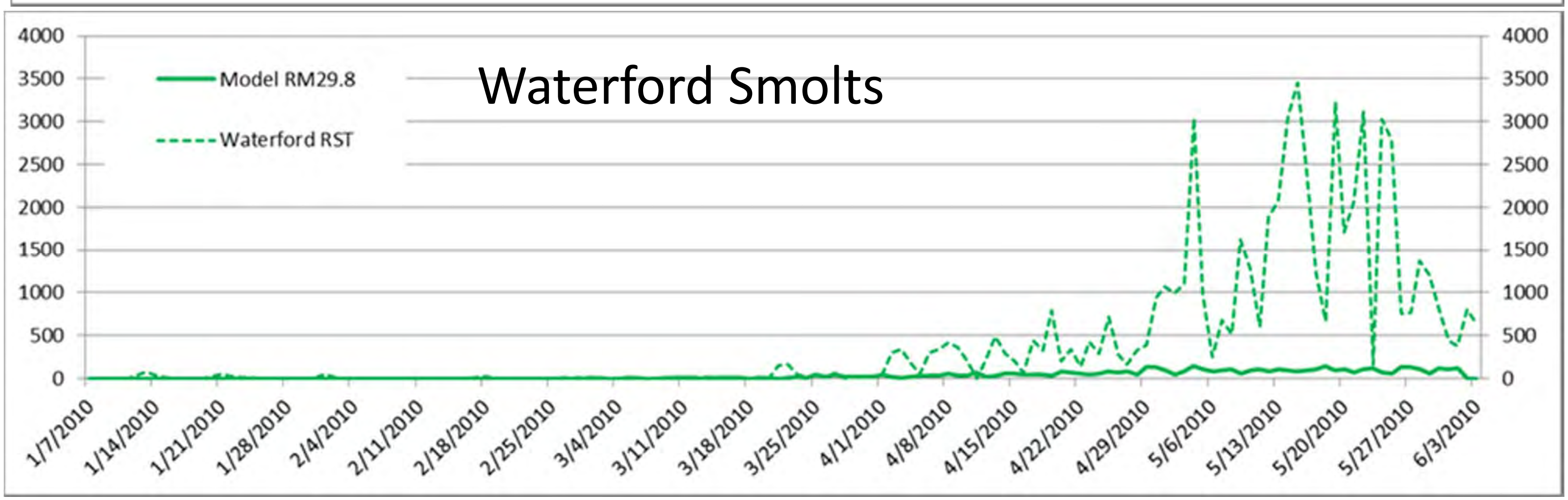


Water Year 2009 (Dry)

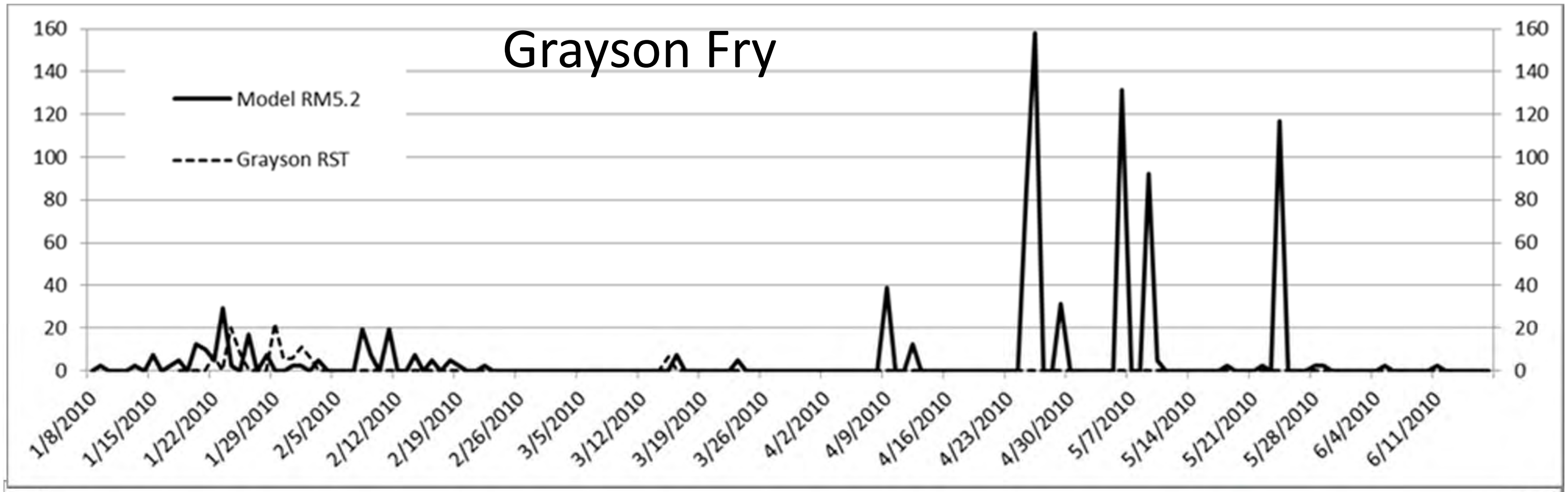
Modeling Calibration and Validation

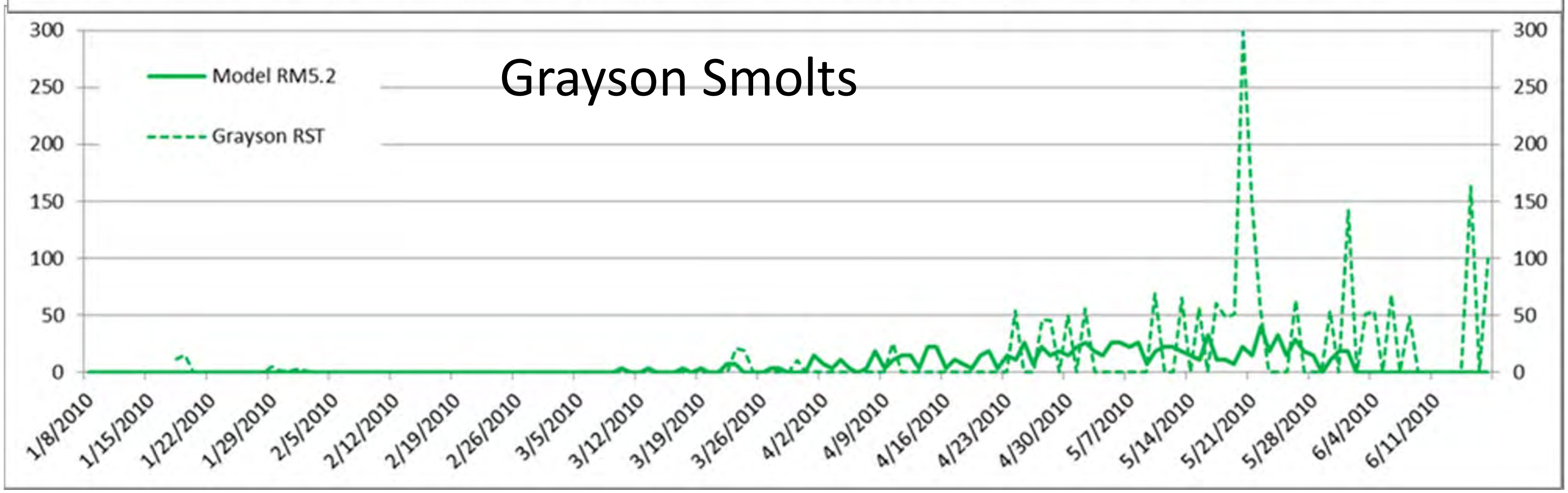
RST passage of Chinook salmon (Fry, Smolt) in 2010



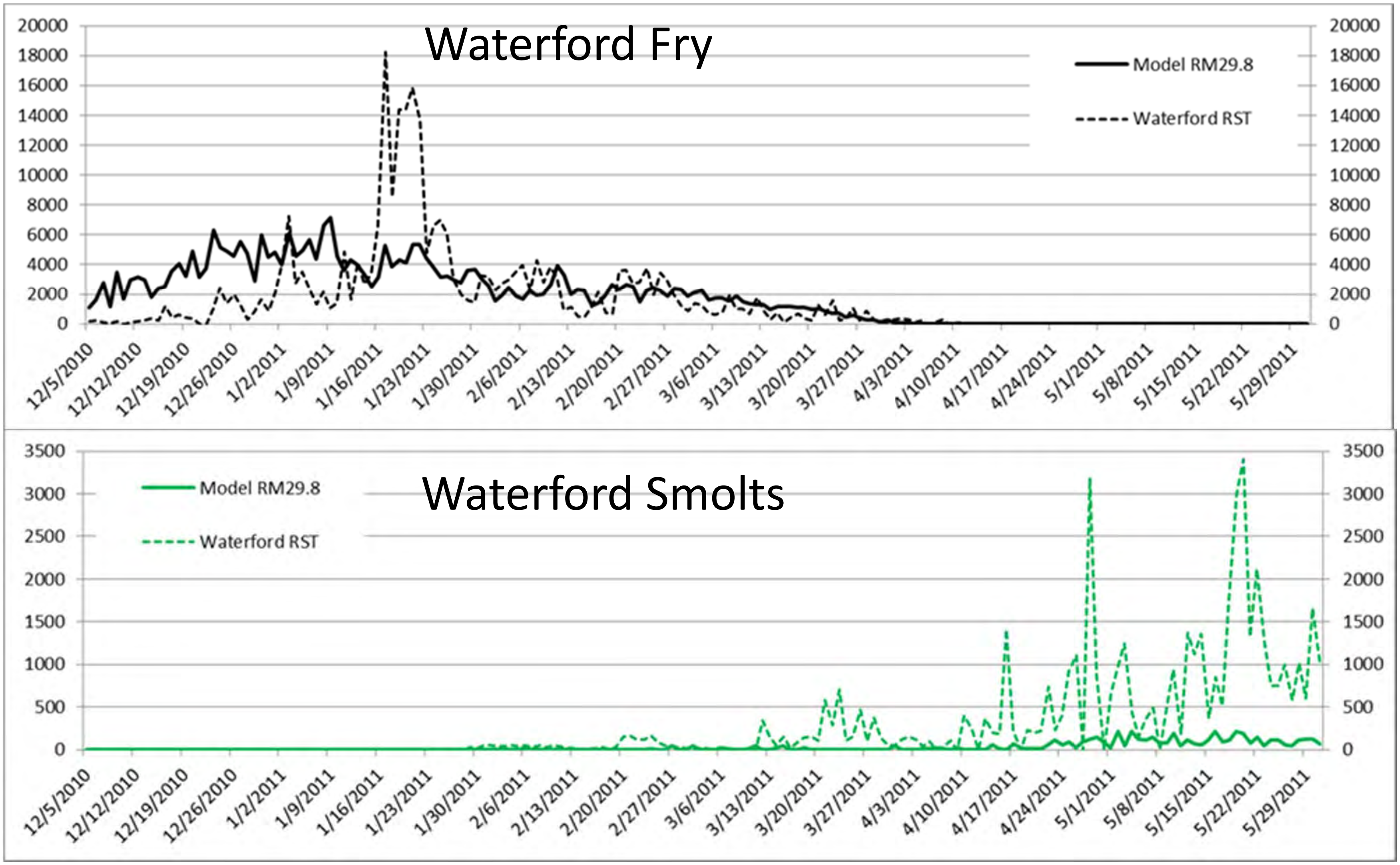


RST passage of Chinook salmon (Fry, Smolt) in 2010



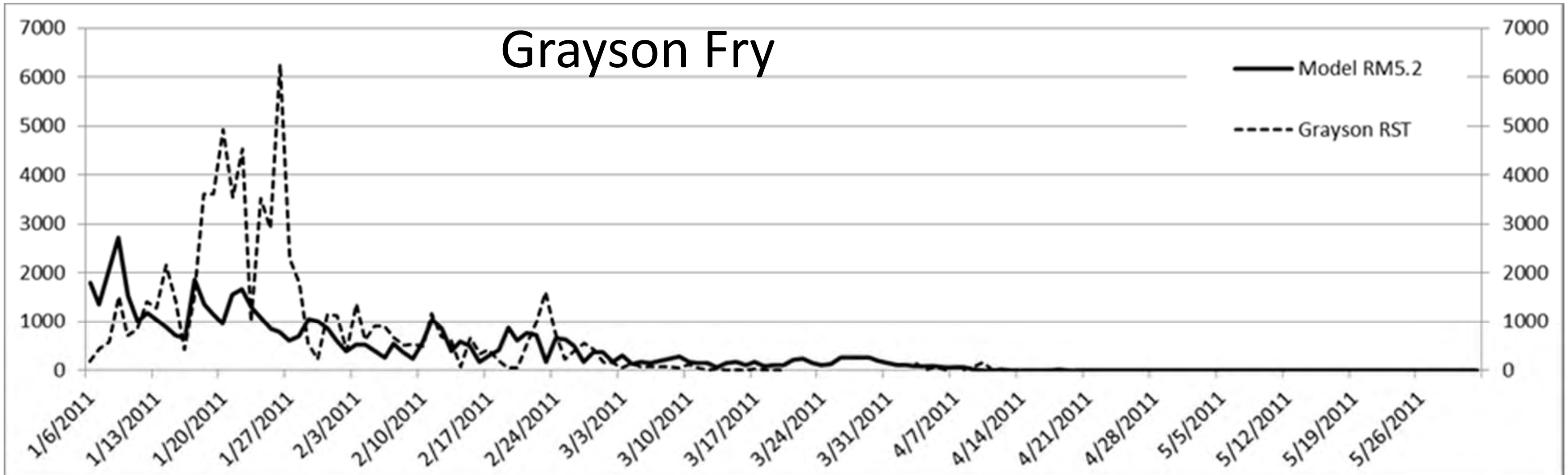


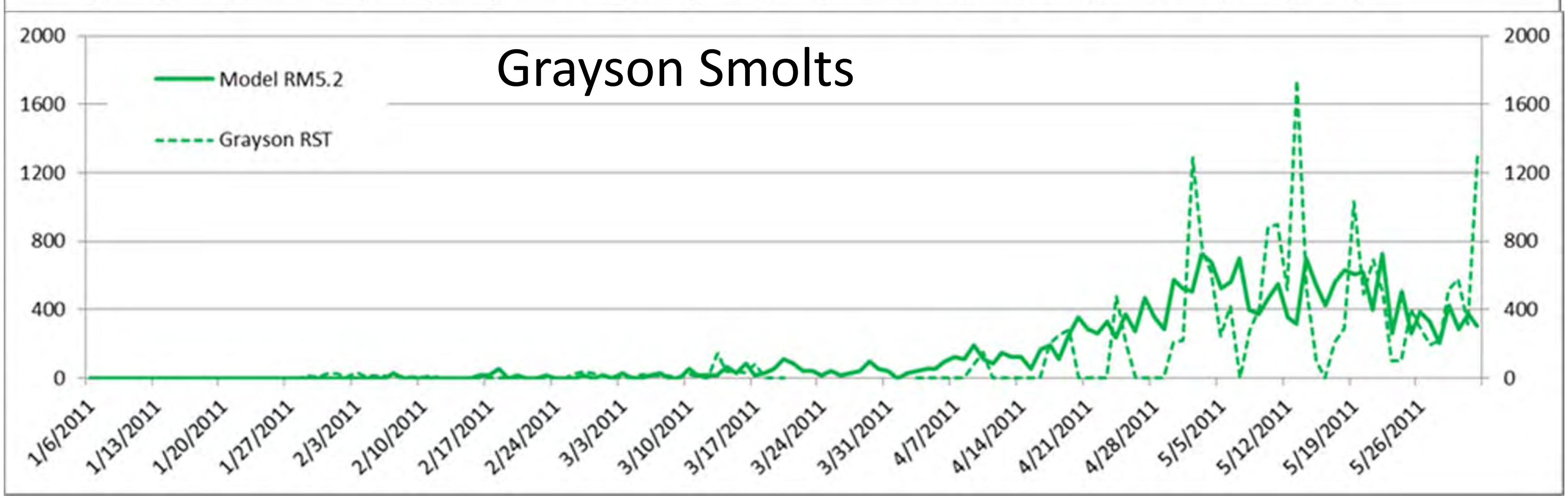
RST passage of Chinook salmon (Fry, Smolt) in 2011



Modeling Calibration and Validation

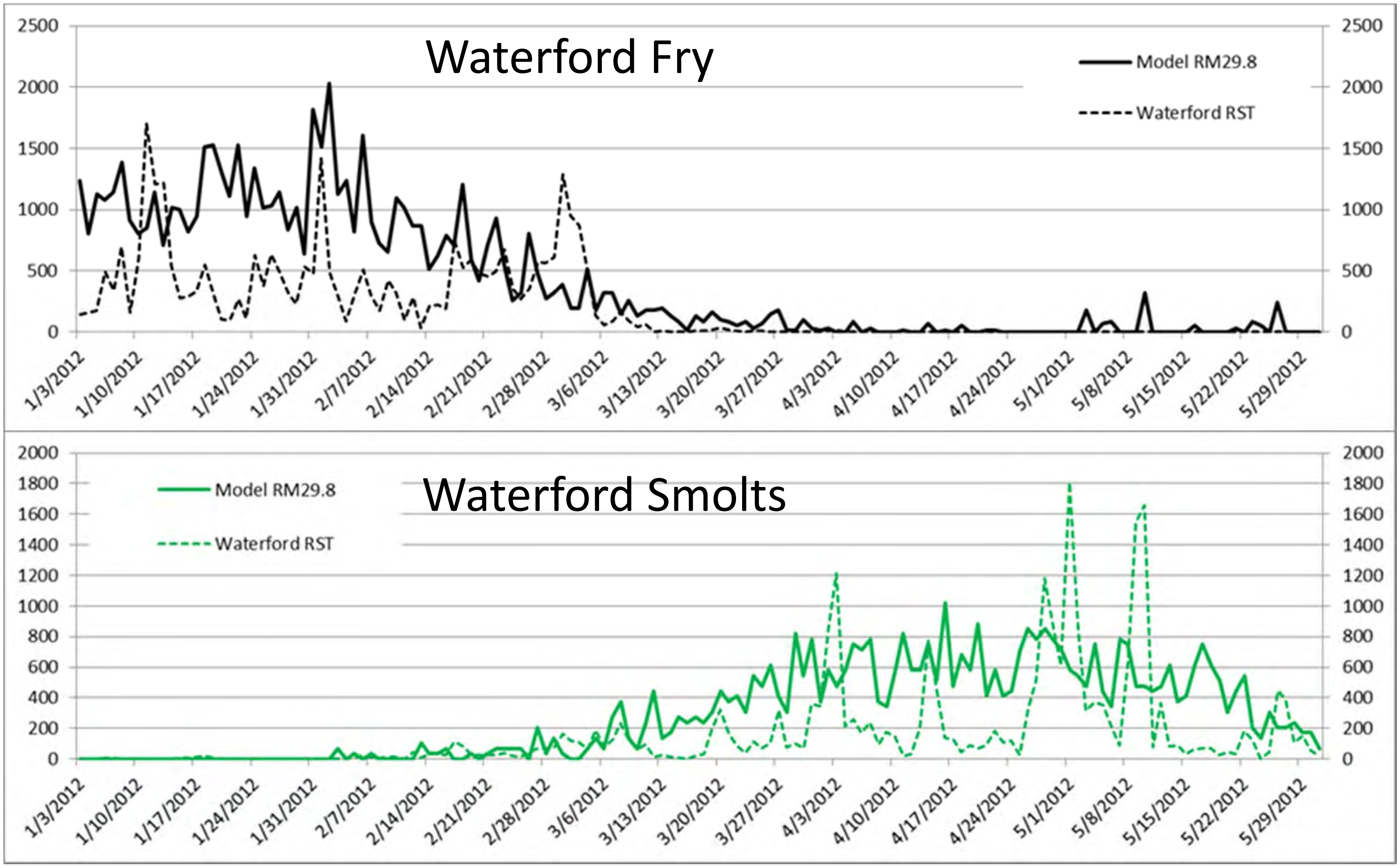
RST passage of Chinook salmon (Fry, Smolt) in 2011



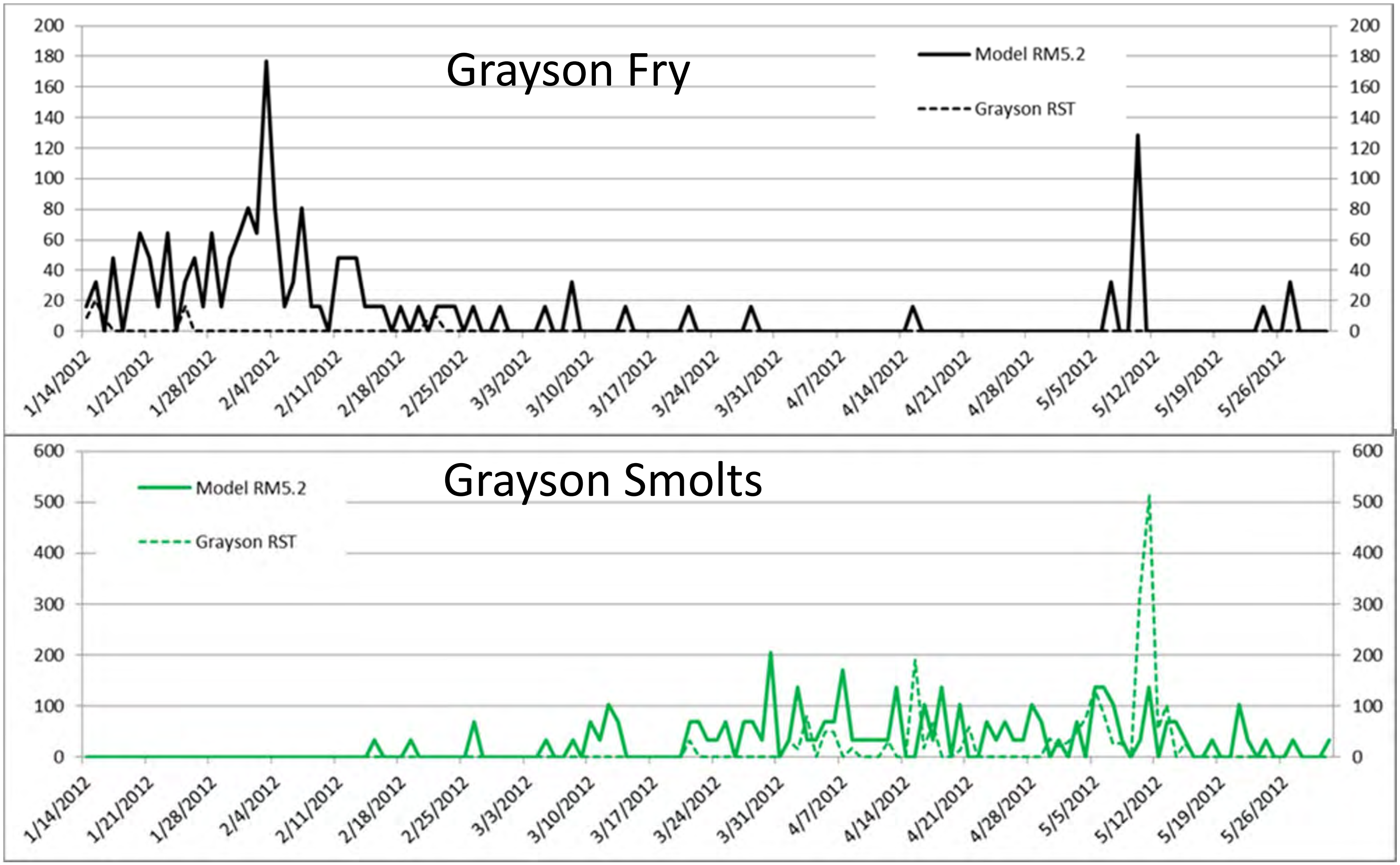


Modeling Calibration and Validation

RST passage of Chinook salmon (Fry, Smolt) in 2012

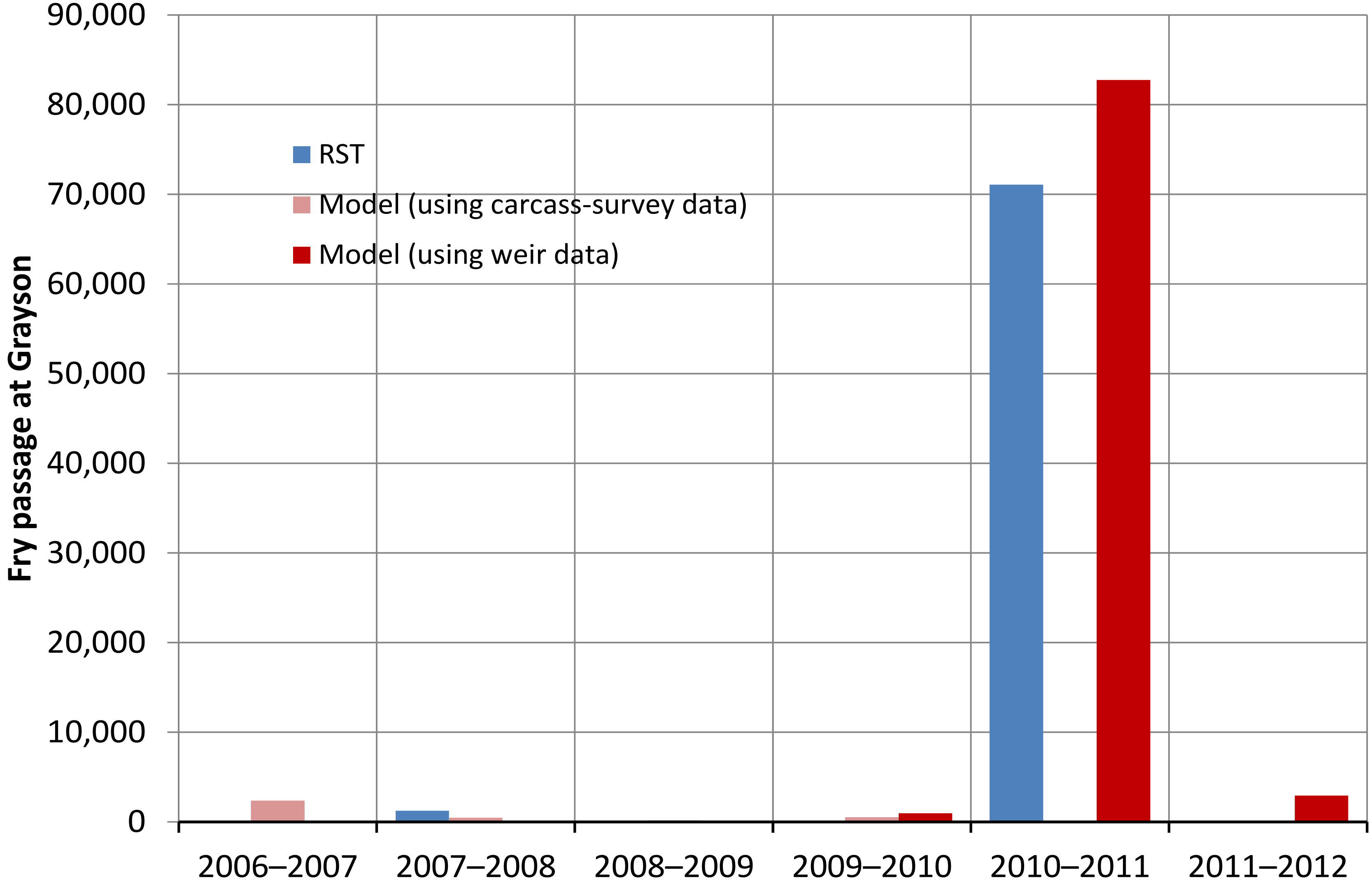


RST passage of Chinook salmon (Fry, Smolt) in 2012



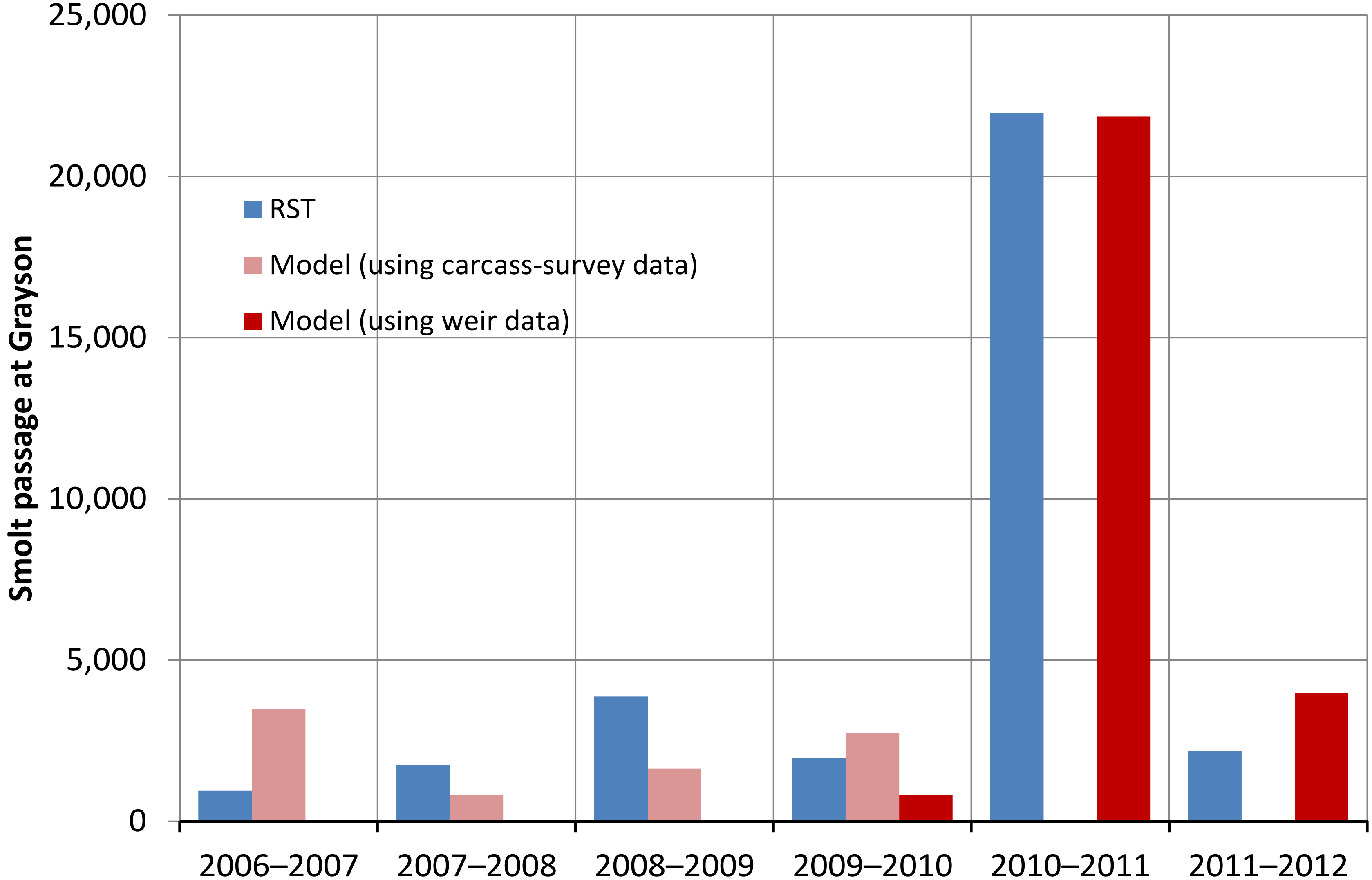
Modeling Calibration and Validation

Annual Fry Passage at Grayson (2007-2012)



Modeling Calibration and Validation

Annual Smolt Passage at Grayson (2007-2012)



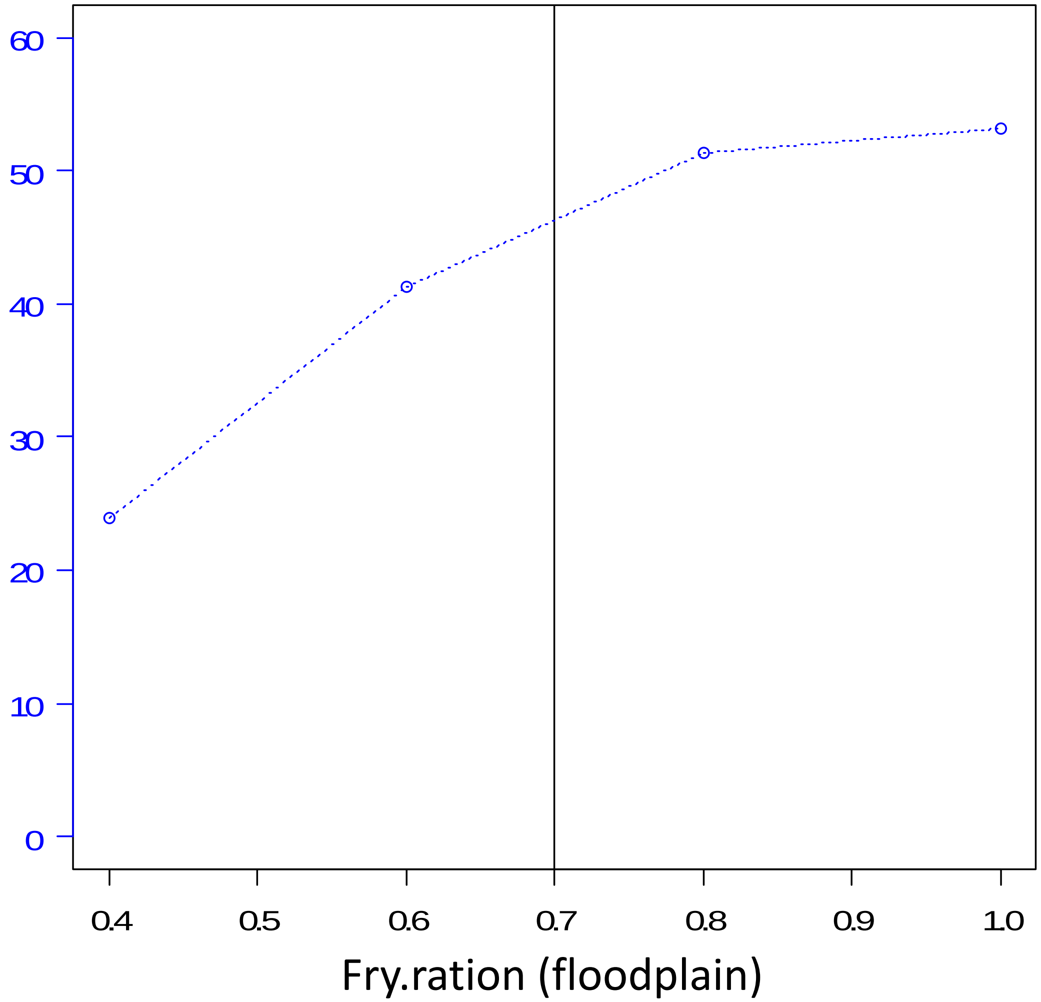
Parameters Affecting Juvenile Productivity

- Vary each parameters around calibrated value
  - Reasonable Range vs. +/- 25% or more around calibrated value
  - All other parameters held constant
- Examine smolt productivity change
  - Evaluation Metric = smolts/female spawner
- Test under broad range in hydrology
  - WY 2009 (Drier WY Type) = Low Discharge
  - WY 2011 (Wetter WY Type) = High Discharge
  - Reasonable Range vs. +/- 25% or more around calibrated value
- Test under broad range in spawning escapement
  - Reference runs of 200 and 10,000 female spawners
- 1,920 model simulations performed

Modeling Sensitivity Testing

Fry feeding ration on floodplain (Example)

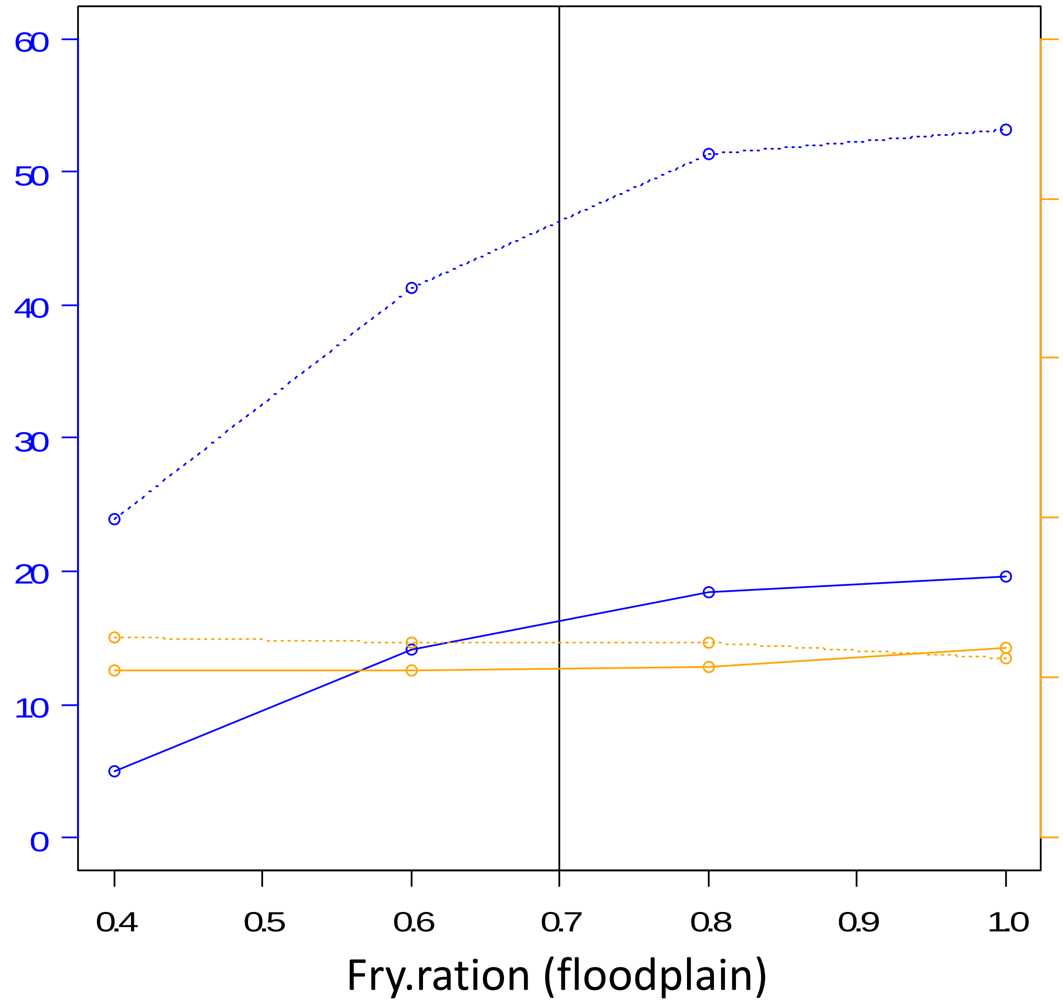
- Smolt productivity vs fry feeding ration on the floodplain.
  - Results for WY 2011 (Wet) shown at 200 spawners
  - Vertical line represents calibrated value = 0.7
  - Moderate sensitivity to reductions in food ration



Modeling Sensitivity Testing

Fry feeding ration on floodplain (Example)

- Blue Lines = High Discharge (2011 “Wet”)
- Orange Lines = Low Discharge (2009 “Drier”)
- Dashed Lines = 200 spawners (“Low”)
- Solid Lines = 10,000 spawners (“High”)
- **Moderate sensitivity in Wet WY type**
- **No sensitivity in Dry WY Type**



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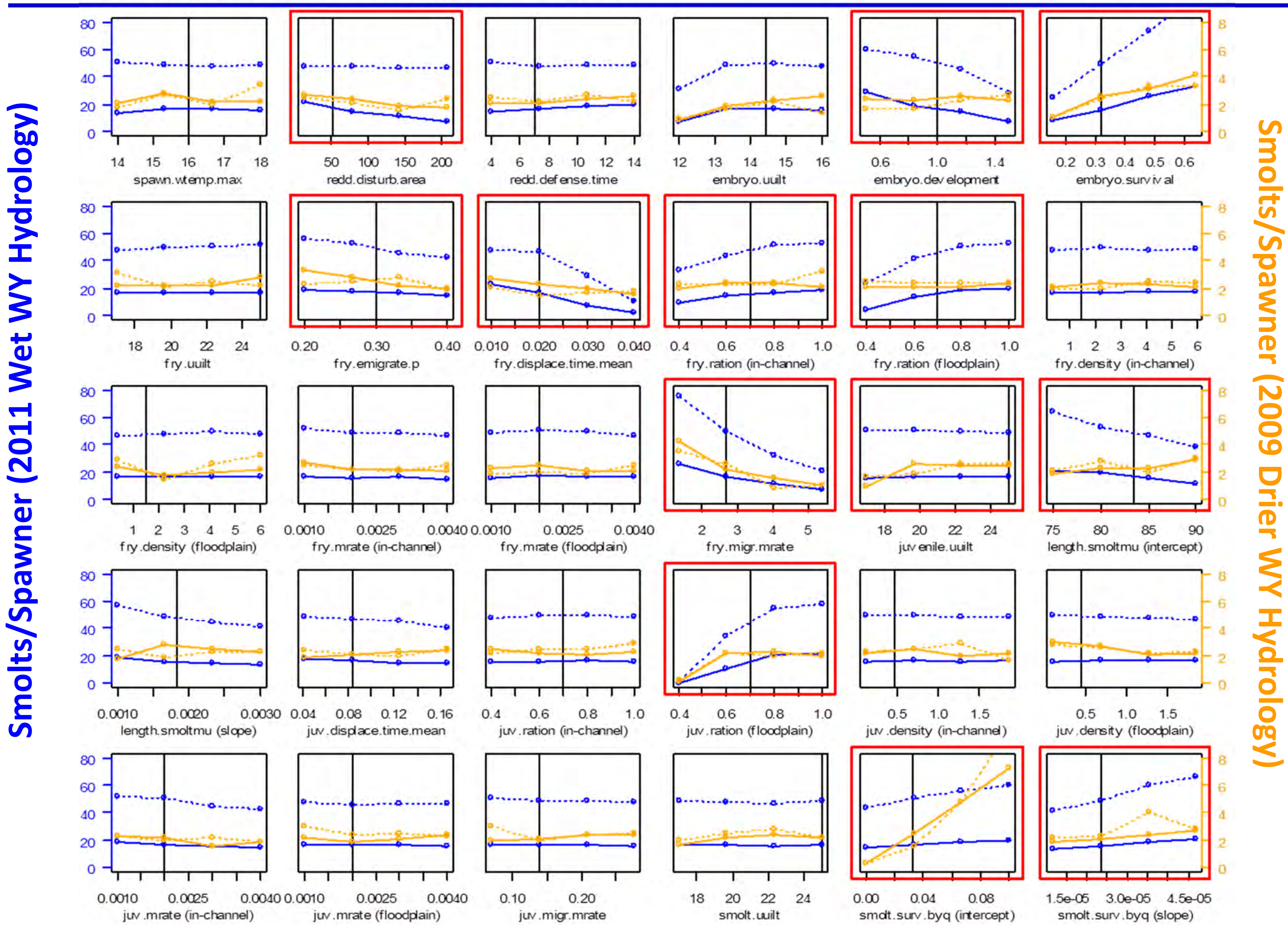

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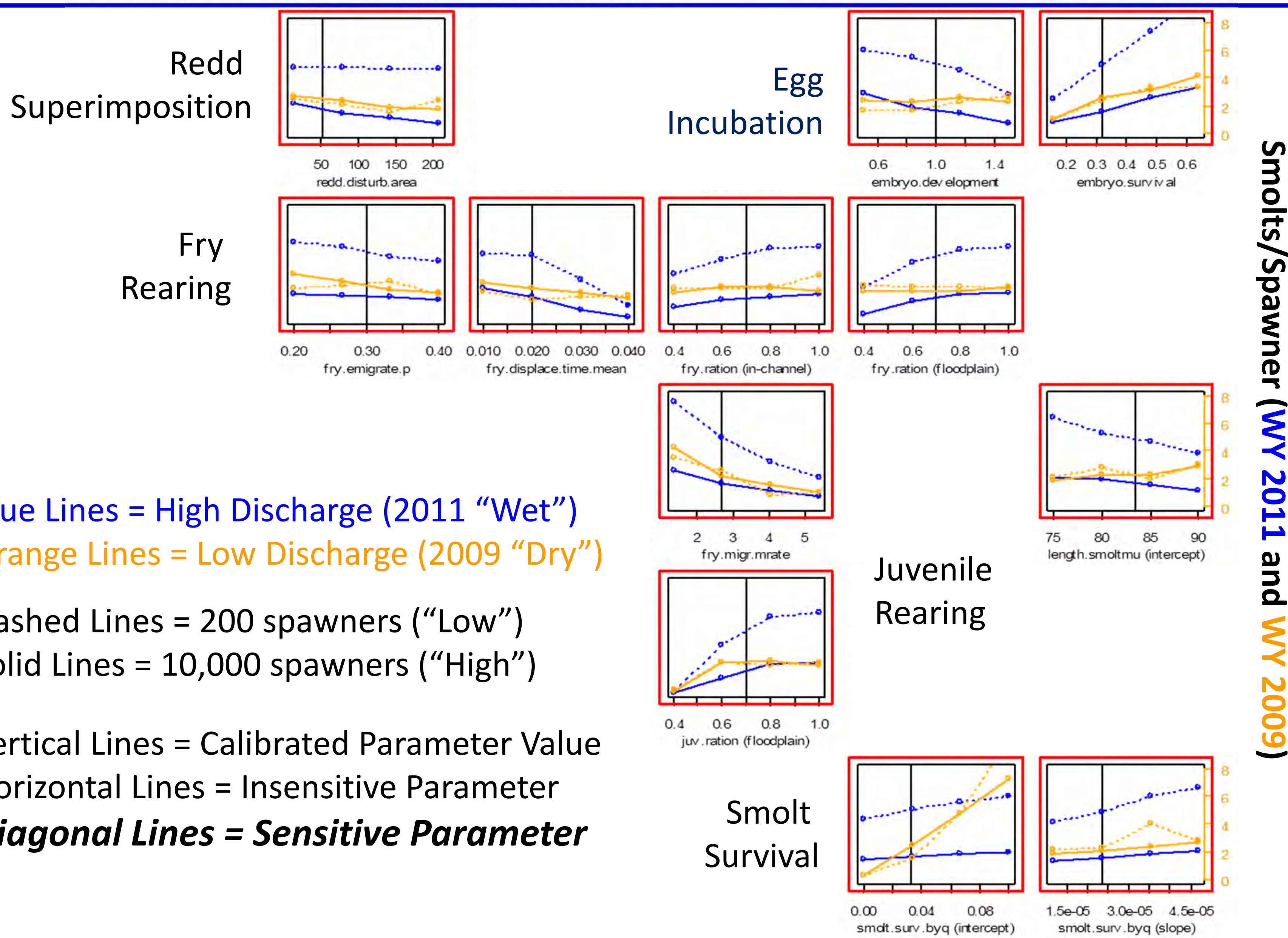


Blue Lines = High Discharge (2011 “Wet”)
Orange Lines = Low Discharge (2009 “Dry”)

Dashed Lines = 200 spawners (“Low”)
Solid Lines = 10,000 spawners (“High”)

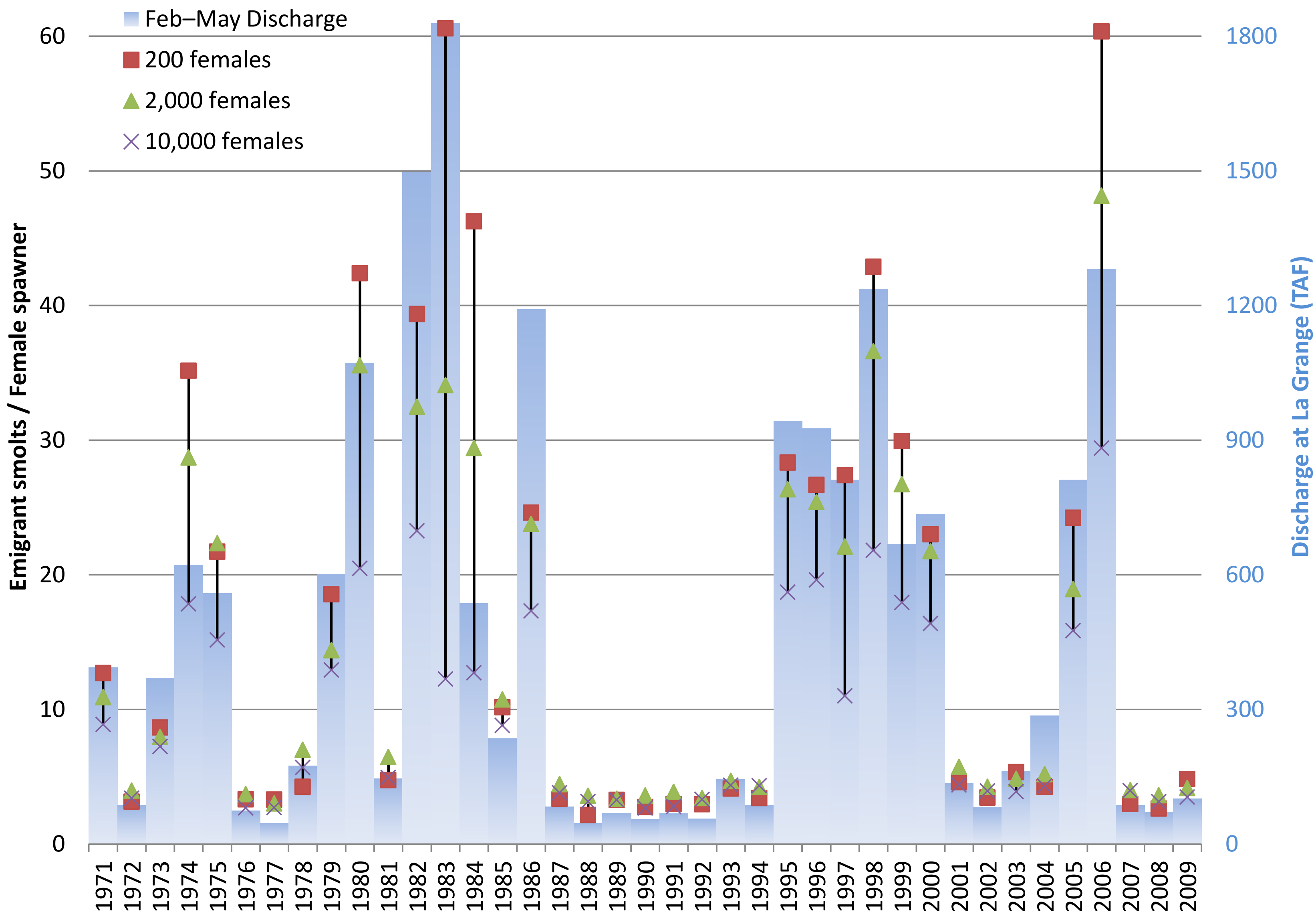
Vertical Lines = Calibrated Parameter Value
Horizontal Lines = Insensitive Parameter
Diagonal Lines = Sensitive Parameter

Modeling Sensitivity Testing

Sensitive parameters affecting smolt productivity:

- Upmigration and Spawning
  - Larger vs. smaller redd size (redd.disturb.area)
- Egg incubation and fry emergence
  - Slower vs. faster incubation rates (embryo.development)
  - Lower vs higher survival-to-emergence due to gravel quality (embryo.survival)
- Fry rearing
  - Greater or lower proportions of emigrant fry upon emergence (fry.emigrate.p)
  - Changes in movement (fry.displace.time.mean) and predation rates (fry.mrate)
- Juvenile rearing
  - Lower vs. higher food availability (juv.ration) within floodplain areas
  - Smaller vs. larger size at smoltification (length.smoltmu)
- Smolt emigration
  - Smolt survival as a function of flow (smolt.surv.byq)

Base Case Simulations (1971-2009)



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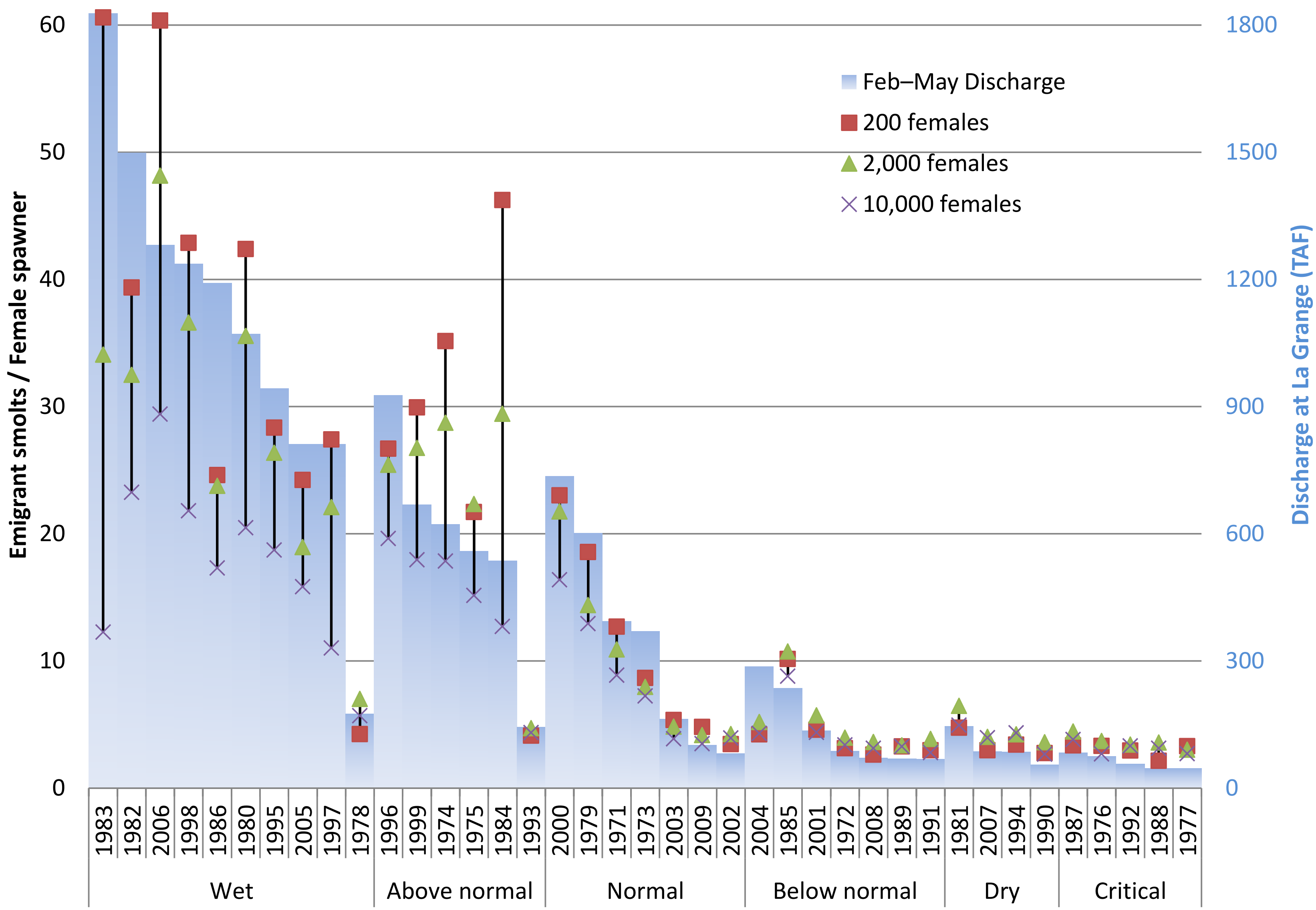
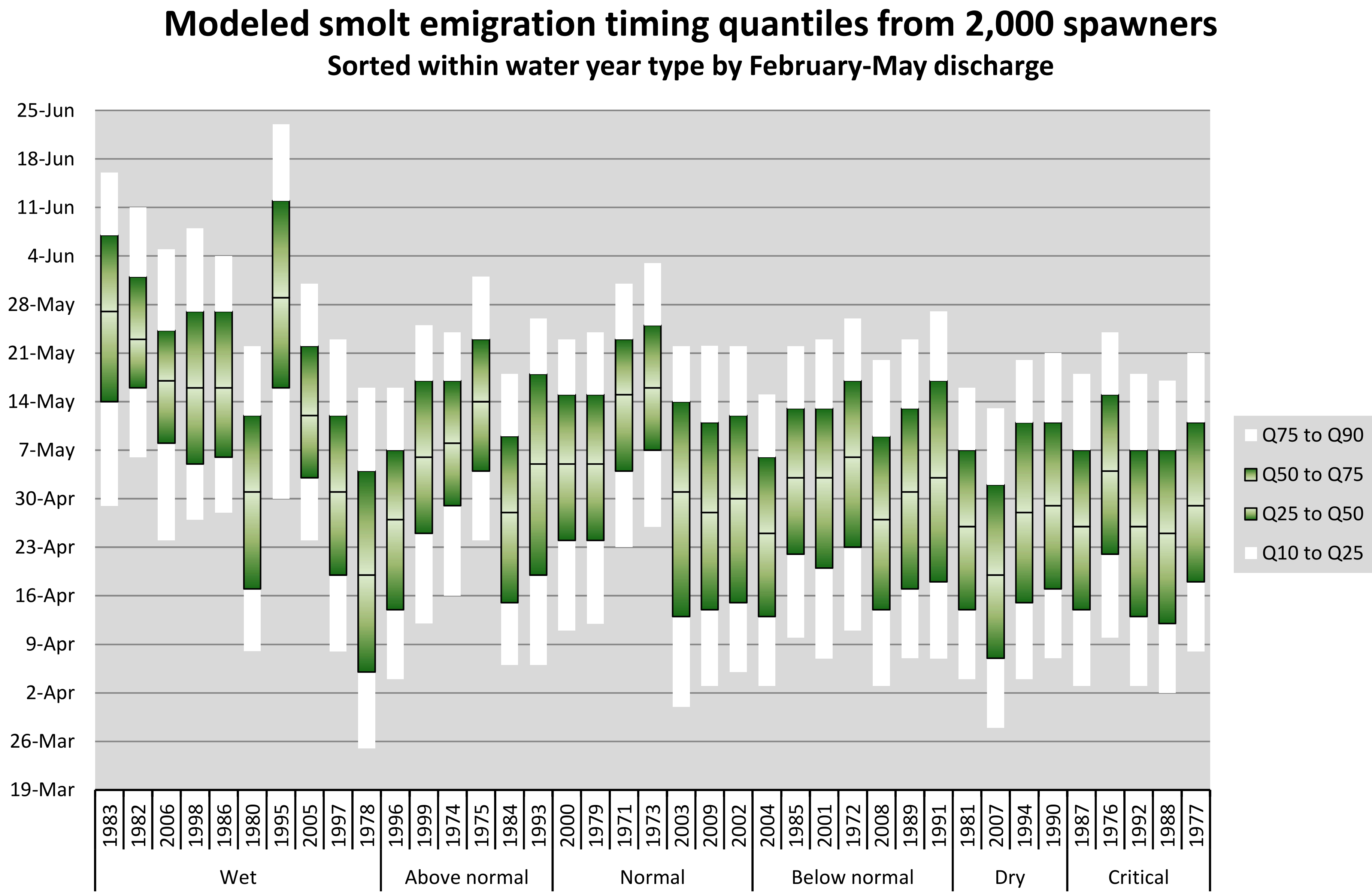


Base Case Simulations (1971-2009)

Don Pedro Project
FERC No. 2299



Factors Affecting Production

Spawning Habitat

1. **Redd superimposition effects**
   – Reductions in smolt productivity with increasing escapement for the Base Case
   – Model sensitivity to redd area
   – Model sensitivity to increased incubation times
2. **Consistent with previous and ongoing studies**
   – Superimposition observations (W&AR-8, TID/MID 1992)
   – Increased “preference” for upstream spawning sites (W&AR-5, W&AR-8)
   – Loss of upstream riffles in 1997 flood (W&AR-4, McBain & Trush 2004, TID/MID 1992)

Factors Affecting Production

Fry/Juvenile Rearing Habitat

1. **No identified rearing habitat limitation**
   - Low model sensitivity to rearing density
   - Low model sensitivity to increased food availability
   - Some sensitivity to reduced food availability below calibrated values
2. **Consistent with previous studies**
   - High food ration estimates from direct stomach content analyses (TID/MID 1997)
   - USFWS (2001, 2002) smolt condition assessments

Factors Affecting Production

Flow Effects

1. **Increased smolt productivity with discharge**
   - Flow linkages with habitat suitability (WUA) and Water Temperature
   - Sensitivity to fry movement and predation mortality parameters
   - Sensitivity of smolt size and emigration timing with rearing temperatures
   - Sensitivity of smolt survival with flow
2. **Consistent with previous studies**
   - Relationships between spring discharge and subsequent escapement 3-years later (W&AR-5 and W&AR-6 citations)
   - Relationships between RST passage and spring discharge (Mesick et al. 2008)

Factors Affecting Production

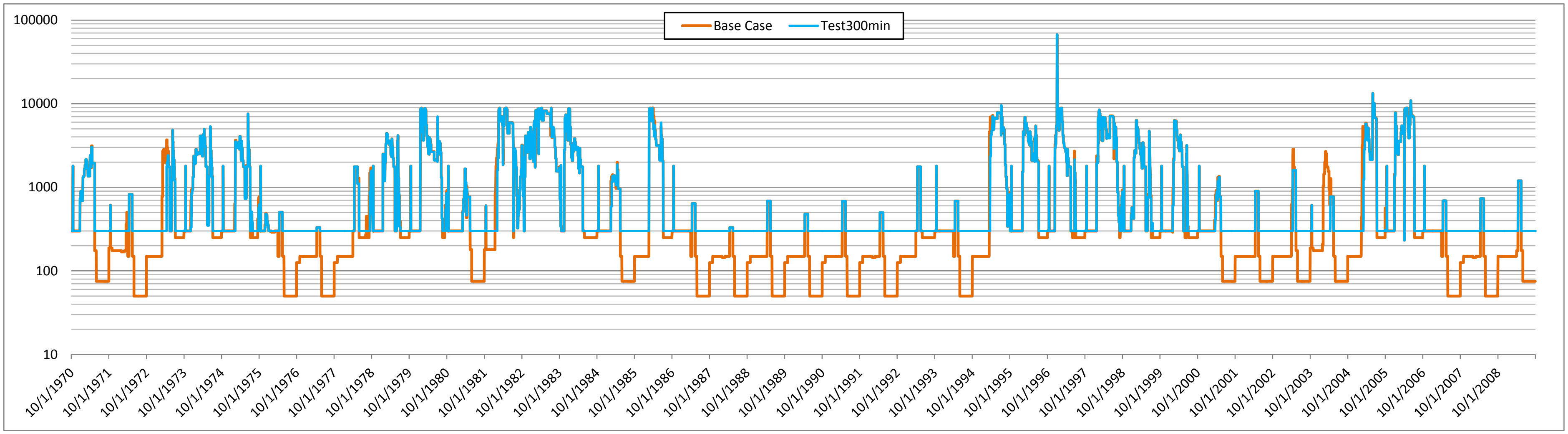
Water Temperature Effects

1. Spawning and Egg Incubation
   - No sensitivity to maximum spawning temperature (14-18°C)
   - No sensitivity to egg mortality threshold (13-16°C)
   - Sensitivity to incubation rate (i.e., slower at lower temps, etc.)
2. Fry/Juvenile Rearing
   - No sensitivity to mortality thresholds (18-25°C)
   - Growth rates affected by water temperature
3. Smolt Emigration
   - No sensitivity to mortality thresholds (18-25°C)
4. Consistent with existing data (W&AR-5)
   - Suitable spawning temperatures by mid- to late-October
   - Suitable rearing temperatures from January through mid-May
   - Peak emigration occurs during mid-to late-April of most years
   - Unsuitable emigration temperatures by early June in most years

Modeling Scenario Example

1. 300 cfs Test Case

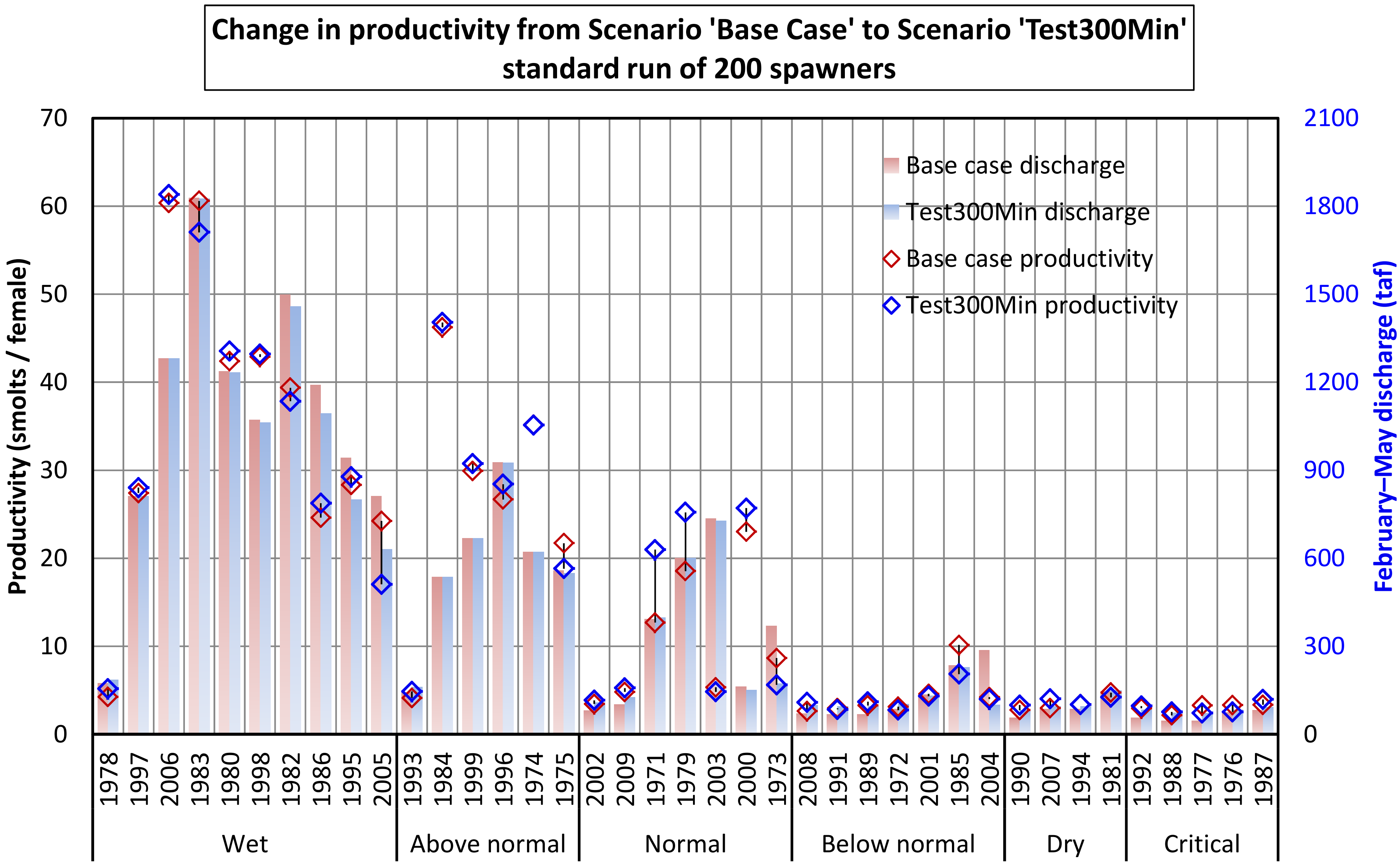
- Provides 300 cfs or FERC (1996) minimum flows, whichever is greater



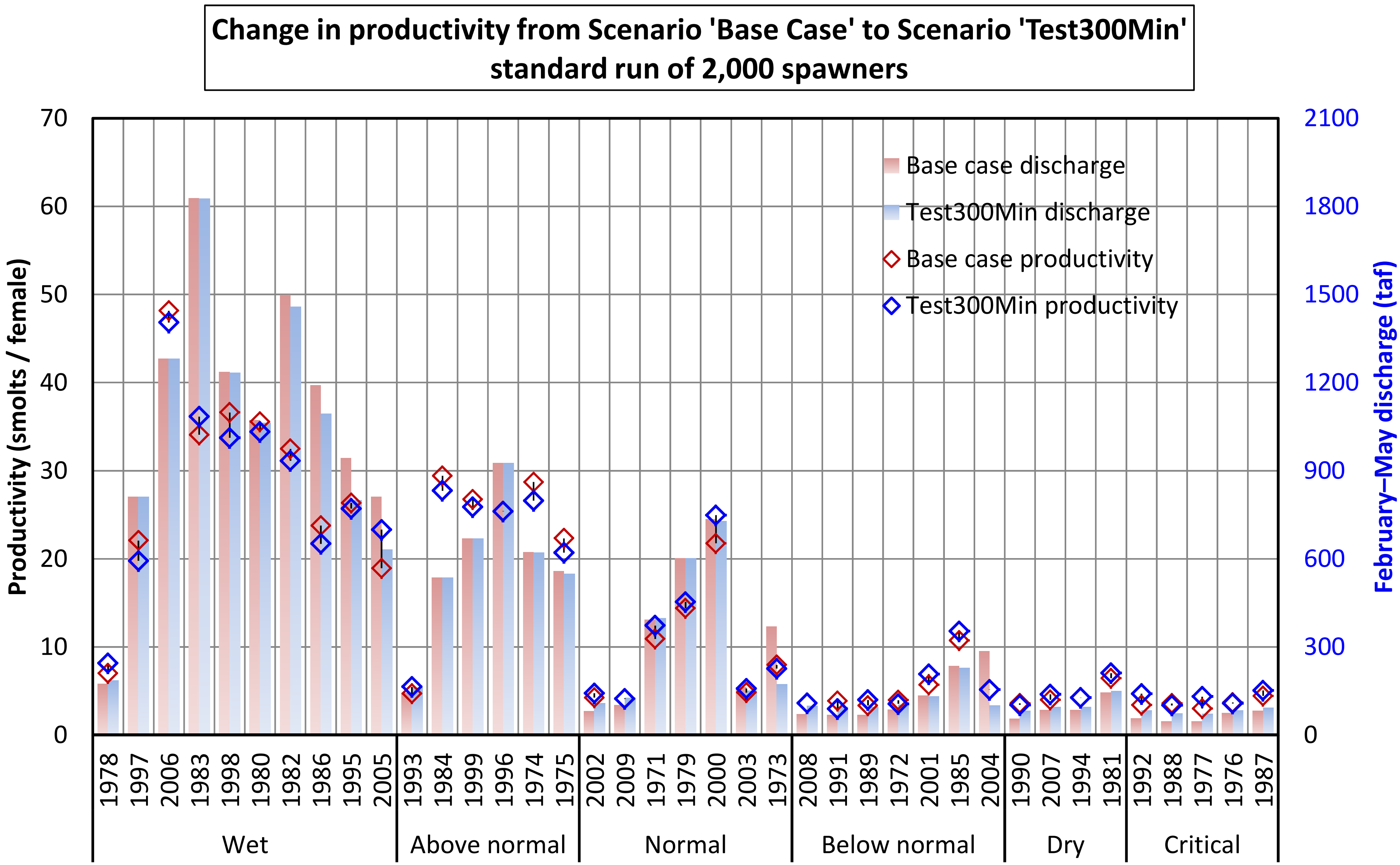
- Smolt productivity results shown for 200 and 2,000 spawners

300 cfs Test Case (Example Scenario)

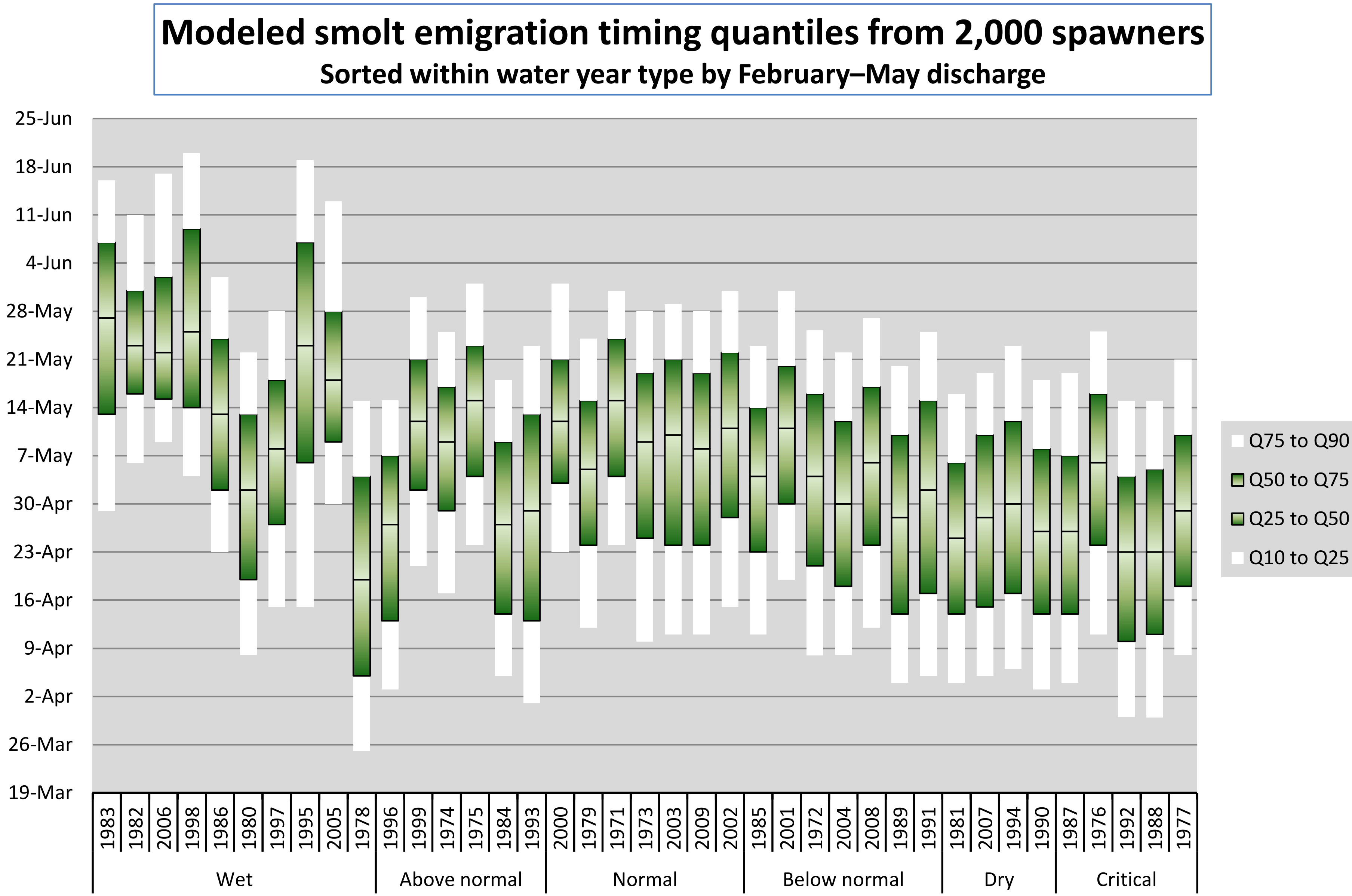
Don Pedro Project
FERC No. 2299



300 cfs Test Case (Example Scenario)



300 cfs Test Case (Example Scenario)



Next Steps

1. Relicensing Participant comments on report and model
2. Scenario testing
3. User-interface model code availability
4. Model training?
5. Future model refinements
   - 2014 Studies (W&AR-7, W&AR-21)
   - RP Comments
   - Other Refinements

Additional Slides

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From: Staples, Rose
Sent: Monday, August 05, 2013 11:48 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Chinook Salmon Population Model Workshop No 2 Reminder-August 6 - HDR Offices Sacramento

Chinook salmon Population Model Workshop No. 2 is being held tomorrow, August 6th, in the HDR Offices in Sacramento at 2379 GATEWAY OAKS DRIVE, Suite 200 (916-679-8700).

AGENDA for the meeting is below—link to the LiveMeeting (and audio call-in number) is also below for those who cannot attend in person. In addition, later today (early evening), I will be posting on the relicensing website (www.donpedro-relicensing) a copy of the PowerPoint presentation that will be used in the meeting. I will post it both as an attachment to the meeting date and as an announcement. I will notify you all when it has been posted. Thank you.

Chinook salmon Population Model Workshop No. 2
Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994
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Join online meeting

https://meet.hdrinc.com/carin.loy/HM5F42M3
First online meeting?
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- 300 cfs Test Case Run
- Requests for Additional Scenarios

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Subject: RE: Don Pedro Chinook Salmon Population Model Workshop No 2 Reminder-August 6 - HDR Offices Sacramento

The PowerPoint presentation has been uploaded both as an attachment to an announcement under the ANNOUNCEMENT tab and also as an attachment to the meeting date under the CALENDAR tab— on the www.donpedro-relicensing.com website. Thank you.

JOHN DEVINE
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From: Staples, Rose
Sent: Wednesday, August 21, 2013 3:20 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro August 6 W-AR-06 Consultation Workshop Draft Notes for Review and Comment
Attachments: 2013-08-06 WAR6 Workshop Meeting Notes Draft.pdf

Please find attached Draft Meeting notes from the August 6th Workshop No. 2 on W&AR-06: Chinook Population Model study. In accordance with the FERC-approved Consultation Workshop protocols, these notes are issued for a 30-day review and comment period. We are also extending the review and comment period on the Draft Chinook Salmon Population Model report issued on July 26 to correspond to the meeting notes due date of September 20th. A question came up in the Workshop of whether the Draft report should be considered a final draft ready for review and comment. This was answered in the affirmative in the Workshop. While additional studies planned for 2014 may lead to refinements in the model, we are not anticipating these would amount to wholesale changes in key parameters. Therefore, we affirm that the July 26th Draft report is intended to be a final draft for your review and comment.

Please send all comments to me at rose.staples@hdrinc.com by Friday, September 20th. Thank you.

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Don Pedro Project Relicensing
W&AR-6 Workshop No. 2
Tuesday, August 6, 2013

Draft Meeting Notes

Attendees

Peter Baker – Stillwater	Ramon Martin - USFWS
Steve Boyd – TID	Gretchen Murphey – CDFW
John Devine – HDR	Bill Paris – MID
Karl English – LGL, Ltd.	John Shelton – CDFW, *by phone*
Donn Furman – CCSF Attorney, *by phone*	Chris Shutes – CSPA
Art Godwin – TID	Dale Stanton – CDFW
Jim Hastreiter –FERC, *by phone*	Josh Strange – Stillwater, *by phone*
Noah Hume – Stillwater	Nicola Ulibarri – Researcher, Stanford Univ.
Zach Jackson – USFWS	Amber Villalobos – SWRCB
Bill Johnston – MID	Scott Wilcox – Stillwater
Ellen Levin – CCSF, *in person in morning, phone in afternoon*	Ron Yoshiyama – CCSF
Carin Loy – HDR	

Introductions and Background

Following introductions, John Devine provided some background on the study process to date.

- This is the second Workshop for this W&AR-6 modeling effort, and is being conducted in accordance with the Consultation Workshop protocols.
- The purpose of Workshop No. 2 is to: (1) update Relicensing Participants (RPs) on study progress; (2) demonstrate model functionality through Calibration/Validation and Base Case simulations; (3) provide updated assessment of important factors affecting Chinook salmon; and (4) solicit input on potential scenarios for evaluation.
- Other studies incorporated in this modeling effort include W&AR-4 (spawning gravel), W&AR-5 (salmonid information synthesis), W&AR-8 (redd mapping), W&AR-16 (water temperature); the one-dimensional (1D) Instream Flow study, and the two-dimensional (2D) Pulse Flow study.
- The *Lower Tuolumne Floodplain Hydraulic Assessment* study plan (W&AR-21) will be released shortly (*Note: this study plan was subsequently released to RPs for 30-day review and comment on August 9, with comments due on or before September 9*). Districts must file the study plan with FERC by September 16, 2013. .

USFWS asked if the draft report should be considered a final draft for purposes of RP's review and comment.

- John Devine responded yes, the report should be considered a final draft with comments due 30 days after issuance of the Workshop Meeting notes in accordance with Consultation Workshop protocols.

Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production

- Noah reviewed and discussed the relationship of the W&AR-6 model to the W&AR-5 Synthesis Study completed in 2012.
- Model structure: the model is largely individually based, spatially explicit, with a simulation period of fall through spring to cover habitat use by in-river life stages.
- Model structured as linked sub-models addressing individual life stages. Allows use of available empirical data for calibration and validation.
- Noah reviewed slides on represented life stages, processes and parameters that are included in the model, and described its modular structure (slide 6).
- The modeled reach (RM 52.2–RM 0) was subdivided into smaller sub-reaches representing uniform habitat conditions. Spatial resolution may be changed by individual life stage.
- Key sub-model relationships by life stage were presented and discussed. These included:
    - Upmigration and spawning: timing (slide 9)
    - Upmigration and spawning: habitat suitability (slide 10)
        - Superimposition effects were noted (e.g., spawners tend to concentrate further upstream)
    - Spawner preference to upstream spawning sites (slide 11)
        - Fitted curve (red) to single-year data (black) from *Redd Mapping Study* (W&AR-8). Cumulative curve (grey) shows 3-year totals of redd counts by RM.
    - Upmigration and spawning: fecundity and mortality (slide 12)
        - No pre-spawning mortality for high water temperature included, since spawners had already passed high water temperature threats further downstream in the San Joaquin River and South Delta.
    - Egg incubation (slide 13)
        - Standard degree-day relationship to hatching with modifications to account for variable temperatures during incubation.
    - Fry rearing: movement (slide 14)
        - Gray contours are density of fry-sized fish, green contours are density of smolt-sized fish. Graphics depict more concentrated upstream rearing under low flow conditions than under high flow conditions, and show a season-long "drift" of the rearing juvenile populations downstream.
    - Fry rearing: habitat use (slide 15)
        - Fry use of both in-channel and overbank areas in the model in proportion to available habitat at a given location and flow condition.
        - Overbank habitat estimate in Shiloh Bridge to San Joaquin River sub-reach is probably an artifact of agricultural field flooding and backwater effects from the San Joaquin (slide 16). Figures to be modified in Final Report to keep the color of the lines for each reach consistent between the two graphics.
        - Carrying capacity is established for each sub-reach on the basis of usable area and maximum rearing density estimates. Fish in excess of carrying capacity are moved downstream to the next sub-reach that has suitable habitat available.
    - Fry rearing: growth (slide 17)
        - Ration is incorporated as a bioenergetic input, not further divided by quantity vs. quality of the food (i.e., existing ration estimates from Tuolumne River reflect stomach contents of Tuolumne River prey items).

        - Ration is assumed to be consistent among different floodplain locations.
        - Noah to provide Stauffer (1973) reference to Ramon
    - Fry rearing: mortality based upon fitting to RST data (slide 19)
    - Juvenile rearing: habitat use and growth (slides 20-22)
        - Follows same approach as for fry described previously
    - Smolt emigration (slides 23-24)
        - Primarily based on size threshold (i.e., developmental), water temperature, historical data documenting size at emigration.
        - Fish generally tend to emigrate at larger sizes in wet year types, smaller in dry year types, later in wet year types, earlier in dry year types.
    - Smolt mortality and survival (slides 25-26)
        - Prior TRTAC smolt survival relationship found to be inconsistent with observed RST data that show lower apparent survival at all flows.
        - The updated smolt survival relationship determined from RST data in Attachment C of the report was used to identify representative periods for smolt movement between the upper and lower RSTs in response to specific flow conditions.
        - QA/QC review identified anomalous conditions on some RST days (e.g., breaking loose from moorings during highest flows).
        - The relationship is sensitive to flow and reflects the observed RST results fairly well.

Model Calibration and Validation Results

- Upmigration and spawning timing
    - There is a time lag of approximately two weeks between weir passage and spawning activity (slide 27) represented as upmigration speed. Note that this only applies when using spawner arrival via weir counts vs. redd count data.
- Rearing patterns (slide 28)
    - Note: Upper x-axis on slide should be showing 2010-11 dates, not 2009-10.
    - Contour plots represent density of fish by river mile
    - Model generally reproduces wet/dry pattern of fish distribution in the river
- RST passage (slides 31-36)
    - Grayson fry and smolt timing are reproduced by the model reasonably well, as well as fry passage at Waterford
    - Timing of Waterford smolts are not as well modeled, in part because model is rearing more fry in lower river
    - Modeled annual passage totals for fry and smolts at Grayson match RST data well (slides 37 and 38), demonstrating good model performance over a range of flow conditions
    - Model can be run using either carcass survey or weir data. Further comparisons can be made as additional spawning data become available (2010–2012).

Model Sensitivity Testing

- Noah and Peter reviewed the general approach to sensitivity testing (slide 39)
    - Different water year and escapement combinations considered along with variations in individual parameter values.
    - Evaluation metric is “smolt productivity”, defined as the number of smolts produced per female spawner.

- Sensitive parameters result in a diagonal (sloped) line, showing a change in productivity with change in the parameter. Less sensitive parameters have a more horizontal line, showing little change in response to different parameter values.
    - Results (smolt productivity) presented for wet/dry conditions~~,~~ and for more/fewer spawners (slides 40-41)
- Modeling Sensitivity Tests (slide 42)
    - 13 relationships show the greatest sensitivity
    - Most sensitive parameters presented in slides 43-44.
    - Animation example of a model run
        - Peter walked the group through an animated example of model run results
        - Smolt emigration travel speed was discussed but is currently not used in the model to assess exposure to predation. Rather than using movement, smolt survival is represented as a direct function of flow based on RST data. Regardless, data indicate smolts move out of the river very quickly (1–2 days); this is consistent with physiological requirements as well.

Lunch Break

Discussion of Base Case (1971–2009) Scenario Results

- Noah introduced the base case simulations (slides 45–47)
    - Run for three reference spawning run sizes
        - Demonstrates a spawner density-dependent effect, with productivity per spawner going up when spawner numbers go down.
        - Demonstrates a positive relationship of smolt productivity with flow
        - Reservoir refilling effects after very dry water years are apparent in 1978 and 1993, where La Grange gage flows are low even though the water year meets a Wet WY designation.
    - There was a question from Chris Shutes about the slide 46 results for 1982 vs. 1983.
        - Subsequent examination of the individual hydrographs showed an average of 8,500 cfs during the pulse flow period (4/15-5/15) in 1982 vs. 10,000 cfs in 1983. In addition, discharge in 1983 drops after the pulse flow period, which did not occur in 1982. This may result in a stronger interaction with escapement size effects upon superimposition and subsequent smolt emigration timing in 1983 than in 1982.
    - Emigration timing (slide 47) shows earlier emigration in drier years, later in wetter years. It also shows variation in timing within each water-year type.
    - Ramon asked if VAMP-year flows were excluded from slide 47.
        - John Devine responded that VAMP flows are not included in the Base Case flows to the lower Tuolumne River.
        - Noah stated that including VAMP flows above Pulse Flow amounts would have marginally higher smolt productivity in years that VAMP was implemented, but would not be expected to alter the observed emigration timing significantly.

Discussion of Factors Affecting Chinook Production

- Model can be used to look at how different factors affect production. Some of these effects include the following (slides 48- 51)
- Spawning habitat
  - Redd superimposition effects: smolt productivity per spawner declines with increased escapement
- Rearing habitat
  - There is low model sensitivity to rearing density (e.g., quantity of rearing habitat area) or increased food availability
  - The assumption of greater food availability in lower reach overbank areas causes some improvement in rearing capacity there during high flows, although not that many fish rear that far downstream.
  - A question was raised regarding whether the carrying capacity and rearing may obscure any important indirect effects such as increased exposure to predation (Dale Stanton, John Shelton). Actual fish habitat use is patchy, and although fish movement and thus predator exposure may vary on smaller scales, the current treatment of rearing habitat in the model reproduces RST passage well.
- Flow effects
  - Increased smolt productivity with spring discharge. Model is reproducing observed historical results (slide 50)
- Water temperature
  - Little sensitivity to temperature during the times of year the fish are present (slide 51)
  - Mortality thresholds came from guidance documents and literature reviews prepared as part of the EPA (2003) development.
    - Peter mentioned that even lowering the mortality threshold (UUILT) to 18C in sensitivity testing did not produce significant change in productivity.
  - Question raised by John Shelton regarding microhabitat distribution of temperature and behavioral responses and potential effects.
    - John Devine mentioned the recent deployment of numerous in-river thermographs to provide more information about local temperature refugia as compared to broader longitudinal patterns in historical thermograph data and model output.
    - Noah noted that 2-dimensional temperature variations are below the resolution of the current model. .

Discussion of Modeling Scenarios

- John Devine introduced the concept of modeling scenarios and opportunity to run alternative scenarios proposed by the group.
- Noah discussed the 300 cfs Test Case run that was completed as part of the *Operations Model* training (slides 52-53)
  - Small increase in productivity in drier water year types relative to Base Case.
  - Up-migration timing is not significantly affected by flow or temperature factors. However, year-to-year variations in up-migration timing can affect when smolts go out and how that overlaps with scheduled pulse flows, which can substantively affect overall productivity.
  - Results differ based on numbers of spawners, and water year type

- A concern was expressed (Gretchen) that smolts/spawner might be a misleading metric, and for some presentations the total smolt production might be a more helpful metric. Others noted that this is simply a matter of multiplying by the sizes of the represented reference runs.

Requests for Additional Scenarios

- Model can be run using alternate input data, such as operations model output and river temperature model output.
- Dale Stanton suggested experimenting with timing of spring pulses to match emigration peaks.
- A second alternative included the 35% unimpaired flow scenario developed as part of the *Operations Model* (W&AR-2). Model runs will be made with 2,000 and 10,000 spawners.
- John encouraged RPs to call Noah with questions or other scenario ideas, in addition to putting them in writing.
- As a sensitivity evaluation, Ramon requested substitution of the 7-day average daily max (7DADM) and Daily Maximum temperatures as input data for the Base Case. These alternate input data will be evaluated at the 25C UUILT or other mortality thresholds from EPA (2003) that are relevant to the averaging periods of the water temperature input data.

Next Steps/Action Items (slide 56)

- A user interface is in development to make model runs simpler for others to execute
- An offer for model training was made, no RPs are currently requesting training.
- Any other scenario requests will be provided by RPs along with their comments on the report.
- Noah to provide Stauffer (1973) reference to Ramon. [*Note: Transmitted by e-mail on 8/9/2013*]
- Figures represented in Slide 16 graphics to be modified in Final Report to keep the color of the lines for each reach consistent between the two graphics.
- RP comments should be provided on the Final Draft Report. Although the report may be potentially be updated on the basis of RP comments and any 2014 Study results, RPs should consider the W&AR-6 report as a “Final” report.
- Ramon will likely wait for the floodplain inundation study before focusing on results of runs of the salmon model. Noah indicated that he would not expect significant changes to model results coming from the floodplain inundation study. Model runs performed with the current parameterization will provide very useful comparisons between the Base Case and other operations scenarios.

Attachments

Attachment 1: Agenda

Attachment 2: Modeling Workshop No. 2 Slides. *Note the slides below were revised following the meeting*:

- Slide 15 (Usable Area for Fry) – Re-formatted data series to match colors by sub-reach
- Slide 17 (Fry Rearing (Growth) – Insertion of Stauffer (1973) reference.
- Slide 15 (Usable Area for Juveniles) – Re-formatted data series to match colors by sub-reach
- Slide 28/29 (Fry and Juvenile Rearing Patterns) – Correction of date scale in WY 2011
- Slide 39 (Parameters Affecting Juvenile Productivity) – Deletion of repeated bullet.
- Slide 44 (Sensitive parameters) – Inserted bullet Re: sensitivity to lower food-ration on in-channel and floodplain habitats for fry.

Attachment 1

Agenda

Chinook salmon Population Model Workshop No. 2
Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994

[Join online meeting](https://meet.hdrinc.com/carin.loy/HM5F42M3)

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First online meeting?

Agenda

9:00 a.m. – 9:15 a.m.	**Introductions and Background**
9:15 a.m. – 10:30 a.m.	**Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production** **1. Relationship to W&AR-5 Synthesis Study** **2. General assumptions and model structure** **3. Key Sub Model Relationships by Life-Stage**
10:30 a.m. – 11:00 a.m.	**Model Calibration and Validation Results**
11:00 a.m. – 12:00 p.m.	**Modeling Sensitivity Testing**
12:00 p.m. – 1:00 p.m.	**Lunch (on your own)**
1:00 p.m. – 2:00 p.m.	**Discussion of Base Case (1971–2009) Scenario Results**
2:00 p.m. – 3:00 p.m.	**Discussion of Factors Affecting Chinook Production**
3:00 p.m. – 3:45 p.m.	**Discussion of Modeling Scenarios** - **300 cfs Test Case Run** - **Requests for Additional Scenarios**
3:45 p.m. – 4:00 p.m.	**Next Steps**

Attachment 2

Modeling Workshop No. 2 Slides

Tuolumne River Chinook salmon (W&AR-6) study

Modeling Workshop No. 2

August 6, 2013

Don Pedro Project Relicensing
FERC No. 2299

Agenda/Overview

Introductions and Background

1. Purpose of Meeting
2. Relationship to Other Studies

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Salmon Juvenile Production

1. Relationship to W&AR-5 Synthesis
2. General Assumptions and Model Structure
3. Key Sub Model Relationships by Life-Stage

Modeling Calibration and Validation

1. Upmigration and Spawning
2. Fry and Juvenile Rearing
3. RST passage of Fry and Smolts

Agenda / Overview

Sensitivity Testing of Parameters by Life Stage

1. Upmigration and Spawning
2. Egg Incubation
3. Fry Rearing
4. Juvenile Rearing
5. Smolt Emigration

Base Case Scenario Results

Factors Affecting Chinook Production

Discussion of Modeling Scenarios

1. 300 cfs Test Case (Example Scenario) Run
2. Requests for Additional Scenarios

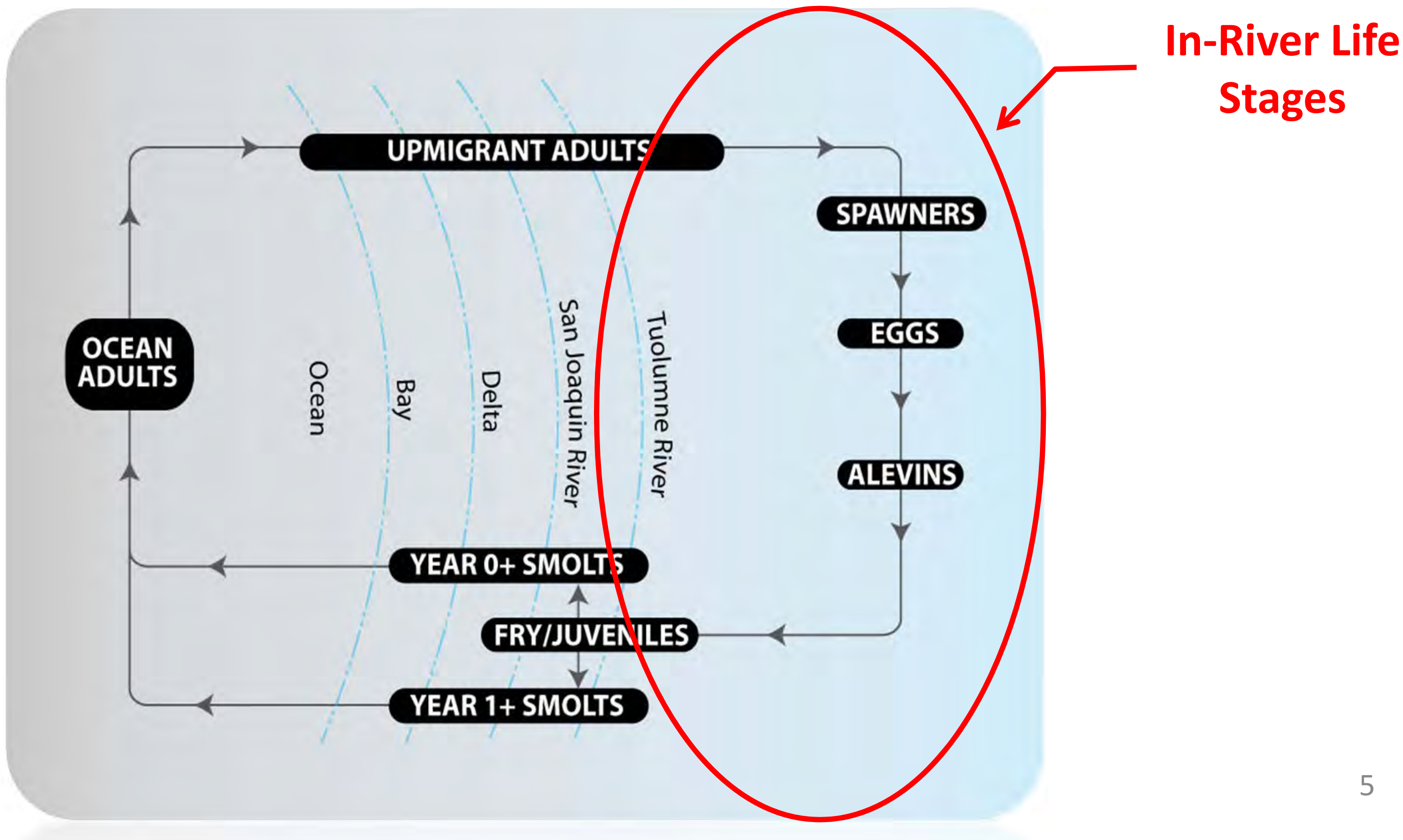
Next Steps

Relationship to W&AR-5 Synthesis

- Literature Review
- Initial assessment of in-river and out-of-basin factors affecting overall population levels
- Production models intended to examine relative importance of identified ***in-river factors upon juvenile production***
- Inclusion of some factors for modeling not recognized as important in initial W&AR-5 assessment
- Recognition that some factors may not be feasibly modeled

General Assumptions and Model Structure

- Independent sub-models separate life-history transitions
  - calibration and verification (e.g., weir counts, redd counts, egg-survival, RST passage)



Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Don Pedro Project
FERC No. 2299

Events	Life stages
arrival at weir location	spawner
burial of fertilized eggs	redd
emergence from gravels	swimup
arrival at RST locations	passage fry
exit from Tuolumne River	emigrant fry
attainment of dev. threshold (fork length = 50 mm)	parr
arrival at RST locations	passage juvenile
exit from Tuolumne River	emigrant juvenile
smoltification	smolt
remaining after the spring outmigration	summer

Life stanzas	Processes (Parameters)
upstream migration, habitat selection, redd construction	gravel area (flow, water temp.) gravel preference redd dimensions, redd defense times
embryo development	development rate (water temp.) acute mortality (water temp.) superimposition mortality gravel quality-related mortality
fry rearing	displacement (flow) migration mortality habitat area (flow, water temp.) development rate (water temp.)
juvenile rearing	habitat area (flow, water temp.) development rate (water temp.) acute mortality (water temp.) background mortality smoltification criteria

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Don Pedro Project
FERC No. 2299

Events	Life stages	Life stanzas	Processes/Parameters
	smolt		
arrival at RST locations	passage smolt	smolt emigration	acute mortality (water temp.) background mortality (flow)
exit from Tuolumne River	emigrant smolt		

Model Structure

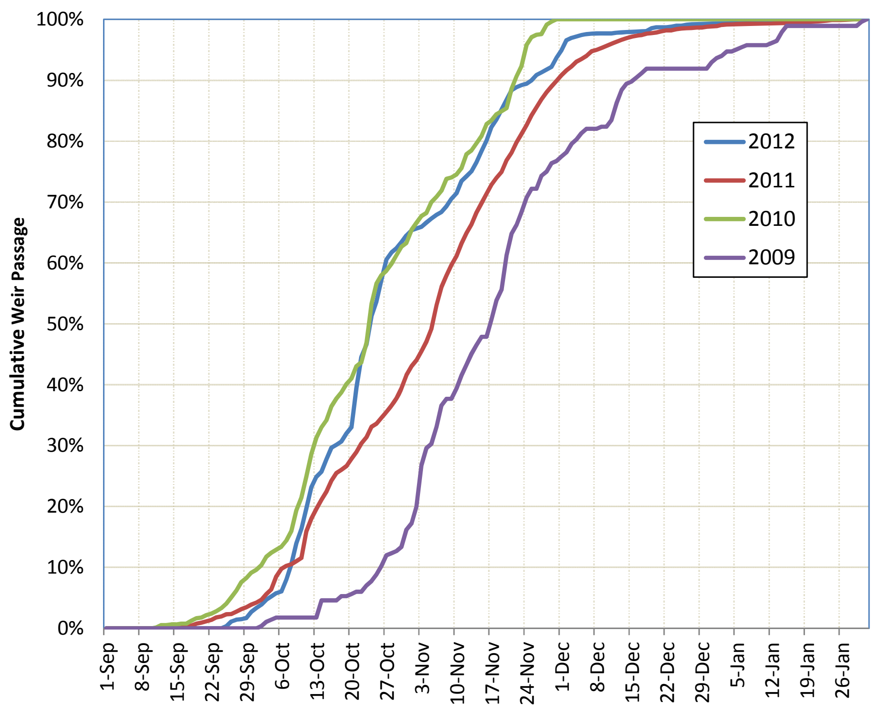
- Subdivision of river into smaller sub-reaches
  - longitudinal variation in habitat composition and availability
- Sub-reach resolution may be altered by sub-model
  - (e.g., spawning vs. rearing, temperature variations, etc.)

W&AR-6 Model Reaches

La Grange dam to OLGB	52.0-50.7
OLGB to TLSRA	50.7-42.0
TLSRA to Hickman Bridge	42.0-31.6
Hickman Bridge to Charles Road	31.6-24.8
Charles Road to Legion Park	24.8-17.6
Legion Park to Riverdale Park	17.6-12.4
Riverdale Park to Shiloh Bridge	12.4-3.5
Shiloh Bridge to mouth	3.5-0.0

Key Sub Model Relationships by Life-Stage

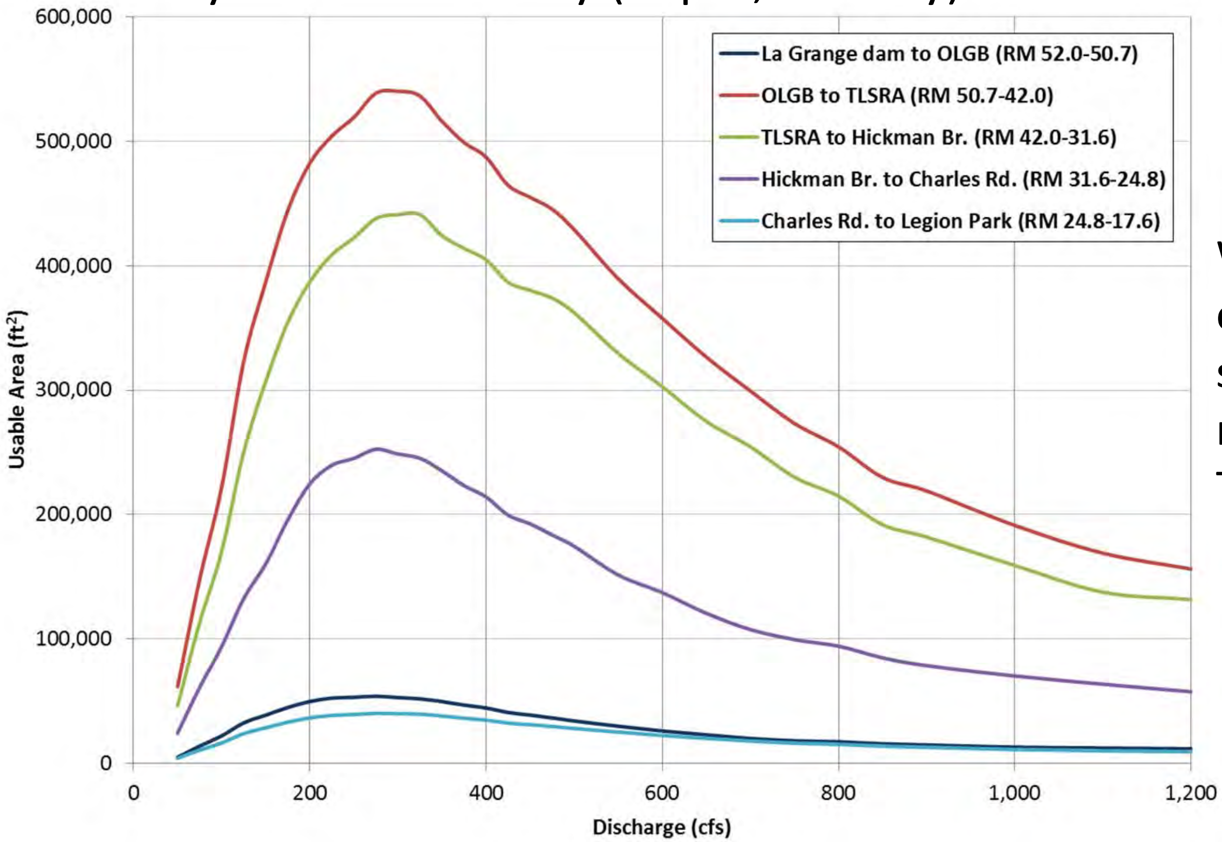
- Upmigration and Spawning (Timing)
  - Migration timing and spawner movement from weir counts
  - Historical spawner survey statistics (e.g., run size, age composition, sex ratio by age, arrival times mean and standard deviation)



Tuolumne River weir passage 2009–2012

Key Sub Model Relationships by Life-Stage

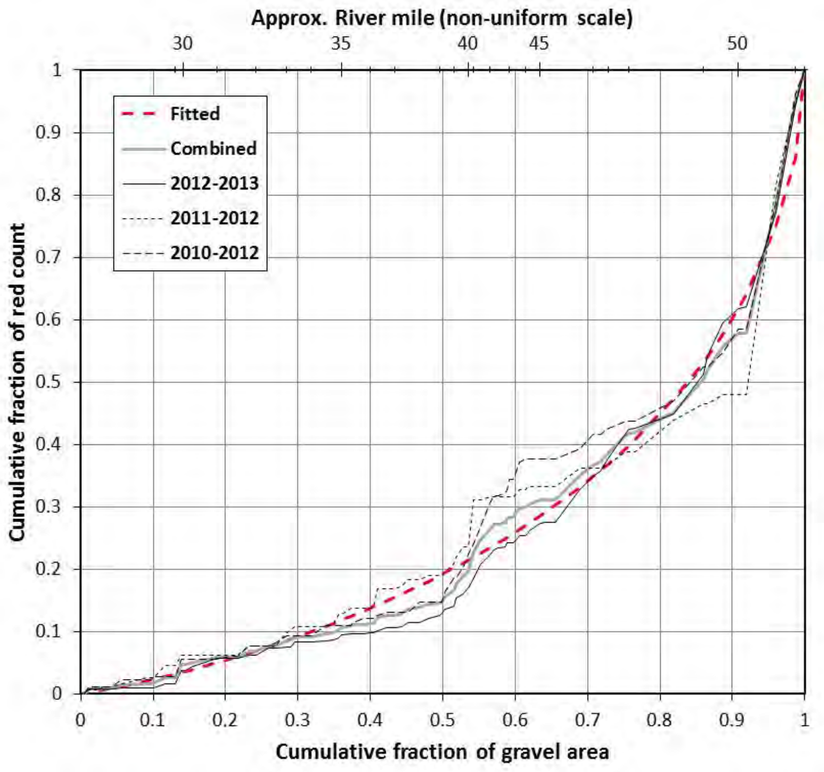
- Upmigration and Spawning (Habitat Suitability)
  - Spawning habitat suitability combines gravel suitability (W&AR-4) with hydraulic suitability (depth, velocity) from IFIM Study.



Weighted usable area estimates for Chinook salmon spawning in sub-reaches of the lower Tuolumne River

Key Sub Model Relationships by Life-Stage

- Spawning (Habitat Suitability)
  - Habitat use of suitable spawning areas as a "preference" function of RM based upon recent redd mapping (W&AR-8)
  - Superimposition onto undefended redds allowed



$$\Phi^{-1}(G(i)) = b_0 + b_1\Phi^{-1}(F(i)),$$

$$\Phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} e^{-t^2/2}\,dt$$

$\Phi(z)$ = probit transform

Φ^{-1} = inverse of the probit transform

$F(i)$ = cumulative fraction of gravel area within and downstream of a mapped riffle number (i)

$G(i)$ = cumulative fraction of the female spawners expected to spawn within and downstream of riffle number (i)

Key Sub Model Relationships by Life-Stage

- Upmigration and Spawning (Fecundity)
  - Egg deposition based upon historical fecundity relationships

$$Eggs = 158.45 \times L - 6138.91$$ *L* = fork length

- Upmigration and Spawning (Mortality)
  - No pre-spawn mortality applied due to high water temperature (W&AR-5).

Key Sub Model Relationships by Life-Stage

- Egg Incubation
  - Embryo development based upon temperature and incubation time (Rombough 1985)
  - Mortality due to superimposition, excess fines, and water temperature

$$\sum_{i=1}^{D} \mathrm{WTU}_i \geq 1, \text{ with}$$
$$WTU_i = \exp(-5.88 - 0.000513W + 0.152T_i)$$

WTU_i = weighted thermal units on day (i)

D = days after fertilization that fry hatching occurs

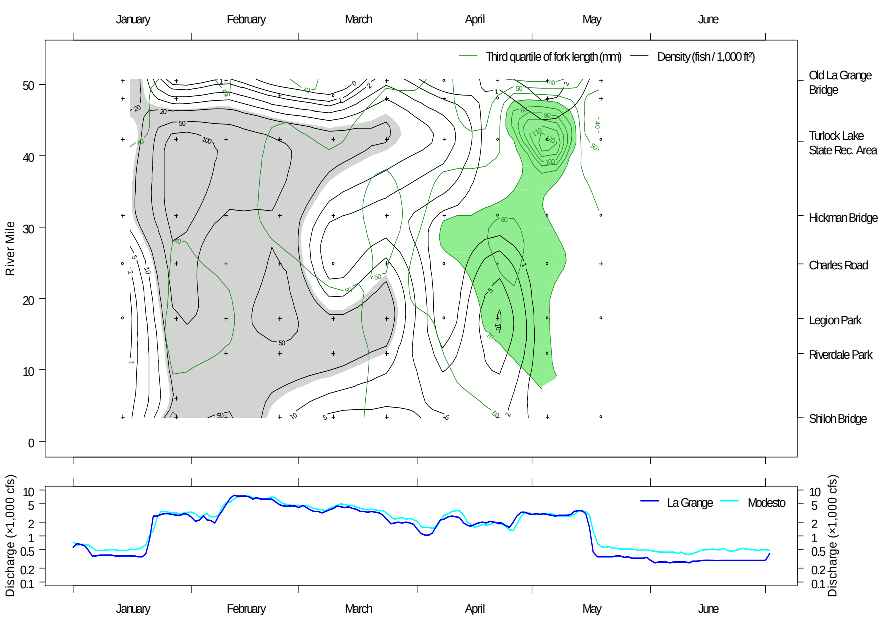
W = estimate of initial egg weight

T = temperature on day (i)

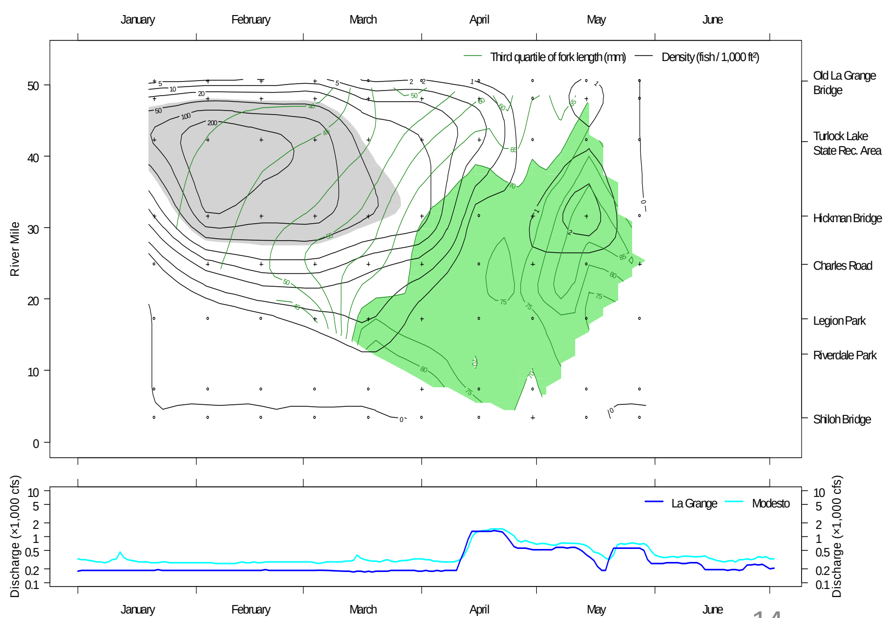
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Movement)
  - Downstream (volitional) movement of fry shortly after emergence (RST data)
  - Riverwide distribution at high/low flows (seine data)

1999 Seine Density



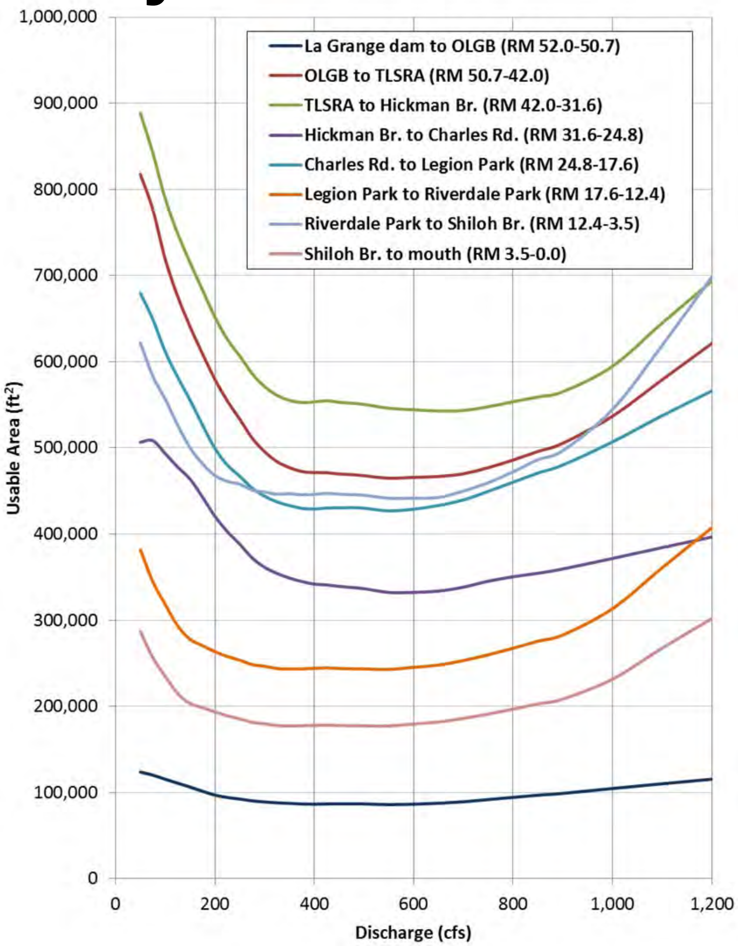
2003 Seine Density



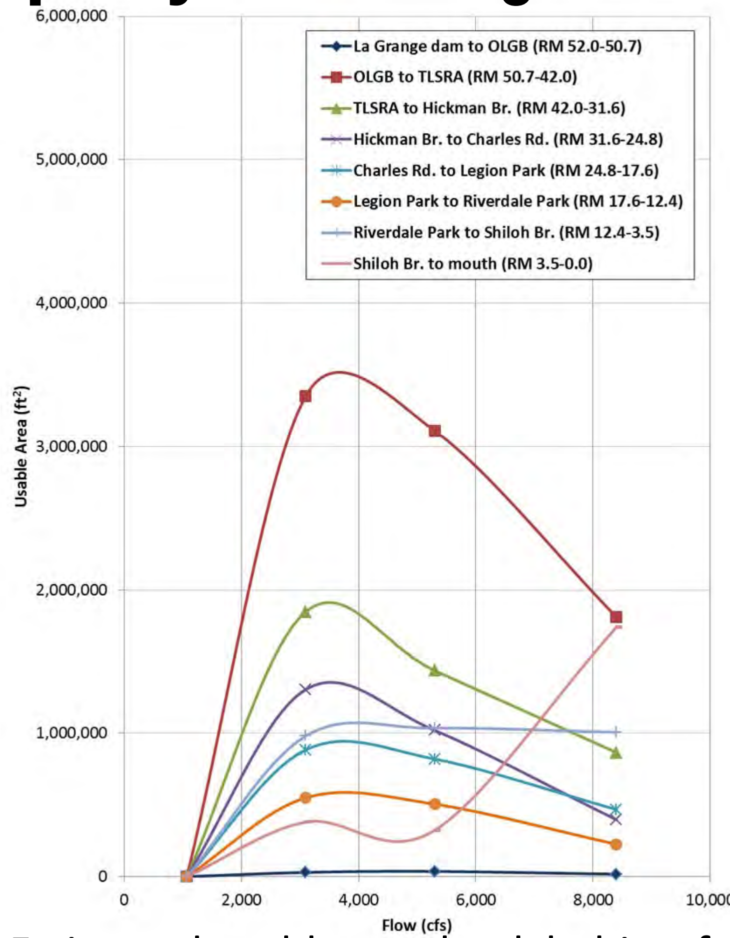
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping (TID/MID 1997) scaled by WUA vs flow relationships from 2D Pulse Flow study .
  - Overbank rearing density in proportion to in-channel and overbank usable area estimates by sub-reach
  - Displacement of resident fry when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon fry rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon fry

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Growth)
  - Growth based upon fish size, ration, and water temperature by Stauffer (1973)

$$W^+ = We^{g\Delta t}, \text{ where} \qquad g = \text{GMAX} \sin\left(\frac{\pi}{2}\frac{R - \text{RMAINT}}{\text{RMAX} - \text{RMAINT}}\right)$$

$$\text{GMAX} = (a_1 + a_2T + a_3T^2 + a_4T^3 + a_5T^4)(a_6W^{-a_7})$$
$$\text{RMAINT} = (l_1 10^{l_2T})(l_3W^{-l_4})$$
$$\text{RMAX} = (-l_5 + l_6 \ln T)(l_7W^{-l_8})$$

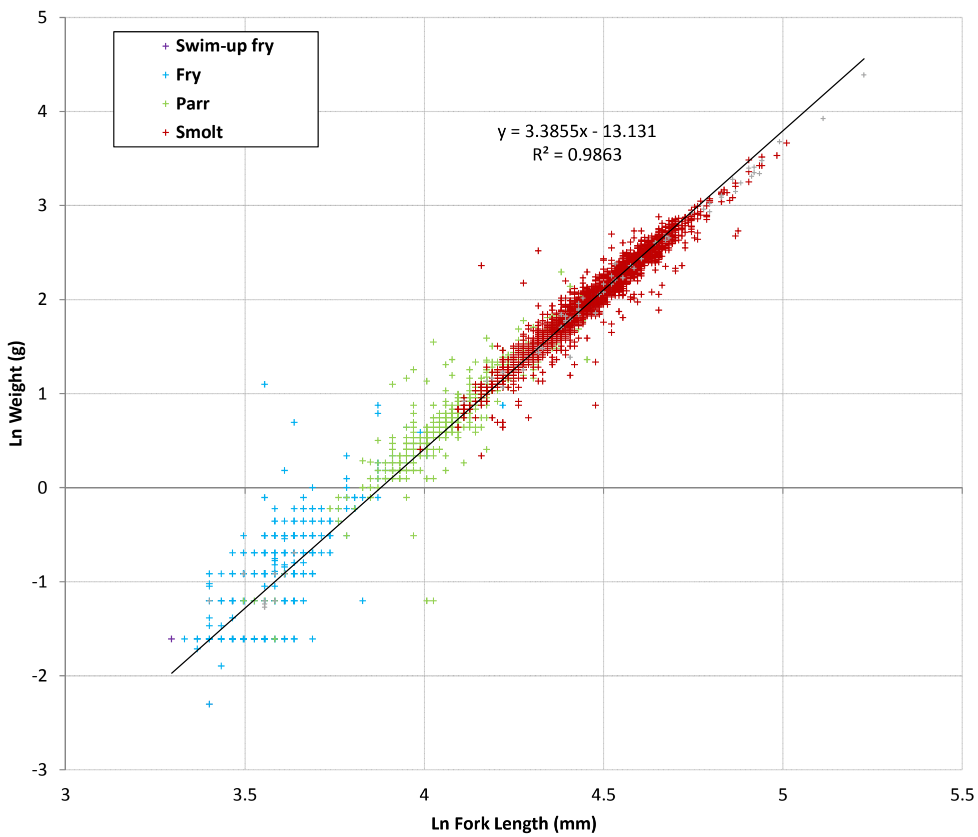
W = starting weight

T = water temperature

R = ration level

weight-length conversions obtained by linear regression of log-weight and log-length of fish from RST sampling

Key Sub Model Relationships by Life-Stage



Length vs. Weight relationship for juvenile Chinook salmon in the Tuolumne River (2004–2010)

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Mortality) sources
  - Background (fixed) daily mortality
  - Movement mortality (e.g., predation, other factors) represented as exposure time (distance)

$$Survival = e^{-\int_{t_1}^{t_2} m(t)dt}$$

Survival = the probability of fry survival for any incremental exposure time from t_1 to t_2

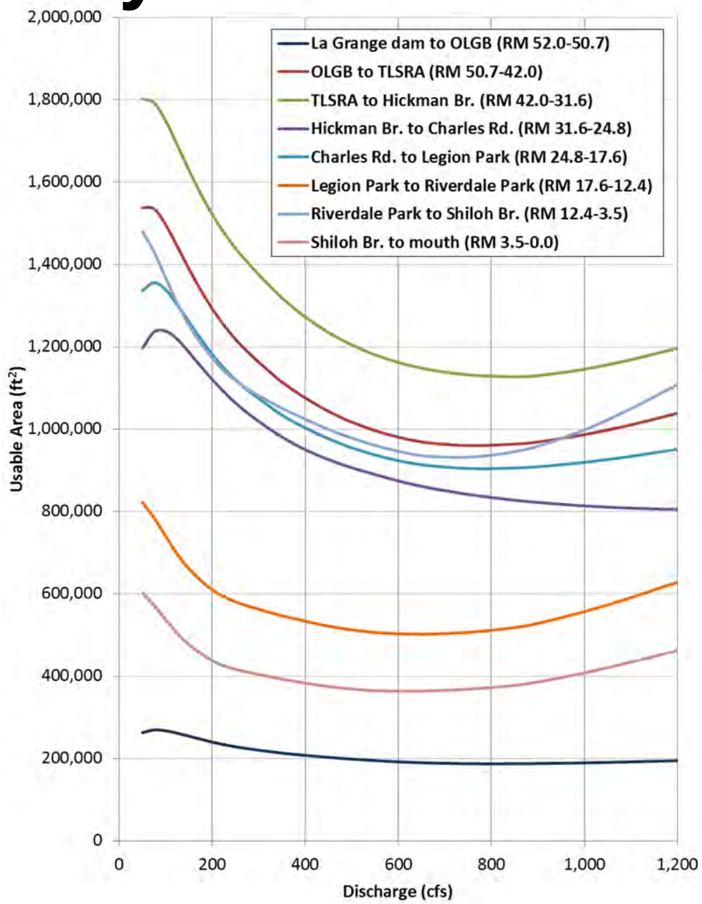
m(t)dt = instantaneous mortality in the main channel

  - Acute mortality due to daily average water temperature exceedance UUILT (T >25^{o}C)

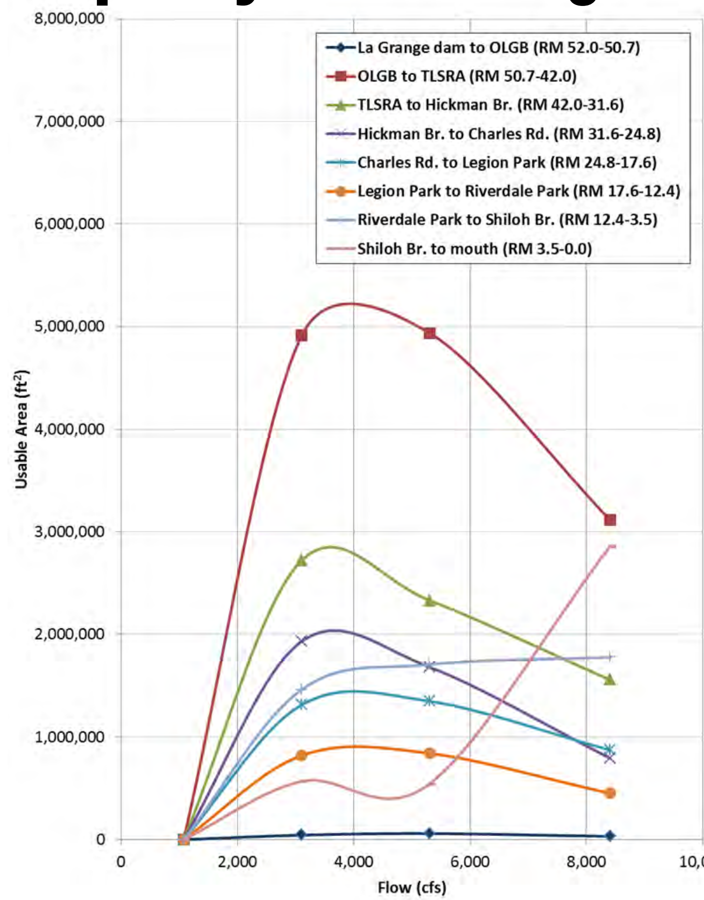
Key Sub Model Relationships by Life-Stage

- Juvenile Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping scaled by WUA vs flow relationships from 2D Pulse Flow study.
  - In-channel and Overbank rearing density in proportion to usable area estimates by sub-reach
  - Displacement of juveniles when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon juvenile rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon juveniles

Key Sub Model Relationships by Life-Stage

- Juvenile growth (same as for Fry)
- Juvenile mortality (same as for Fry):
  - Background mortality
  - Exposure Time $Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt}$
  - UUILT Exceedance (T > 25^{o}C)

Key Sub Model Relationships by Life-Stage

- Smolt Emigration (Size)
  - Emigration of smolt-ready juveniles based upon suitable water temperatures, exceedance of minimum size threshold and probability around historical median size at emigration

$$P = \frac{\frac{1}{\sqrt{2\pi\sigma^2}} e^{-(L-\mu)^2/2\sigma^2}}{\int_L^\infty \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\lambda-\mu)^2/2\sigma^2} d\lambda} \frac{\Delta L}{\sigma}.$$

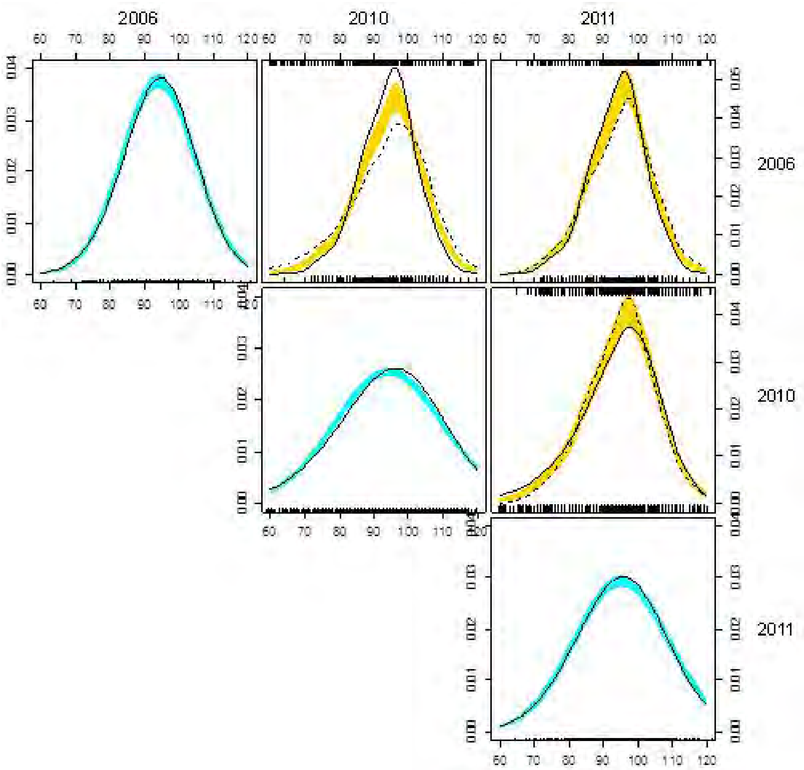
ΔL = the daily growth increment

P = the probability that an individual will smolt at a length between L and $L+\Delta L$

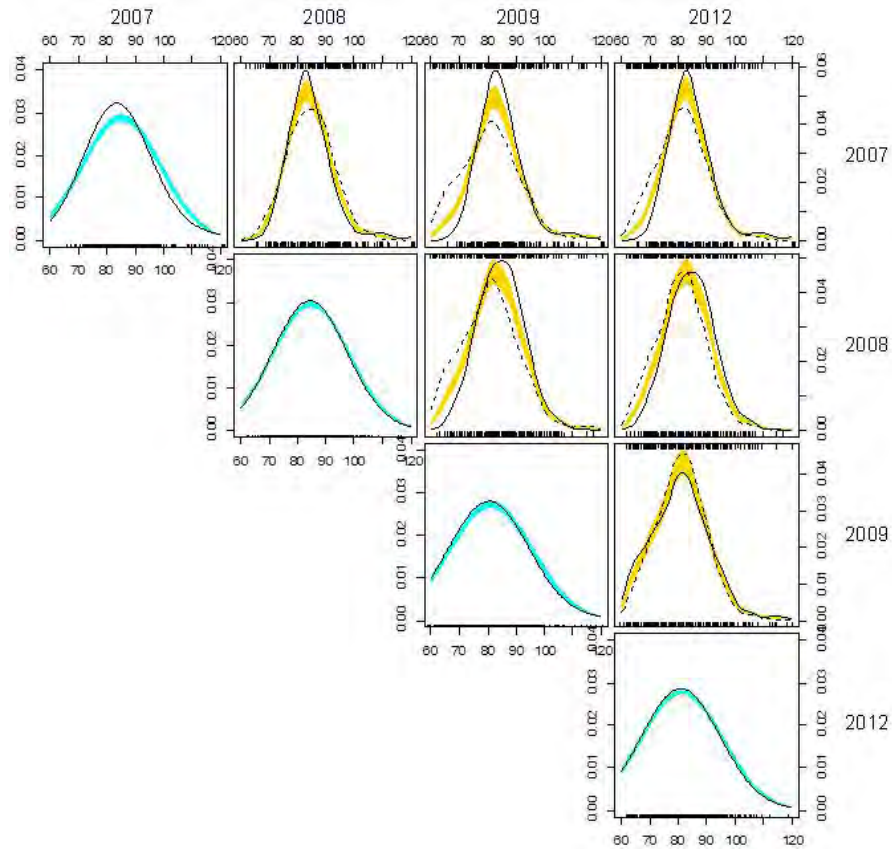
(μ) = mean length

  - Smolt emigration event cues (i.e., pulse flow effects on day-to-day variations in smolt passage) not presently modeled.

Key Sub Model Relationships by Life-Stage



Comparisons of smolt size at emigration in **above average** water year types (2006, 2010, and 2011) in the Tuolumne River



Comparisons of smolt size at emigration in **below average** water year types (2007–2009, and 2012) in the Tuolumne River

Key Sub Model Relationships by Life-Stage

- Smolt Mortality
  - Mortality due to predation and other factors represented as distance travelled (Equation), as well as temperature (T > 25C).
  - Smolt Survival Relationship based upon RST passage data

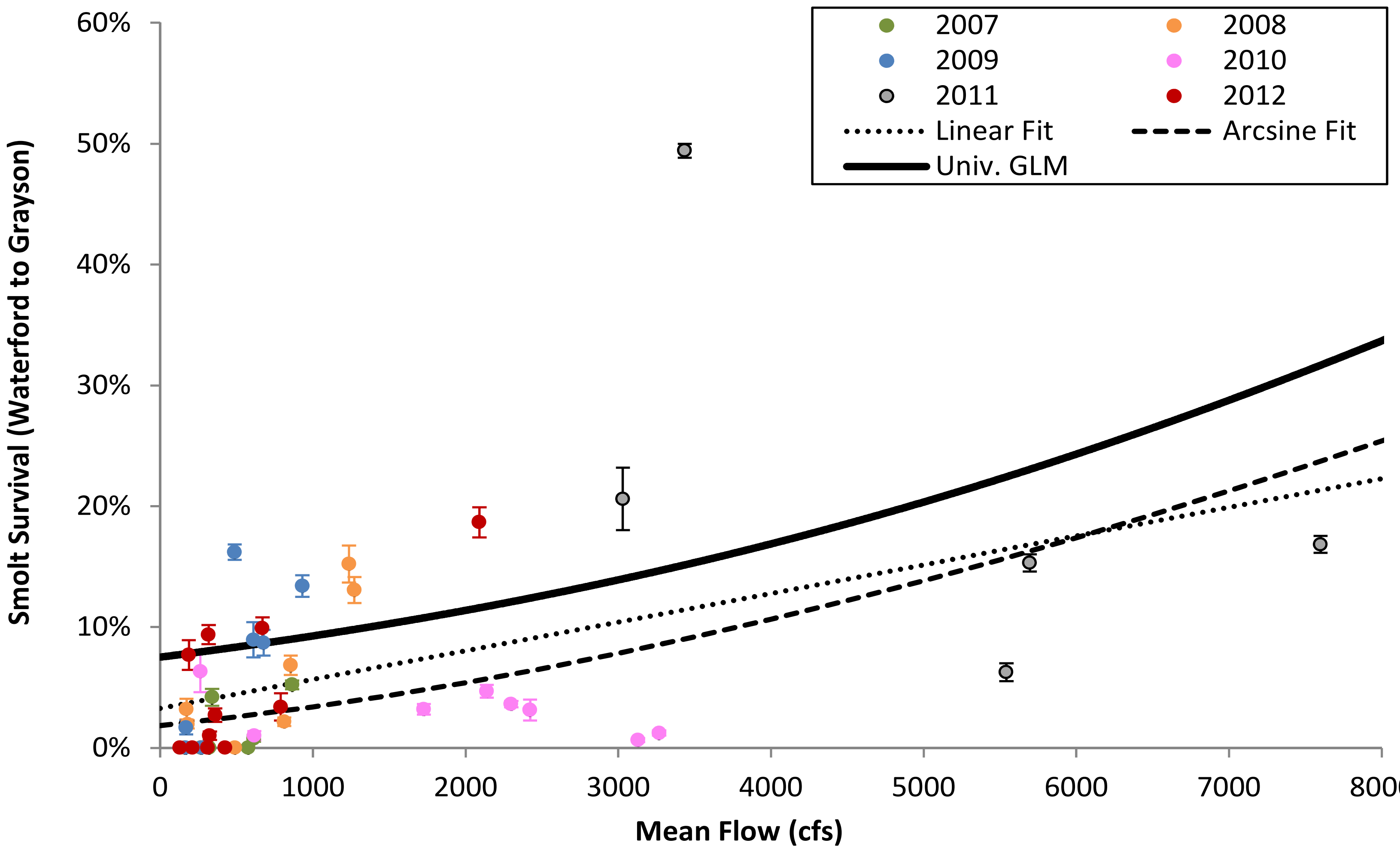
$$S_{RST} = \min(0.03287 + 2.347 \times 10^{-5} \times Q_{LaGrange}\ , 1)$$

$$S_D = e^{-mD}, \text{where } m = -\frac{\log S_{\mathrm{RST}}}{29.8-5.2}$$

Survival = the probability of smolt survival at flow rate, *Q*

D = Distance (RM)

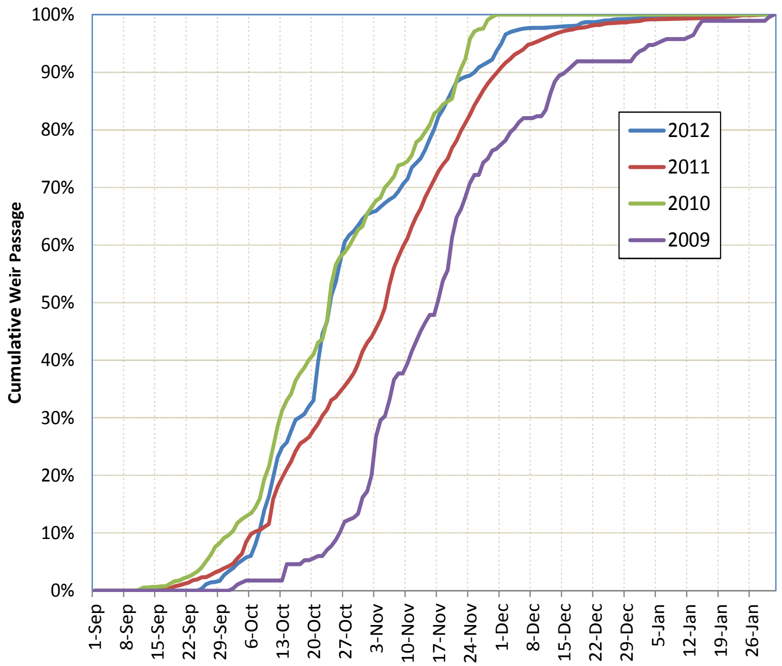
Smolt survival measured by RST passage



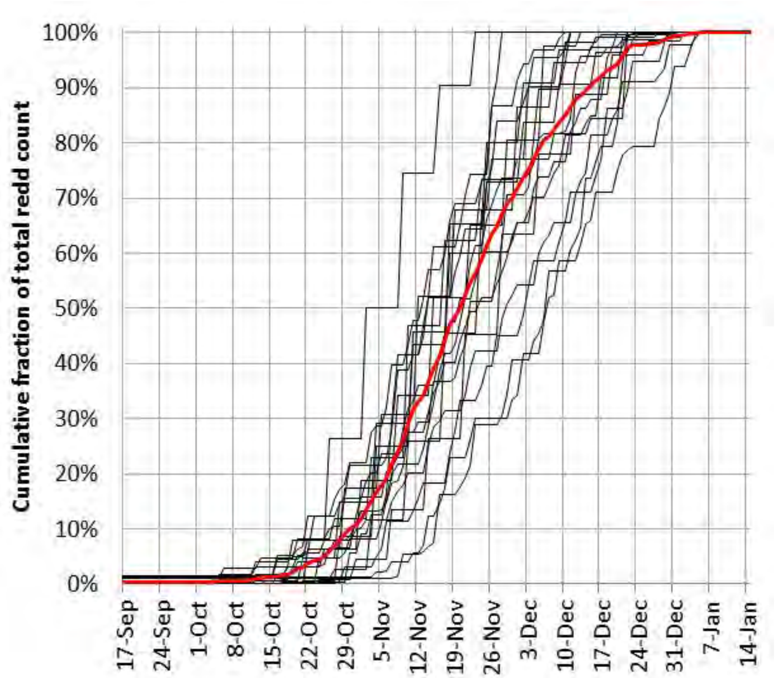
Upmigration and Spawning Timing

- Time lag between weir passage (2009-2012) and spawning activity represented as upmigration speed and not holding

50% weir passage (2009-2012)
Approx. November 5th

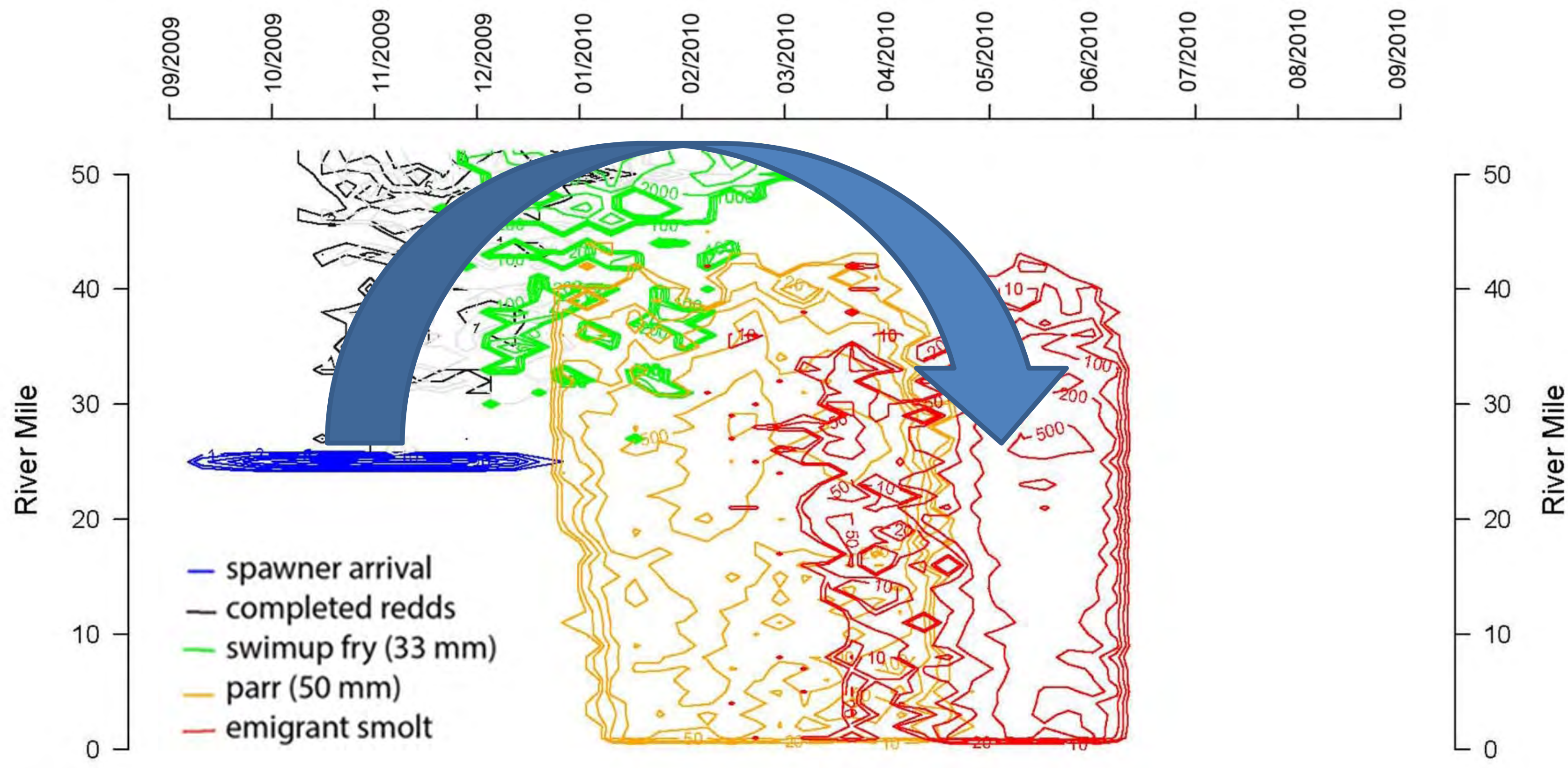


50% redd counts (1992-2010)
Approx. November 20th



Fry and Juvenile Rearing Patterns

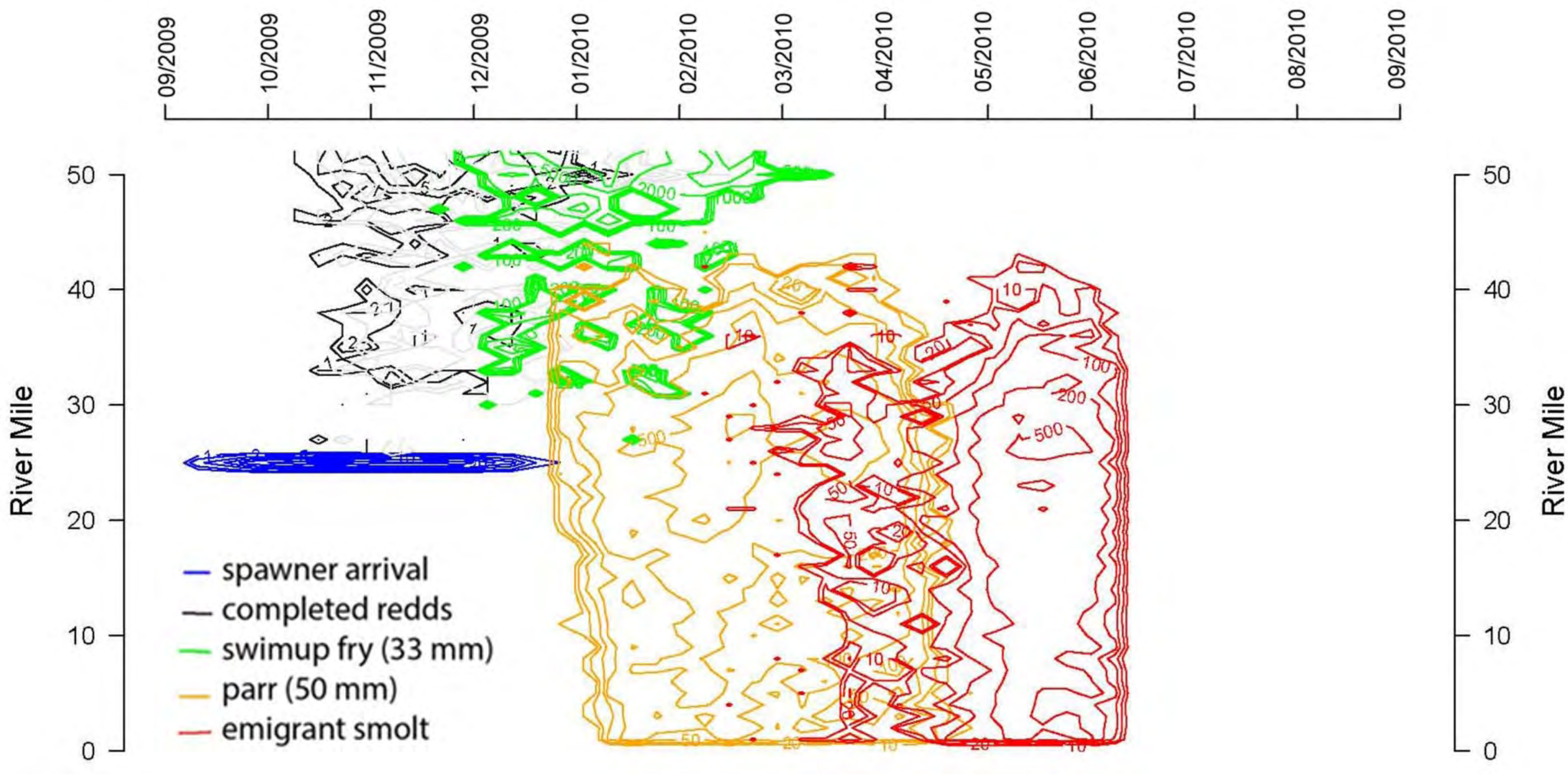
- Matching of life history transition locations and timing



Water Year 2011 (Wet)

Fry and Juvenile Rearing Patterns

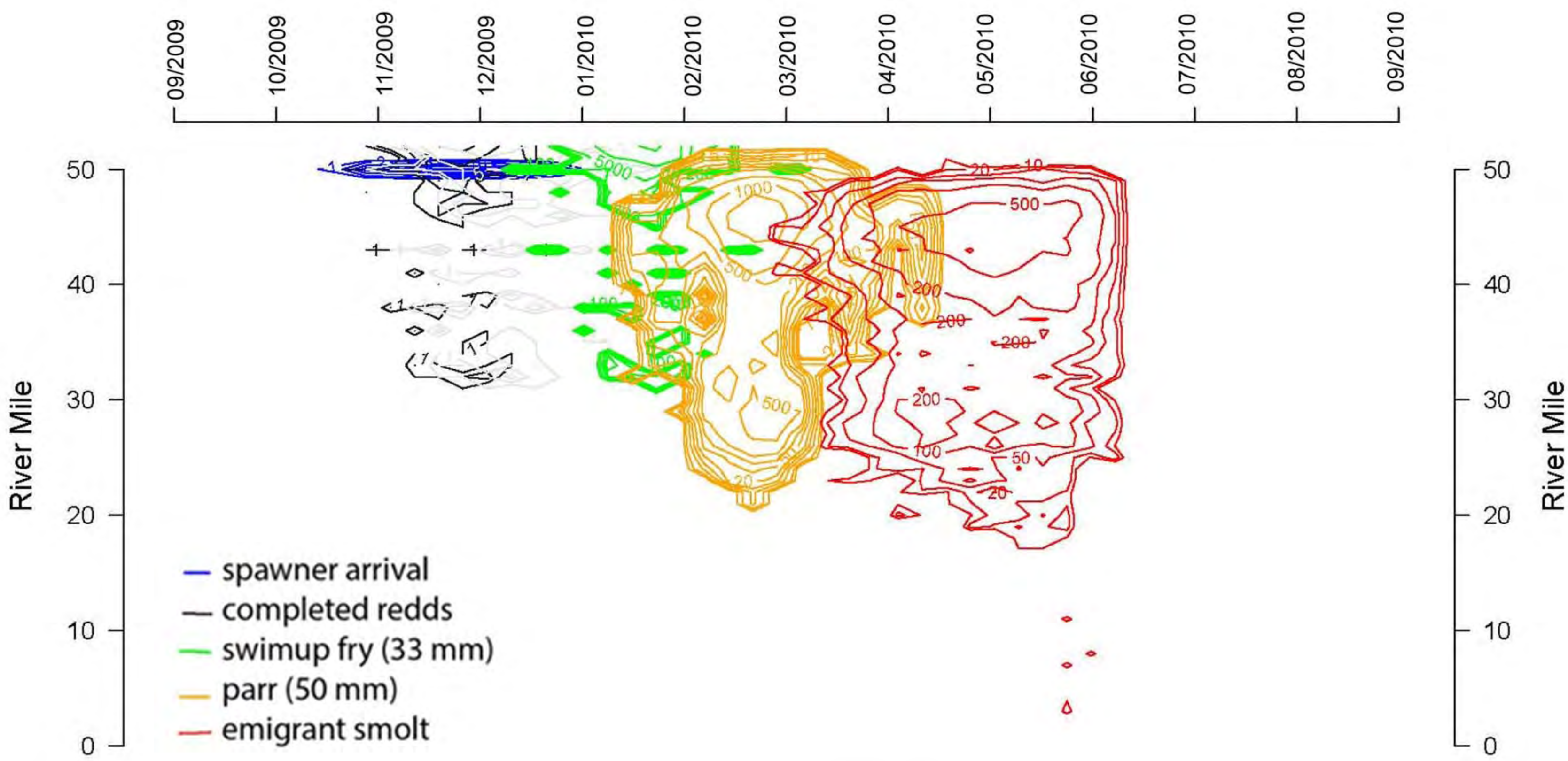
- Matching of life history transition locations and timing



Water Year 2011 (Wet)

Fry and Juvenile Rearing Patterns

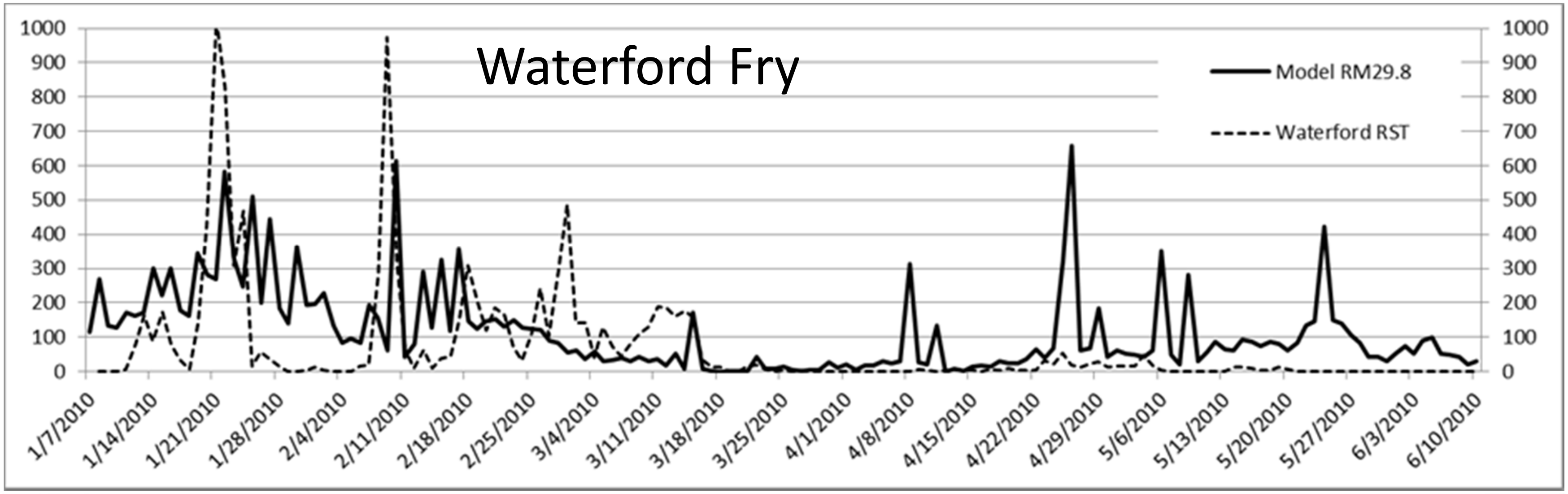
- Matching of life history transition locations and timing

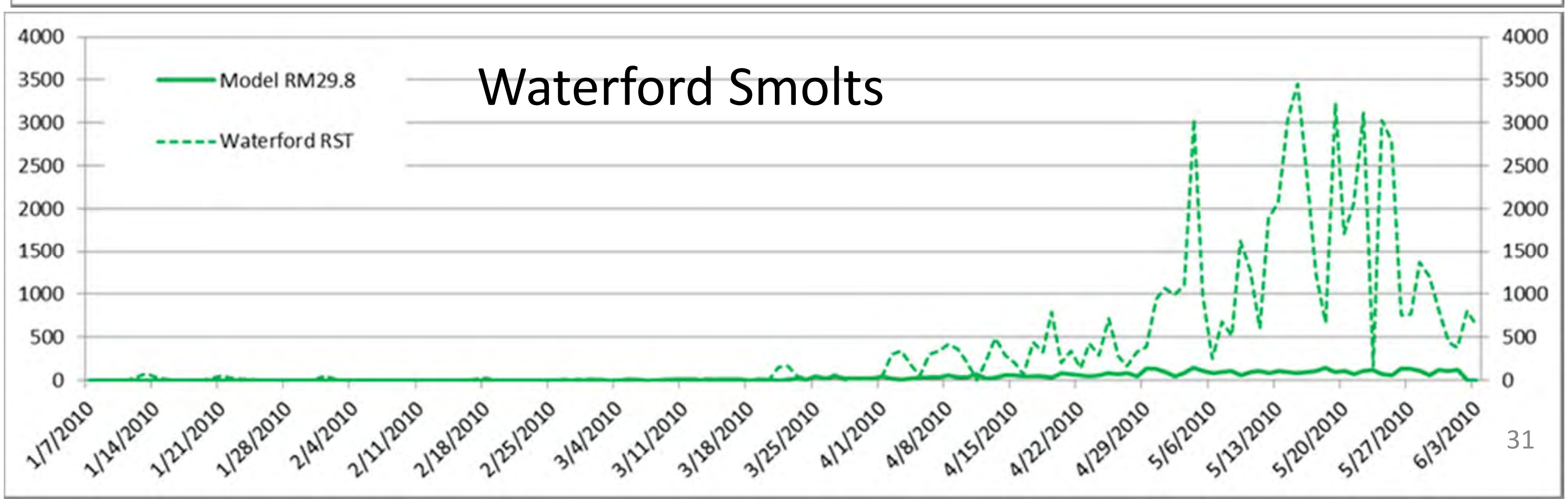


Water Year 2009 (Dry)

Modeling Calibration and Validation

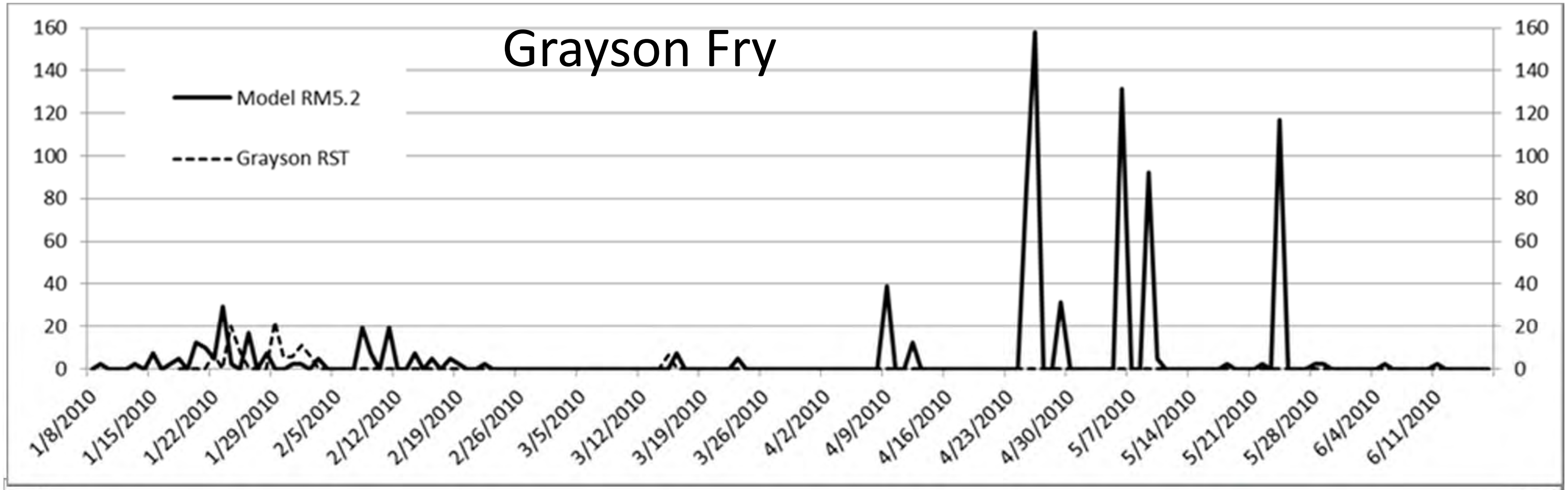
RST passage of Chinook salmon (Fry, Smolt) in 2010

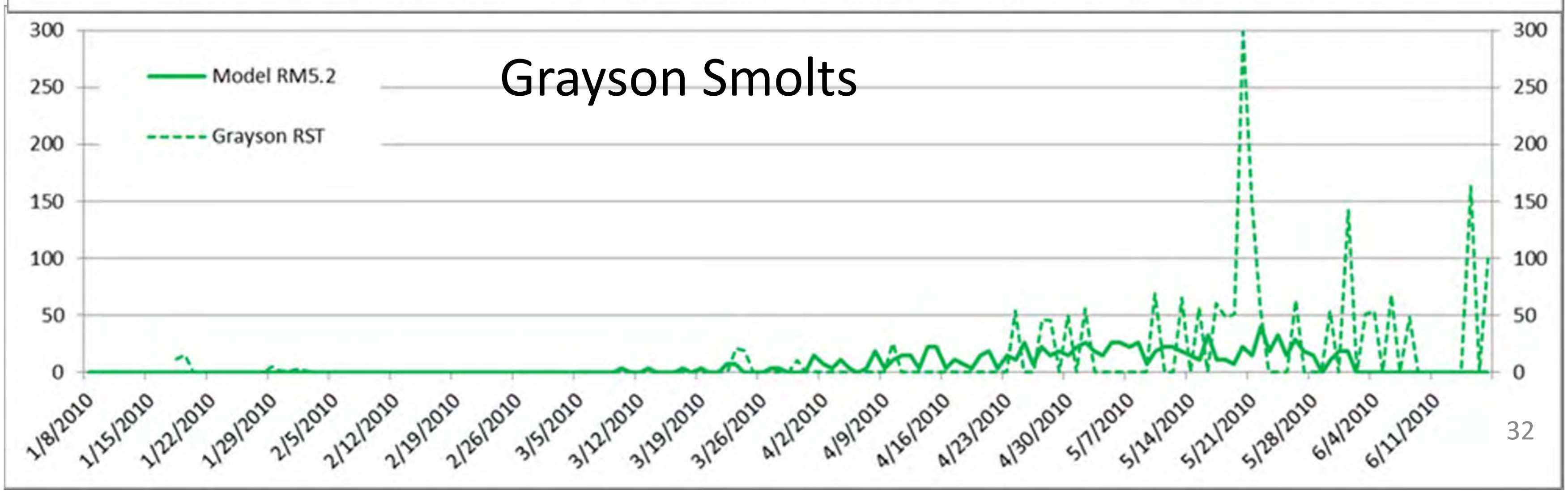




Modeling Calibration and Validation

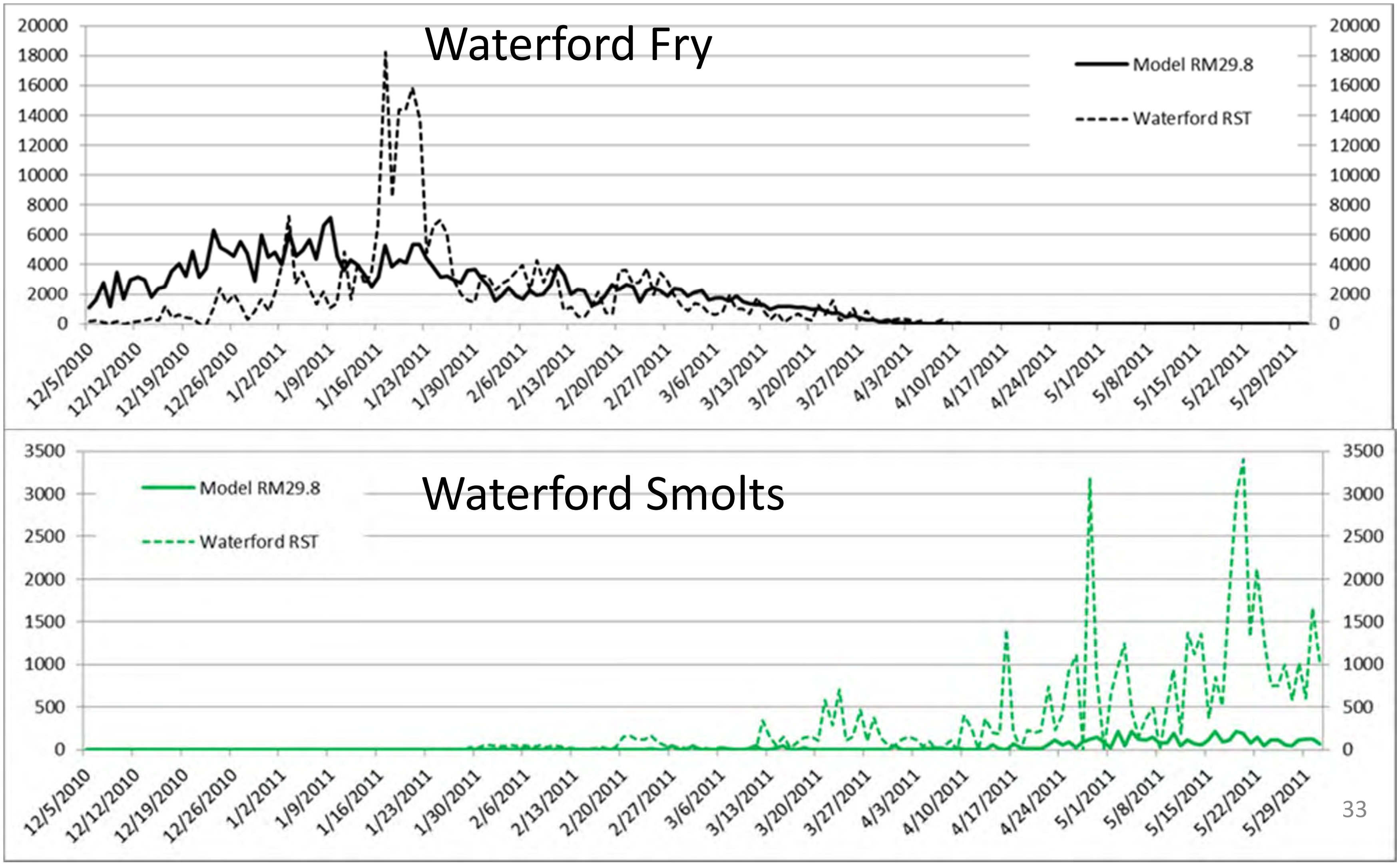
RST passage of Chinook salmon (Fry, Smolt) in 2010





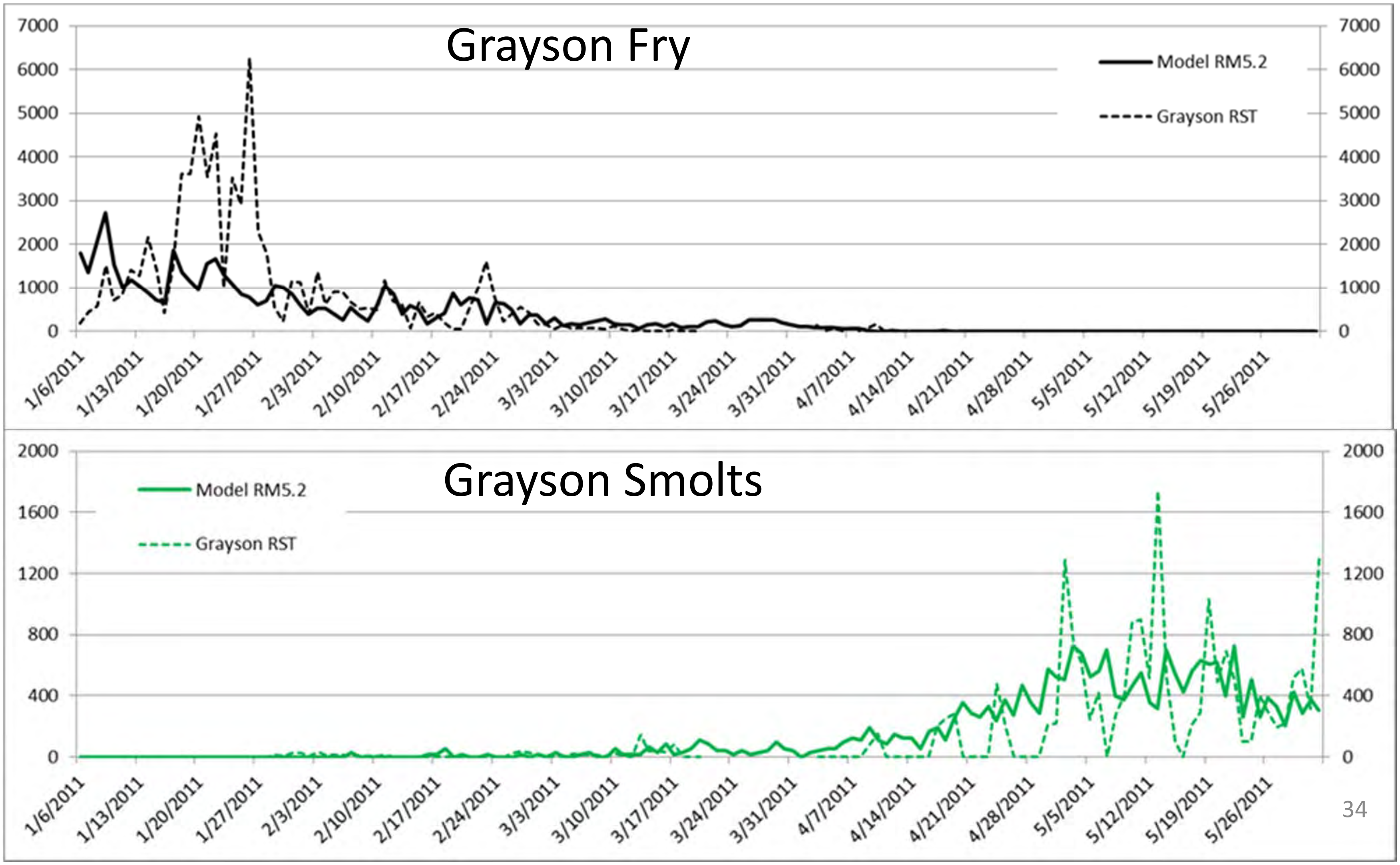
Modeling Calibration and Validation

RST passage of Chinook salmon (Fry, Smolt) in 2011

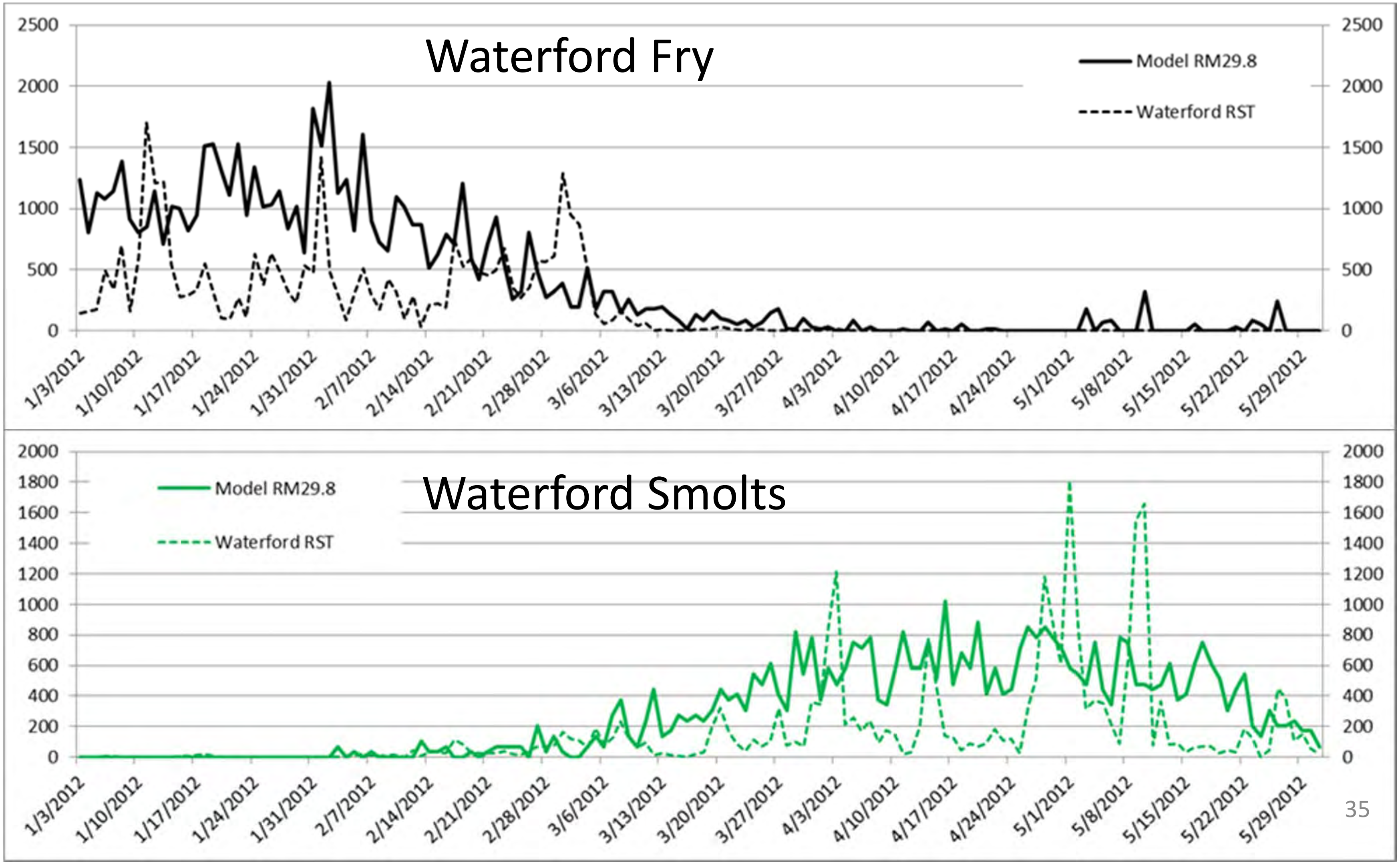


Modeling Calibration and Validation

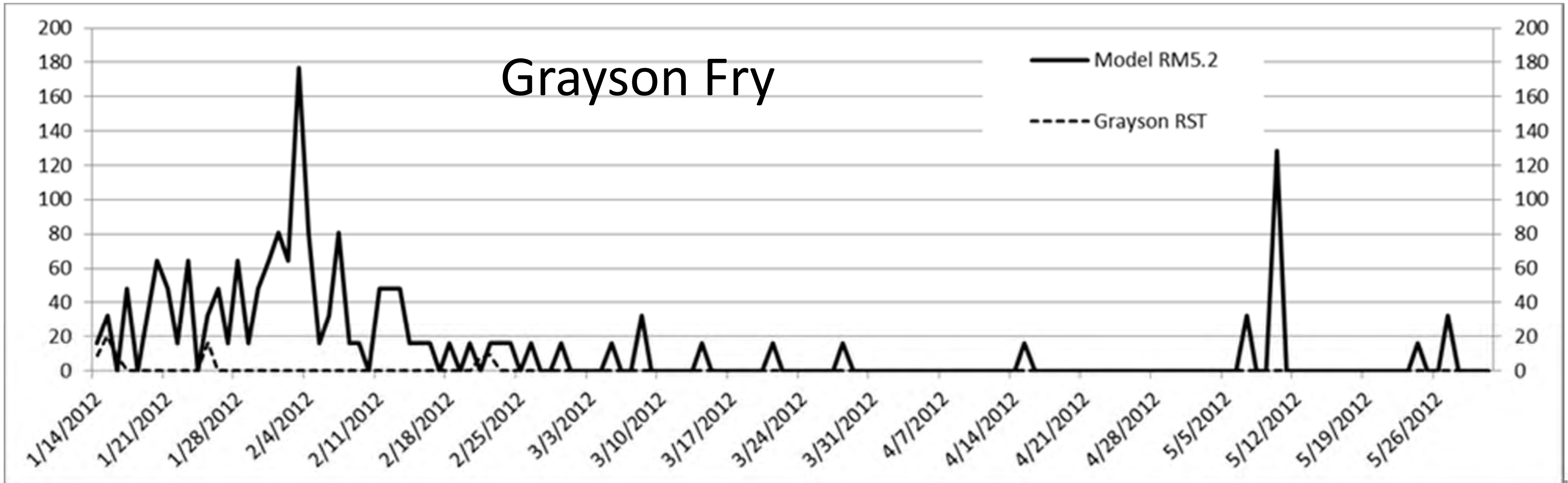
RST passage of Chinook salmon (Fry, Smolt) in 2011

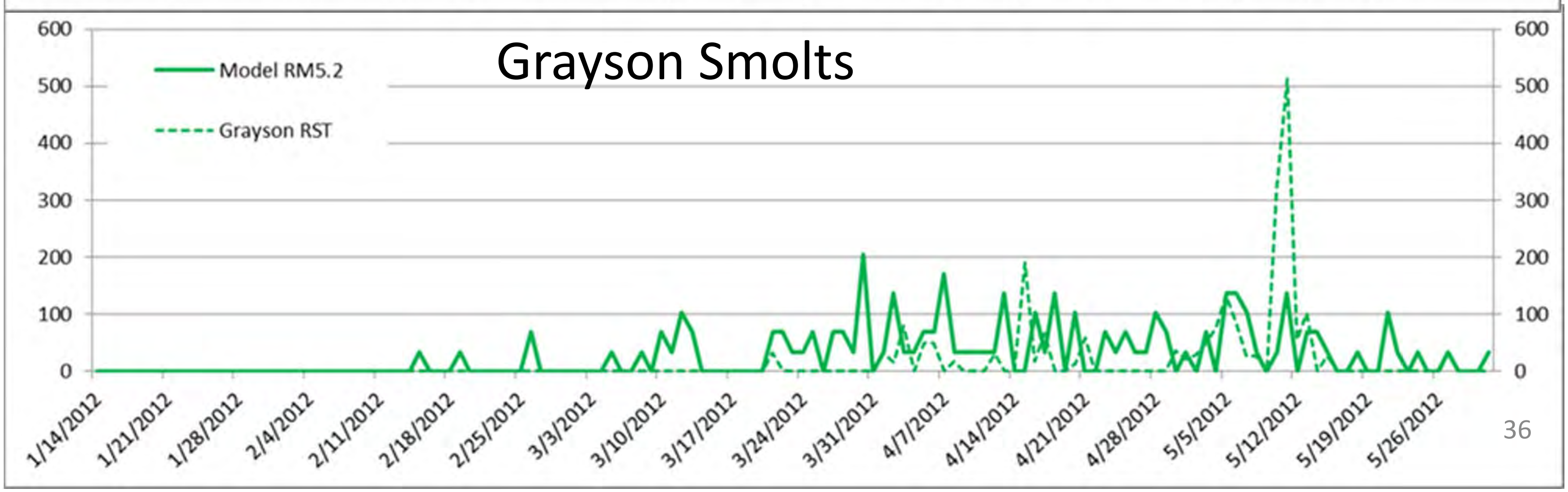


RST passage of Chinook salmon (Fry, Smolt) in 2012



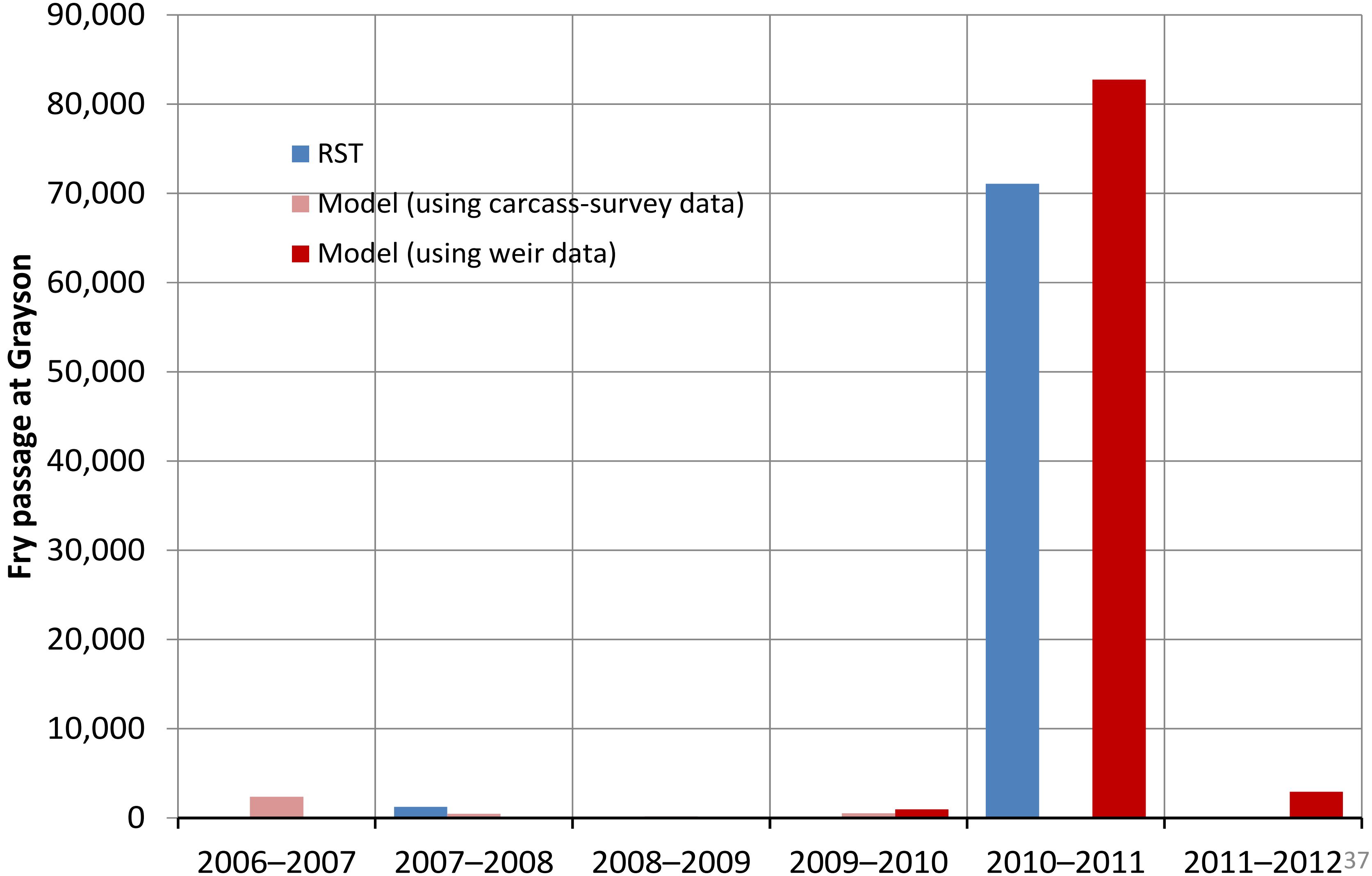
RST passage of Chinook salmon (Fry, Smolt) in 2012





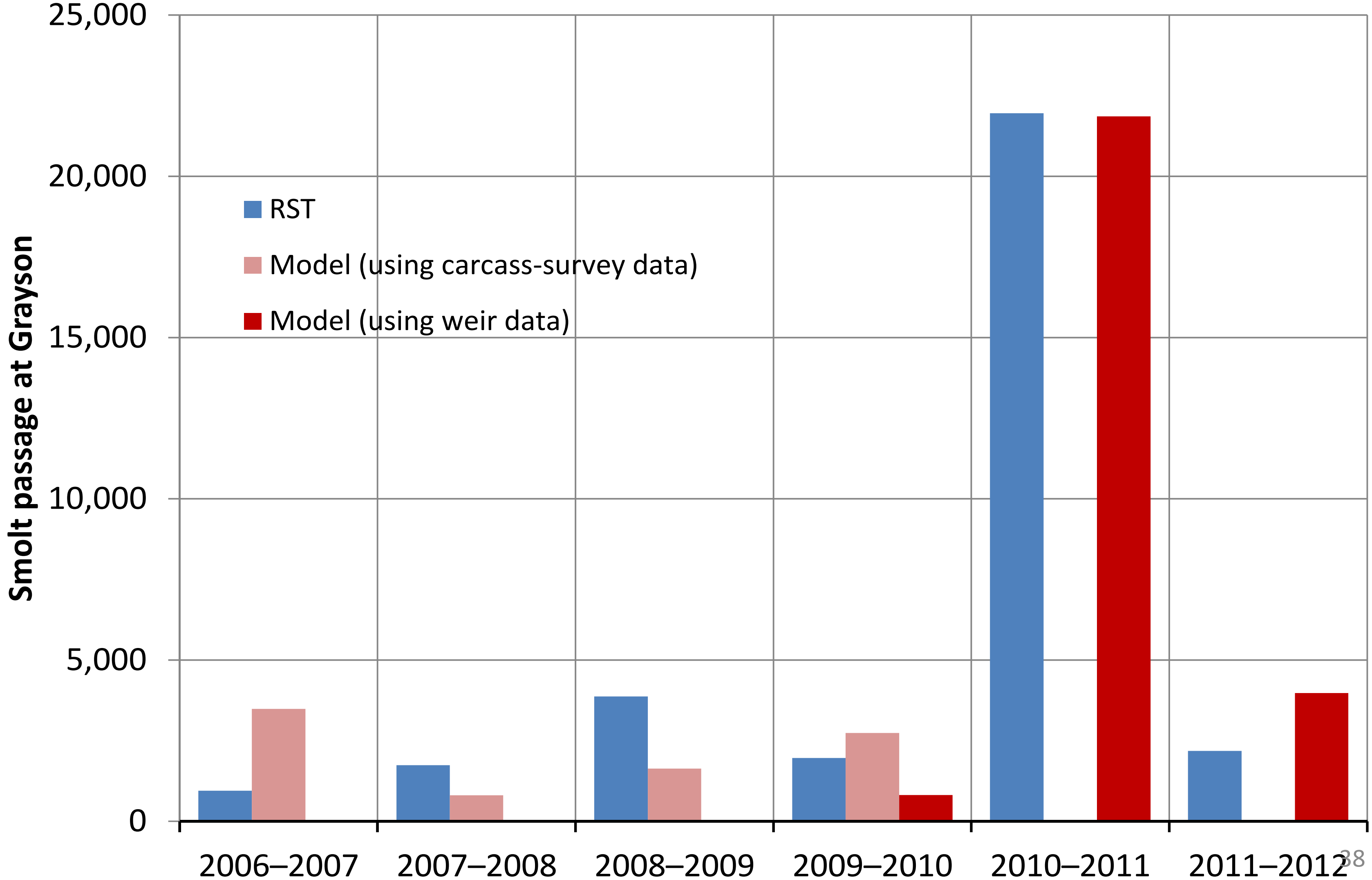
Modeling Calibration and Validation

Annual Fry Passage at Grayson (2007-2012)



Modeling Calibration and Validation

Annual Smolt Passage at Grayson (2007-2012)

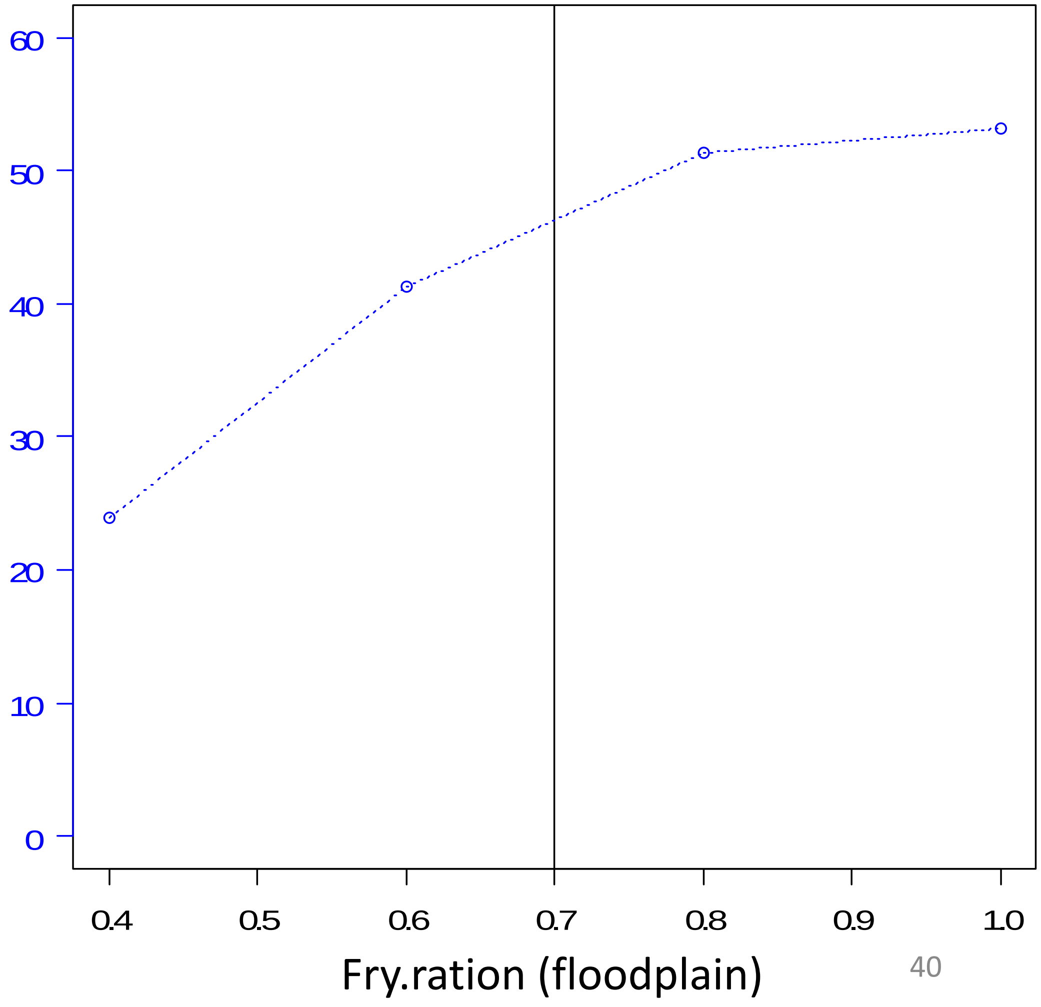


Parameters Affecting Juvenile Productivity

- Vary each parameters around calibrated value
  - Reasonable Range vs. +/- 25% or more around calibrated value
  - All other parameters held constant
- Examine smolt productivity change
  - Evaluation Metric = smolts/female spawner
- Test under broad range in hydrology
  - WY 2009 (Drier WY Type) = Low Discharge
  - WY 2011 (Wetter WY Type) = High Discharge
- Test under broad range in spawning escapement
  - Reference runs of 200 and 10,000 female spawners
- 1,920 model simulations performed

Fry feeding ration on floodplain (Example)

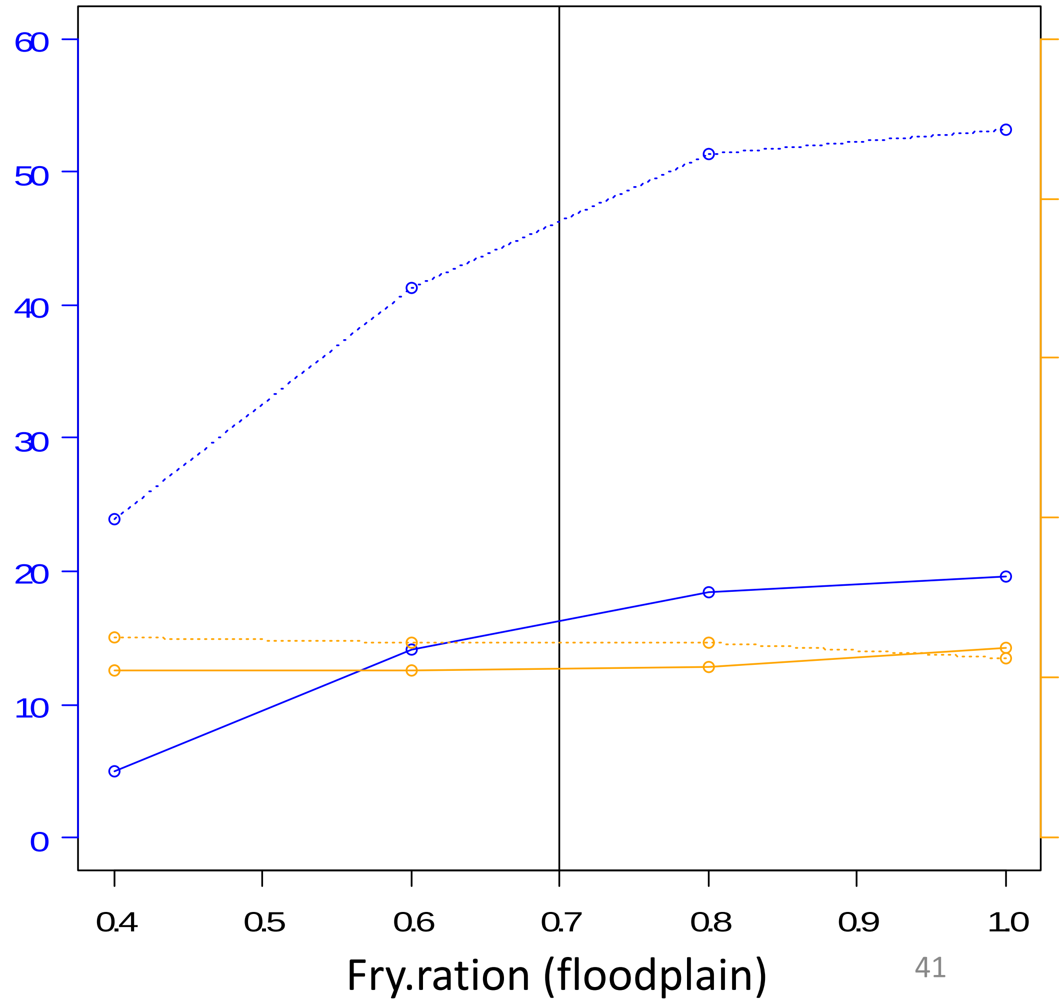
- Smolt productivity vs fry feeding ration on the floodplain.
  - Results for WY 2011 (Wet) shown at 200 spawners
  - Vertical line represents calibrated value = 0.7
  - Moderate sensitivity to reductions in food ration



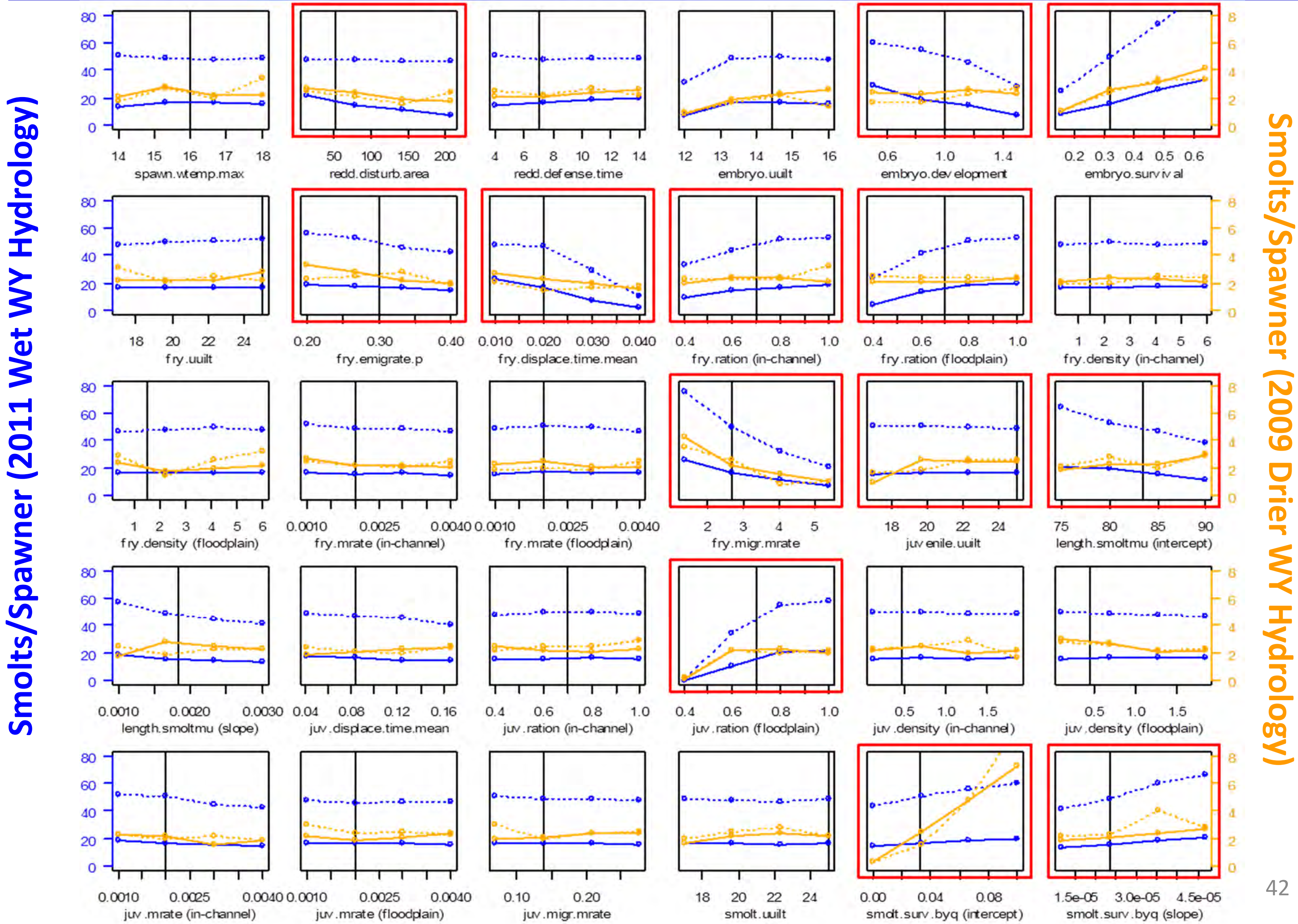
Modeling Sensitivity Testing

Fry feeding ration on floodplain (Example)

- Blue Lines = High Discharge (2011 “Wet”)
- Orange Lines = Low Discharge (2009 “Drier”)
- Dashed Lines = 200 spawners (“Low”)
- Solid Lines = 10,000 spawners (“High”)
- **Moderate sensitivity in Wet WY type**
- **No sensitivity in Dry WY Type**

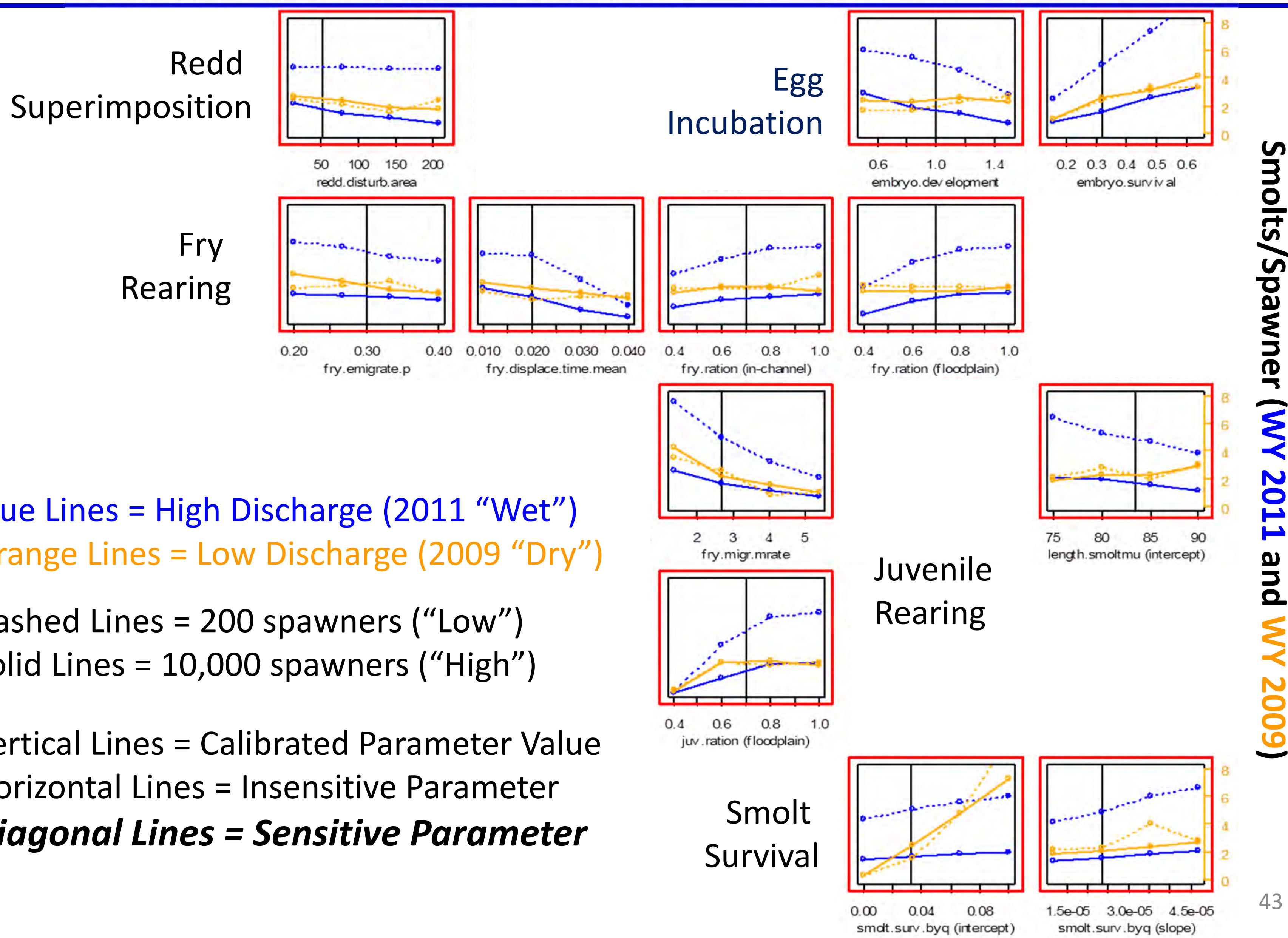


Modeling Sensitivity Testing



Modeling Sensitivity Testing

Don Pedro Project
FERC No. 2299



Blue Lines = High Discharge (2011 "Wet")
Orange Lines = Low Discharge (2009 "Dry")

Dashed Lines = 200 spawners ("Low")
Solid Lines = 10,000 spawners ("High")

Vertical Lines = Calibrated Parameter Value
Horizontal Lines = Insensitive Parameter
Diagonal Lines = Sensitive Parameter

Modeling Sensitivity Testing

Sensitive parameters affecting smolt productivity:

- Upmigration and Spawning
  - Larger vs. smaller redd size (redd.disturb.area)
- Egg incubation and fry emergence
  - Slower vs. faster incubation rates (embryo.development)
  - Lower vs higher survival-to-emergence due to gravel quality (embryo.survival)
- Fry rearing
  - Greater or lower proportions of emigrant fry upon emergence (fry.emigrate.p)
  - Lower vs. higher food (fry.ration) within in-channel and floodplain areas
  - Changes in movement (fry.displace.time.mean) and predation rates (fry.mrate)
- Juvenile rearing
  - Lower vs. higher food (juv.ration) within floodplain areas
  - Smaller vs. larger size at smoltification (length.smoltmu)
- Smolt emigration
  - Smolt survival as a function of flow (smolt.surv.byq)

Base Case Simulations (1971-2009)

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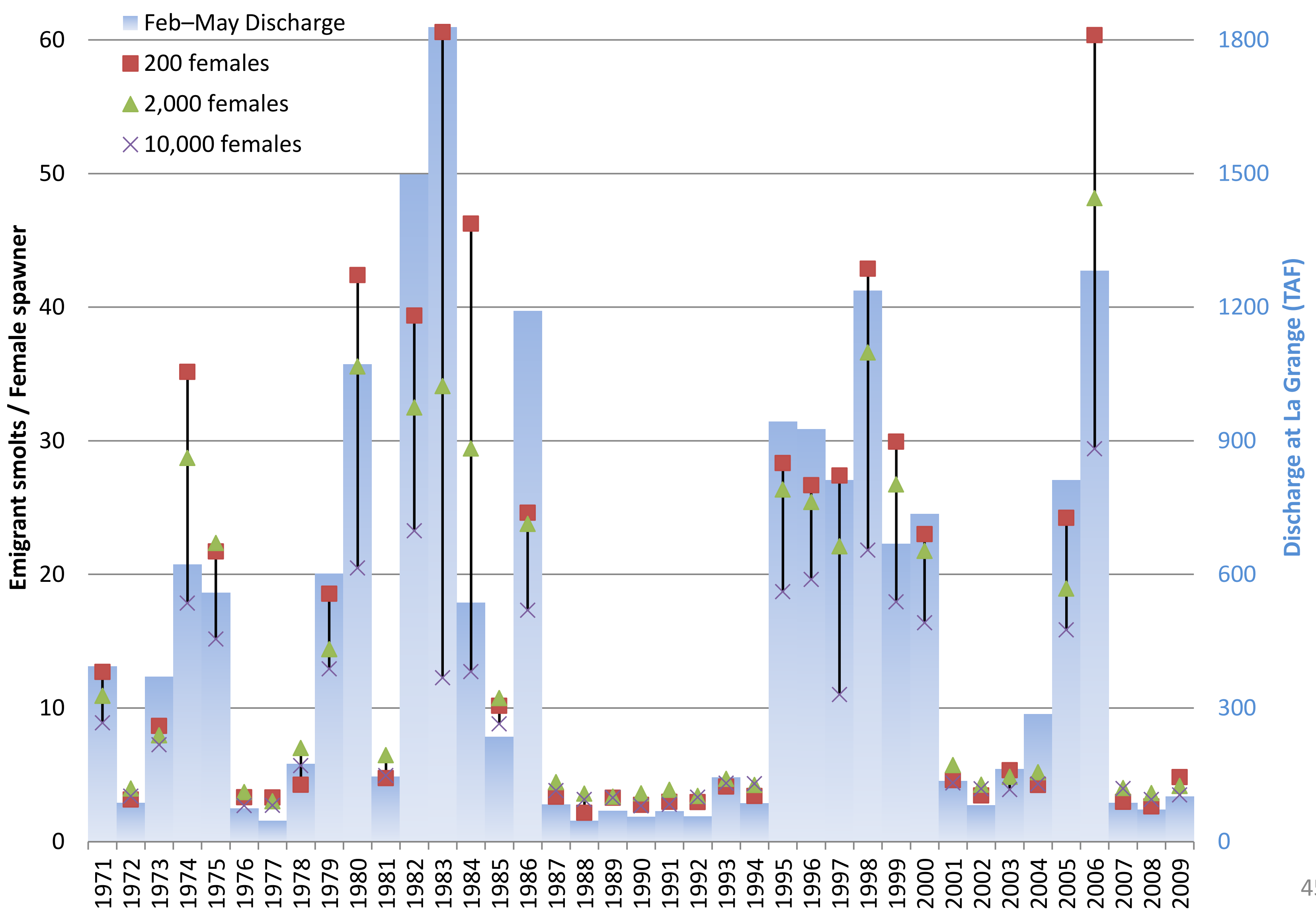
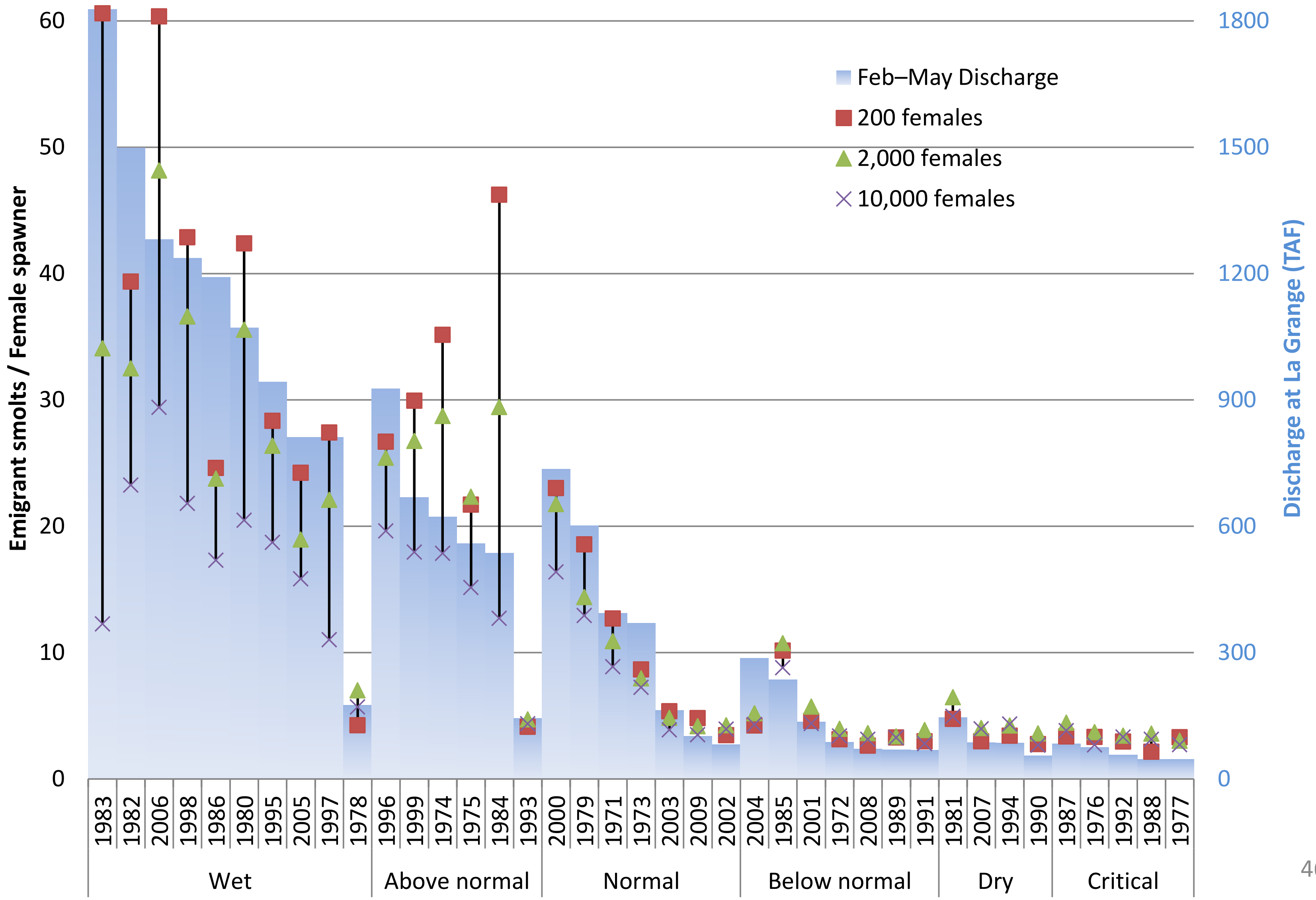
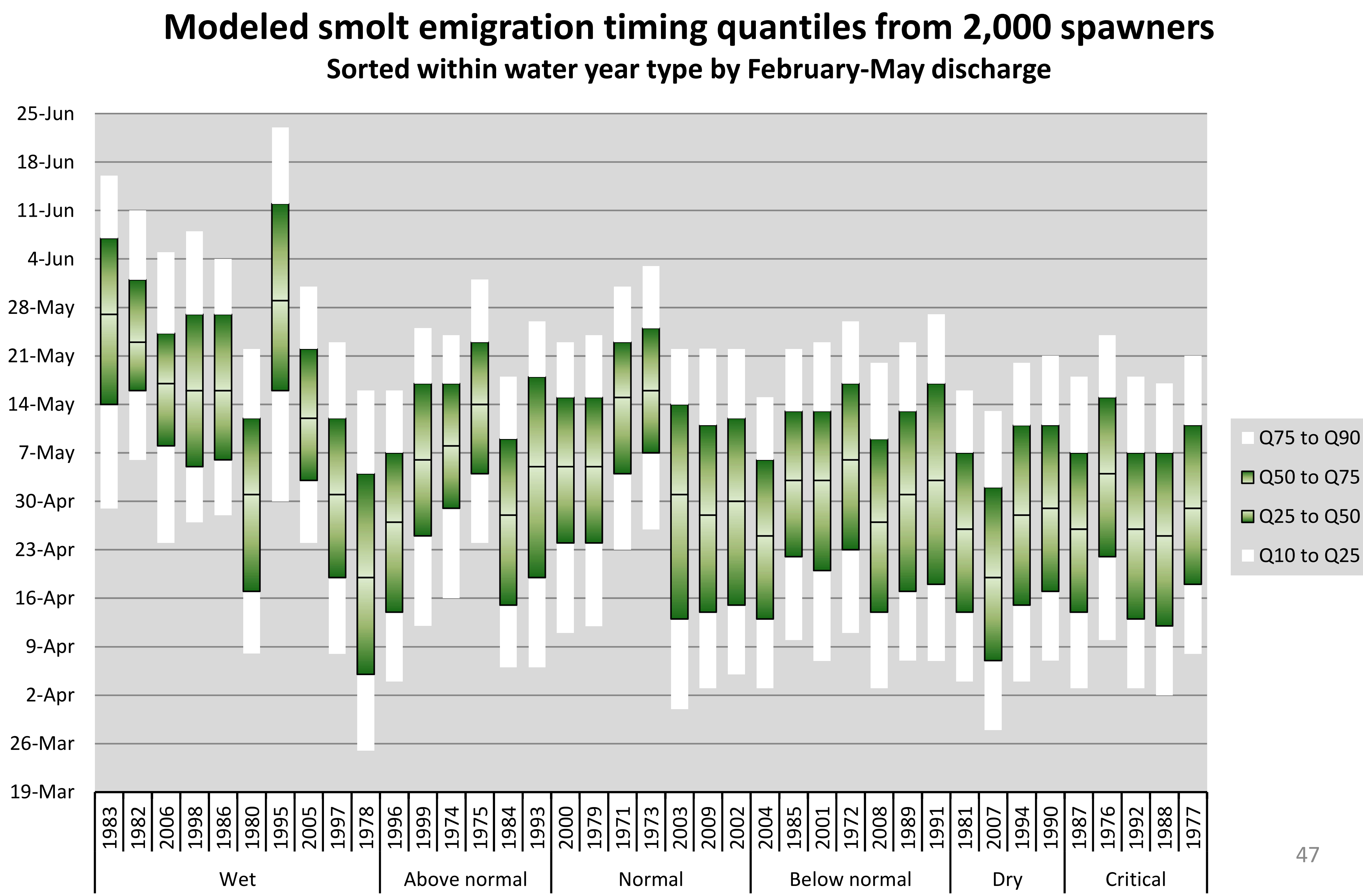
FERC No. 2299



Base Case Simulations (1971-2009)



Base Case Simulations (1971-2009)



Factors Affecting Production

Spawning Habitat

1. **Redd superimposition effects**
   - Reductions in smolt productivity with increasing escapement for the Base Case
   - Model sensitivity to redd area
   - Model sensitivity to increased incubation times
2. **Consistent with previous and ongoing studies**
   - Superimposition observations (W&AR-8, TID/MID 1992)
   - Increased "preference" for upstream spawning sites (W&AR-5, W&AR-8)
   - Loss of upstream riffles in 1997 flood (W&AR-4, McBain & Trush 2004, TID/MID 1992)

Factors Affecting Production

Fry/Juvenile Rearing Habitat

1. No identified rearing habitat limitation
   - Low model sensitivity to rearing density
   - Low model sensitivity to increased food availability
   - Some sensitivity to reduced food availability below calibrated values
2. Consistent with previous studies
   - High food ration estimates from direct stomach content analyses (TID/MID 1997)
   - USFWS (2001, 2002) smolt condition assessments

Factors Affecting Production

Flow Effects

1. **Increased smolt productivity with discharge**
   - Flow linkages with habitat suitability (WUA) and Water Temperature
   - Sensitivity to fry movement and predation mortality parameters
   - Sensitivity of smolt size and emigration timing with rearing temperatures
   - Sensitivity of smolt survival with flow
2. **Consistent with previous studies**
   - Relationships between spring discharge and subsequent escapement 3-years later (W&AR-5 and W&AR-6 citations)
   - Relationships between RST passage and spring discharge (Mesick et al. 2008)

Factors Affecting Production

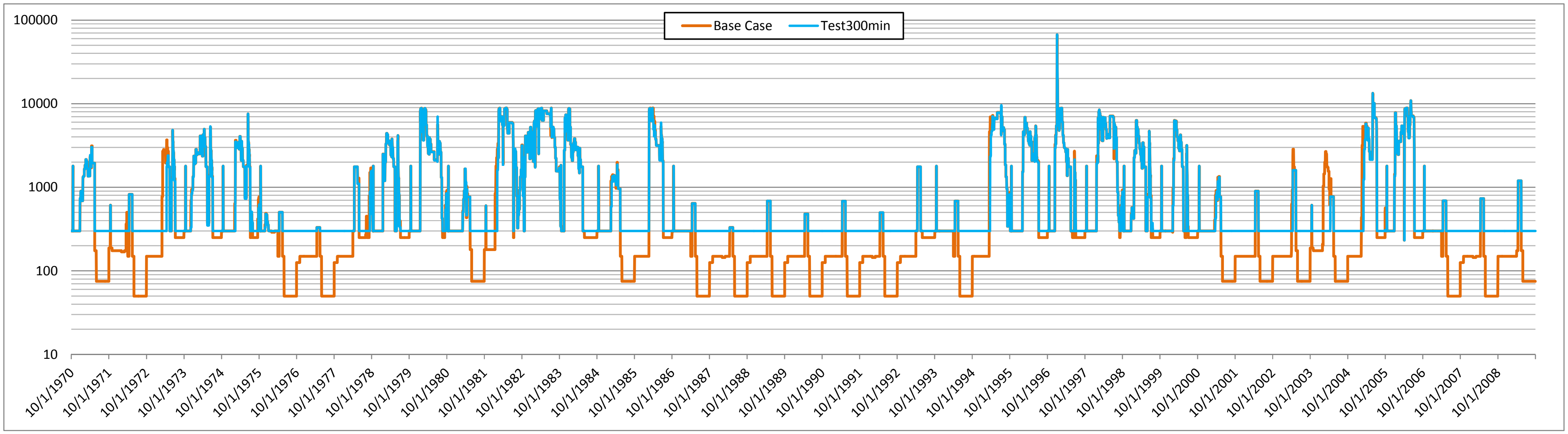
Water Temperature Effects

1. **Spawning and Egg Incubation**
   - No sensitivity to maximum spawning temperature (14-18°C)
   - No sensitivity to egg mortality threshold (13-16°C)
   - Sensitivity to incubation rate (i.e., slower at lower temps, etc.)
2. **Fry/Juvenile Rearing**
   - No sensitivity to mortality thresholds (18-25°C)
   - Growth rates affected by water temperature
3. **Smolt Emigration**
   - No sensitivity to mortality thresholds (18-25°C)
4. **Consistent with existing data (W&AR-5)**
   - Suitable spawning temperatures by mid- to late-October
   - Suitable rearing temperatures from January through mid-May
   - Peak emigration occurs during mid-to late-April of most years
   - Unsuitable emigration temperatures by early June in most years

Modeling Scenario Example

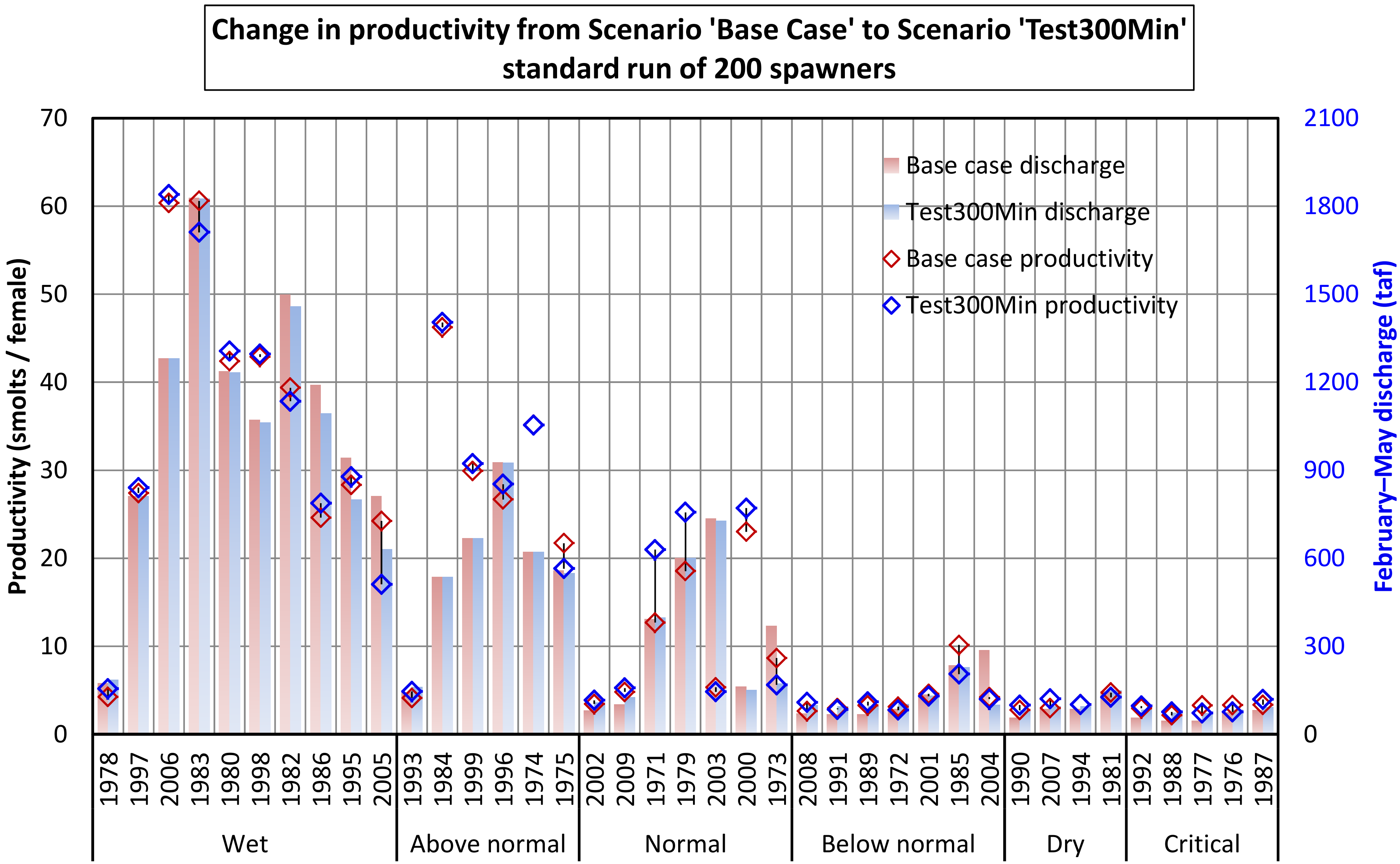
1. 300 cfs Test Case

- Provides 300 cfs or FERC (1996) minimum flows, whichever is greater



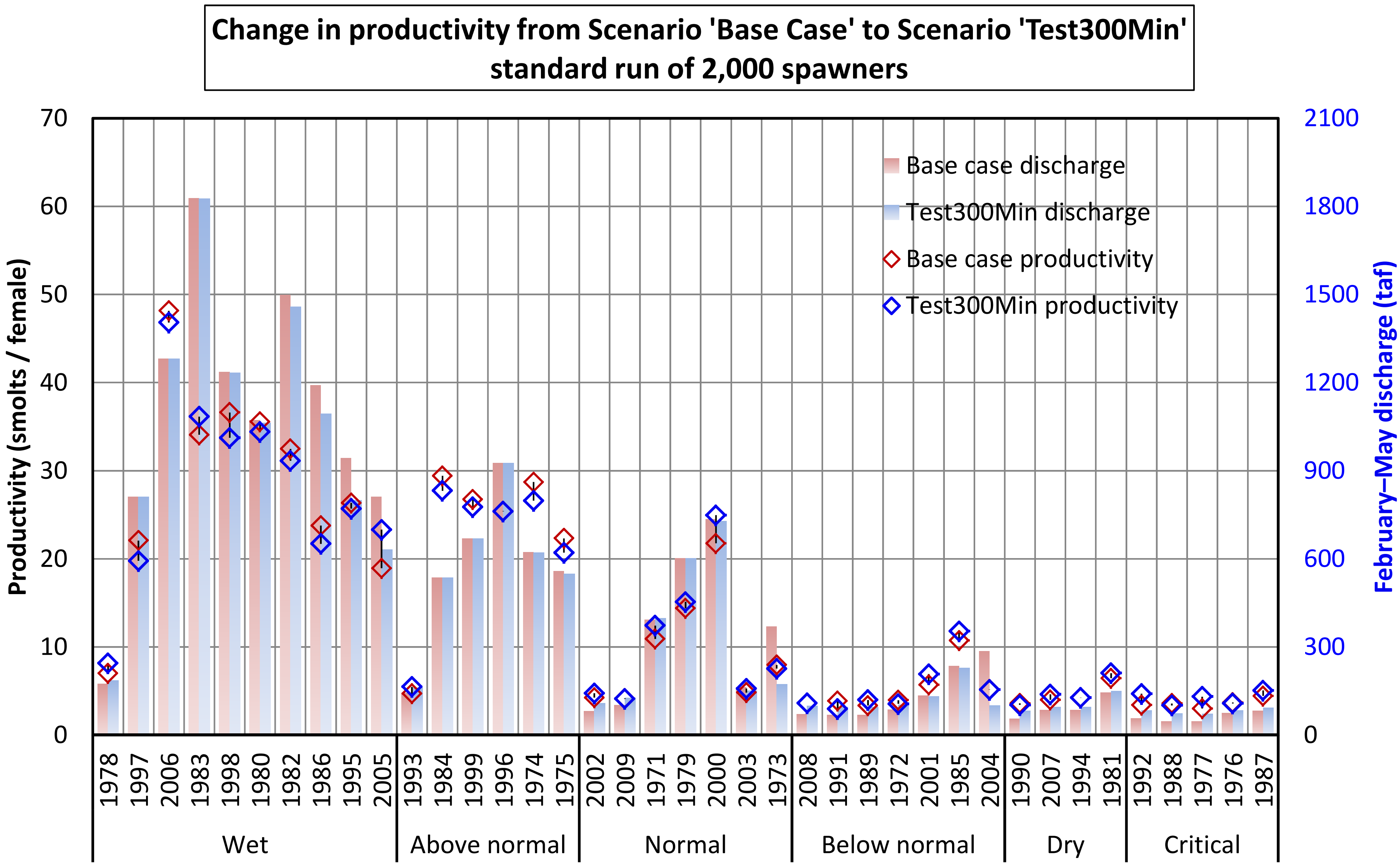
- Smolt productivity results shown for 200 and 2,000 spawners

300 cfs Test Case (Example Scenario)

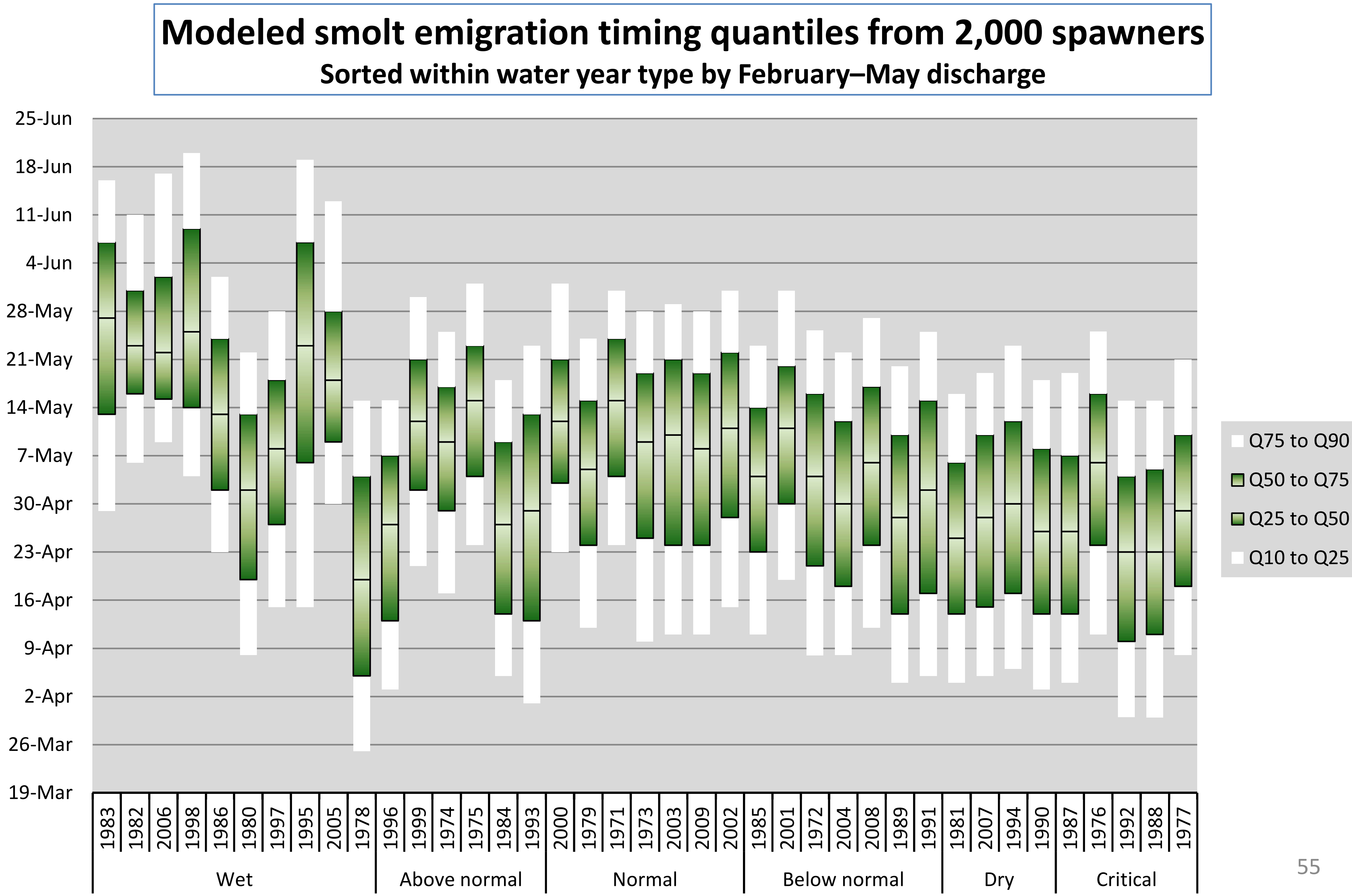


300 cfs Test Case (Example Scenario)

Don Pedro Project
FERC No. 2299



300 cfs Test Case (Example Scenario)



Next Steps

1. Relicensing Participant comments on report and model
2. Scenario testing
3. User-interface model code availability
4. Model training?
5. Future model refinements
   - 2014 Studies (W&AR-7, W&AR-21)
   - RP Comments
   - Other Refinements

Stillwater Sciences

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October 31, 2013 Don Pedro Project
E-Filed FERC No. 2299-075

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
Mail Code: DHAC, PJ-12.3
888 First Street, NE
Washington, DC 20426

RE: Turlock Irrigation District and Modesto Irrigation District
Don Pedro Project - FERC Project No. 2299
Final Meeting Notes and Responses to Relicensing Participant Comments on the W&AR-6 Modeling Workshop No. 2 held on August 6, 2013

On August 6, 2013, as part of the ongoing studies under the Integrated Licensing Process (ILP) for the Don Pedro Project (Project), the Turlock Irrigation District and the Modesto Irrigation District, co-licensees of the Project (collectively the Districts) held their second workshop with relicensing participants on W&AR-06, the *Tuolumne River Chinook Salmon Population Model Study Plan* (W&AR-06). Consultation Workshop No. 2 was held to: (1) review and discuss the selected modeling approach; (2) present the Tuolumne River Chinook Salmon Population Model (TRCh) calibration and validation results; (3) discuss model parameter sensitivity testing results in the context of initial factors identified as part of the interrelated *Salmonid Information Integration and Synthesis Study* (W&AR-05) (Synthesis Study); and (4) present TRCh modeling results for the base case hydrology from the Tuolumne River Operations Model.

A meeting agenda was provided to relicensing participants on July 26, 2013 along with directions to the Don Pedro website where the Draft *Chinook Salmon Population Model Study Report* (model report) was provided for review. At the Workshop, in addition to our description of the model components, relicensing participants were asked to provide initial feedback regarding the TRCh model and model report, additional flow scenario requests, and requests for model distribution and training.

Draft notes for Consultation Workshop No. 2 were provided to relicensing participants on August 21, 2013 for 30-day review. The review period of the draft model report was extended to September 20, 2013. Following the 30-day review period, comments on the draft notes were provided by the California Department of Fish and Wildlife (CDFW), California State Water Resources Control Board (SWRCB), U.S. Fish and Wildlife Service (USFWS), as well as a joint comment letter by the Tuolumne River Trust and California Sportfishing Protection Alliance (TRT/CSPA). The comment letters did not provide any corrections to the draft meeting notes.

In accordance with the Final Workshop Consultation Protocols filed with FERC on May 18, 2012, this letter provides the Final Meeting Notes (Attachment A), as well as relicensing participant comments and supplemental materials within Attachments B through E as indicated below:

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206.914.5031

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Attachment A:	Final Meeting Notes and Workshop Materials – W&AR-6 Modeling Workshop No. 2
Attachment B:	California Department of Fish and Wildlife Comments on Draft Meeting Notes and W&AR-6 Workshop No.2, Don Pedro Hydroelectric Project (Project) No. 2299, Tuolumne River
Attachment C:	California State Water Resources Control Board Comments on the W&AR-6 Chinook Salmon Population Model Study Report and Workshop No.2 Draft Meeting Notes
Attachment D:	U.S. Fish and Wildlife Service Comments on W&AR-6, Chinook Salmon Population Model Study Draft Report and Workshop No.2 Draft Meeting Notes for the Don Pedro Hydroelectric Project, Federal Energy Regulatory Commission Project No. P-2299 on the Tuolumne River; Tuolumne and Stanislaus Counties, California
Attachment E:	Tuolumne River Trust and California Sportfishing Protection Alliance Comments on W&AR-6 Chinook Salmon Population Model Workshop No. 2 Draft Meeting Notes

General Responses to Comments Received

The Districts appreciate the time relicensing participants devoted to attend the Workshop and review the Draft W&AR-06 model report. All comments and suggestions received are being considered for incorporation into the TRCh model and final model report. Although we provide responses to individual comment letters in the following sections, several of the letters provided comments on issues previously addressed by the Synthesis Study. In particular, there appears to be a misunderstanding of how the EPA (2003)[1] water temperature guidelines were applied to the TRCh model. At the recommendation of the FERC Staff in the December 22, 2011 Study Plan Determination (SPD pg 39), the TRCh modeling approach was modified to directly address the “association between flows, water temperature, changing habitat conditions, predation, and population response for specific in-river life stages”. Specifically regarding temperature, the development of the TRCh model relied heavily upon laboratory and observational study results contained in the very same Issue Papers supporting the optimum water temperature recommendations contained within EPA (2003).

On the basis of daily average water temperature, the TRCh model includes temperature related mechanisms related to spawning habitat selection (i.e., avoidance/preference); bioenergetic growth models as continuous functions of water temperature for fry and juvenile rearing; as well as water temperature related mortality for all life stages from spawning through smolt emigration. Although the Districts are certainly willing to discuss alternative metrics or parameter values to quantify behavioral effects or life history outcomes of individual life stages represented in the TRCh model (i.e., avoidance, preference, movement, growth, or mortality), the EPA (2003) recommended summertime maximum 7-day average of the daily maximum temperature (7DADM) metric is intended as a protective standard and does not, in and of itself, provide either the

[1] USEPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, Washington.

necessary or sufficient information to quantify behavioral effects (e.g., avoidance or preference) or life history outcomes (i.e., growth or mortality) of individual life stages represented in the TRCh model.

The Districts are proceeding with the development of the *Temperature Criteria Assessment Study* (W&AR-14), which will present empirical Central Valley and Tuolumne River salmonid habitat use data along with water temperature data in comparison with EPA (2003) recommendations. This includes undertaking a swim tunnel experiment using *O. mykiss* juveniles to examine local adaptations to Tuolumne River water temperatures as well as to better differentiate between optimal and sub-optimal temperature ranges on the basis of empirical fish metabolism data.

Responses to California Dept. of Fish and Wildlife Comments

In its letter of September 17, 2013 (Attachment B), CDFW provided comments on three areas addressed by the modeling studies, including (1) a recommendation for peer review, (2) model assumptions regarding spawner timing, and (3) three identified factors affecting smolt productivity.

1. *Request for Peer Review*. CDFW reiterated its recommendation that a formal peer review be conducted of the underlying TRCh model assumptions and structure, citing disagreement with the interpretation of model results. Although we provide a brief discussion of the reported model results in item No. 3 below, the Districts believe the Consultation Workshops have provided ample opportunity for a rigorous review process and has resulted in improved modeling approaches to better represent in-river effects upon salmonid life history outcomes. In the December 22, 2011 SPD, because of the short timeframe available to complete detailed studies under the ILP, FERC staff did not require a formal peer review as participation by experienced biologists from NMFS, USFWS, CDFW, the Conservation Groups, and Commission staff would ensure a rigorous scientific review. Recognizing the need for a collaborative process, FERC staff required that Consultation Workshops be an integral part of the Synthesis Study and TRCh model development as well as other elements of the *Integrated Life Cycle Models Workshop Report*[2]. Refinements in the TRCh model development have been informed by Workshop participation and comments by CDFW and other relicensing participants. Separate from the time constraints and additional costs of convening a separate peer review panel, CDFW does not provide any rationale that the current level of Workshop participation is inadequate to ensure the TRCh model is addressing the identified in-river issues affecting Chinook salmon in the Tuolumne River.

2. *Model assumptions regarding spawner timing*. CDFW cited potential data limitations regarding use of spawner arrival timing data at the Tuolumne River weir in 2009 and the development of the sub-model's upmigration and spawning timing relationship. In reply, it should be noted that the TRCh model does not

[2] Rose, K., J. Anderson, M. McClure and G. Ruggerone. 2011. Salmonid Integrated Life Cycle Models Workshop. Report of the Independent Workshop Panel. Prepared for the Delta Stewardship Council.

encode any particular arrival timing relationship and requires the user provide a specific spawning run and associated arrival timing as a model input. Both weir- and redd count-based arrival timing were evaluated in the model report for the 2009 spawning run. TRCh model results do indicate that that spawner arrival timing is an important determinant of subsequent life-history timing. However, because the year-to-year variability in spawner arrival timing complicates interpretation of model results, a standardized run based upon 1992–2010 spawning data collected by CDFW was used to examine parameter sensitivity and the Base Case scenario results. Although information reviewed for the Synthesis Study and shared with relicensing participants found no relationship between river flows and arrival timing at La Grange between 1981 and 2006, CDFW and other relicensing participants are free to use the TRCh model to explore the effects of altered arrival timing on smolt productivity by developing scenarios with alternative spawner arrival distributions.

3. *Identified factors affecting smolt productivity*. CDFW provided comments on three potential issues evaluated through sensitivity testing by the model: (a) redd superimposition, (b) juvenile rearing habitat availability, and (c) water temperature.

    a. **Redd superimposition**. CDFW questions the utility of the results of the 1988–1989 redd mapping and superimposition studies conducted by the Districts and summarized in the Synthesis Study, but provides no new data to support its questions. The previously established observations indicate egg losses on the order of 15–20% due to superimposition, corroborated by fry emergence trapping results documenting the numbers and timing of fry emerging from multiple superimposed redds, as well as redd excavation results. Although available spawning gravels are sufficient to support recent spawning runs with only limited redd superimposition indicated in the *Redd Mapping Study* (W&AR-08), the density dependence shown for Base Case scenarios at high and low escapement coupled with the model sensitivity to redd size are consistent with spawning habitat limitation and redd superimposition effects with increasing escapement. The current use of uniform probability of redd placement within suitable habitats at a given riffle is likely an underestimate of greater degrees of preference for previously selected redd locations.

    b. **Juvenile rearing habitat availability.** CDFW questions model results showing no identified rearing habitat limitation for Chinook salmon fry and juveniles, stating a contradiction with inferences from an earlier Draft limiting factors evaluation based upon Stanislaus River rotary screw trap (RST) data[3], as well as observations of floodplain rearing on

[3] Mesick, C., J. McLain, D. Marston, and T. Heyne. 2008. *DRAFT* Limiting factor analyses & recommended studies for fall-run Chinook salmon and rainbow trout in the Tuolumne River. U.S. Fish and Wildlife, National Marine Fisheries Service, California Department of Fish and Game.

the Cosumnes River[4]. TRCh model parameter sensitivity testing of a broad range of rearing densities showed little effect on subsequent smolt productivity. Further, unlike the current study, neither of the above-referenced studies examined the amount or utilization of juvenile rearing habitats on the Tuolumne River. Other than inferences from the out-of-basin study references provided in the comments, no new mechanisms, alternative functional relationships, or alternative model parameterization were suggested by any relicensing participant during model development, nor does CDFW now provide any new in-river data to support its rationale for questioning the Tuolumne-specific relationships used in this model.

c. **Water temperature.** CDFW questions model results showing low sensitivity of smolt productivity to water temperature stating that water temperatures exceed the EPA (2003) guidelines when .juvenile and adult Chinook salmon are present in the lower Tuolumne River. Although application of the EPA (2003) guidelines is discussed further under the SWRCB comments below, model sensitivity testing was conducted over a broad range in assumed mortality thresholds 17–25°C[63–77°F] with no changes in smolt productivity. Both empirical in-river monitoring data as well as modeling results of Tuolumne River fish locations at various times of year indicate that Chinook salmon life history progression from spawning through smolt emigration occurs at temperatures well below identified mortality thresholds. As discussed in the model report, although water temperature is an important factor governing life history progression and mortality of all life stages of Chinook salmon, empirical monitoring data and model results show that the great majority of adult fish arrive late in the fall when water temperatures are well below adult mortality thresholds, and the great majority of juvenile rearing and smolt emigration has been completed before water temperatures approach juvenile mortality thresholds. CDFW offers no new in-river mechanisms, alternative functional relationships, or alternative model parameterization in its comments.

Responses to California State Water Resources Control Board Comments

In its letter of September 23, 2013 (Attachment C), SWRCB comments on two potential issues addressed in the model development: (1) Water Temperature, and (2) Model Validation.

1. *Water temperature*. SWRCB comments that the temperature thresholds used to parameterize various life stage sub-models are in excess of *optimum* temperature recommendations contained within the EPA (2003) water temperature guidance document. The TRCh model relies upon identified mortality thresholds for individual life stages from the Issue Papers used to support the development of

[4] Jeffres, C.A., J.J. Opperman, and P.B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environ Biol. Fish. 83:449-458.

EPA (2003) because they are repeatable and well established within a fairly narrow range in the scientific literature. As stated in reply to CDFW comments above, model sensitivity testing was conducted over a broad range in assumed mortality thresholds 17–25°C[63–77°F] with no changes in smolt productivity. Both empirical in-river monitoring data as well as modeling results of Tuolumne River fish locations at various times of year indicate that Chinook salmon life history progression from spawning through smolt emigration occurs at temperatures well below identified mortality thresholds. For fry and juvenile growth, temperature optima at cooler temperatures are implicitly included in the bioenergetic growth sub-model without need for separate application of the EPA (2003) guidelines as "criteria". That is, for modeled fish exposed to sub-optimal temperature conditions, reduced growth rates would be predicted for the same ration levels by the TRCh model, resulting in later smolt emigration and a greater probability of exposure to potentially lethal water temperatures. .

2. *Model Validation*. Under the heading "Model Validation" SWRCB recommends a third party peer review be conducted of the TRCh model report. The Districts appreciate the review comments provided as part of the five workshops held to date by the SWRCB and other relicensing participants. However, as stated in reply to CDFW comments, FERC staff did not require additional peer review as participation by experienced biologists from NMFS, USFWS, CDFW, the Conservation Groups, and Commission staff would ensure a rigorous scientific review. Separate from the time constraints and additional costs of convening a separate peer review panel, SWRCB does not provide any rationale that the current level of Workshop participation is inadequate to ensure the TRCh model is addressing the identified in-river issues affecting Chinook salmon in the Tuolumne River.

<u>Responses to U.S. Fish and Wildlife Service Comments</u>

In its letter of September 20, 2013 (Attachment D), USFWS provided comments on five issues, including (1) importance of essential stressors and limiting factors, (2) application of EPA (2003) water temperature criteria, (3) clarification of fry growth model assumptions, (4) clarification of in-channel and floodplain rearing parameterization, and (5) additional scenario requests.

1. *Importance of essential stressors and limiting factors*. USFWS expressed concern that the information underlying the modeling to support this study did not include essential stressors and limiting factors that must be addressed in order to sustain populations. Citations were provided to broad literature sources covering topics including: quantity and quality of juvenile rearing habitat (in-channel, off-channel, floodplain), disease incidence of several life stages (spawners, eggs, smolt emigrants) at elevated water temperatures, as well as the importance of large woody debris and nutrients to the food supply of rearing juvenile Chinook salmon. The Districts are in agreement with the general concepts related to the referenced stressors raised in the USFWS comments; however, the majority of these issues reiterate assessments made in the Districts' earlier Synthesis Study. For example, water temperature effects upon upmigrant survival and egg viability were evaluated in the Synthesis Study, but since no

data were identified showing temperature related effects of this type and since temperatures in the South Delta and lower San Joaquin are higher than those in the Tuolumne River, we reasoned that any temperature related impacts to upmigrant spawners would have occurred at locations far downstream of the effects of cold water releases from Don Pedro Reservoir. If this comment is requesting the addition of water temperature effects to upmigration and spawning beyond those represented in the TRCh model, it is unclear what functional relationship would be used to represent these temperature effects on timing since no relationship was identified as part of the earlier Synthesis Study. Disease incidence was also examined in the Synthesis Study. Recent health assessments did not show clinically high rates of infection[5,6] or linking elevated disease incidence to specific water temperature conditions in the Tuolumne River. Lastly, while various observational studies of fish size in various floodplain habitats in the Central Valley were also reviewed in the Synthesis Study, Tuolumne River specific data showed adequate food resources are available and in-river smolt condition from the above-referenced health assessments did not suggest any food related impairments. Although the Districts appreciate the care and effort taken by relicensing participants in researching many of these previously addressed topics examined as part of the Synthesis Study, the comments provided on the completed model offer no new information on in-river modeled processes, functional relationships, or parameters.

2. *Application of EPA (2003) water temperature criteria.* USFWS stated that the EPA (2003) criteria should be used to model temperature effects of various life stage processes and mortality. As stated in the Districts' General Responses above, although the TRCh model development relied heavily upon literature contained in Issue Papers supporting the optimum water temperature recommendations contained within EPA (2003), these recommendations are not in and of themselves the result of controlled experiments. Although the Districts are willing to discuss the appropriate metrics used to evaluate mortality endpoints—for example, many of literature sources reviewed in the supporting EPA Issue Papers are the result of constant temperature experiments—it is unclear how recommendations for the summertime 7DADM metric contained in EPA (2003) can be applied to the life stage processes represented (i.e., movement, preference, growth, or mortality). None of the comments provided on these temperature related issues are recommending alternative functional relationships based on in-river data to be used instead of those in the TRCh model.

3. *Clarification of fry growth model assumptions.* USFWS requested additional detail related to fry growth methodology as well as use of Tuolumne River length

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[5] Nichols, K., J.S. Foott, and R. Burmeister. 2001. Health monitoring of hatchery and natural fall run Chinook salmon juveniles in the San Joaquin River and Delta, April–June 2000. FY2000 Investigation Report by the U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA

[6] Nichols, K., and J.S. Foote. 2002. Health monitoring of hatchery and natural fall-run Chinook salmon juveniles in the San Joaquin River and Tributaries, April – June 2001. U.S. Fish & Wildlife Service, California- Nevada Fish Health Center, Anderson, CA.

and weight data. As described in the model report, river-wide averages of food ration were based upon stomach content samples (n=525) collected at eleven Tuolumne River locations extending from Old La Grange Bridge (RM 50.5) to Shiloh Bridge (RM 3.5) as well as several San Joaquin River locations for the years 1983–1987. High reach-specific estimates (ration of 70% of maximum) were applied to the gravel-bedded reach upstream of Legion Park (RM 17) with lower estimates applied in the sand bedded reach downstream (ration of 30% of maximum). Recognizing the potential for enhanced food availability on the basis of recent observational studies of floodplain rearing, a high ration estimate of 70% of maximum was made at floodplain locations riverwide. Variations in food availability above and below the parameter values above were examined through model sensitivity testing, showing lower floodplain growth rates with lower ration estimates than that used in the current TRCh model implementation but only small increases in growth rates would be modeled under a higher food ration assumption. With regard to the USFWS comment regarding use of length and weight data from the Tuolumne, Figure 4-7 of the model report presents this data, which was used to allow bioenergetic modeling on the basis of weight and inter-changeably convert model results from length data collected as part of routine seining and RST monitoring. Additional description of the fry and juvenile growth modeling will be provided in the final model report.

4. *Clarification of in-channel and floodplain habitat availability estimates.* USFWS requested additional detail related to the treatment of floodplain habitat and that the results of the 2014 *Lower Tuolumne Floodplain Hydraulic Assessment* (W&AR-21) be used to update the estimates of usable habitat at several flows. With regard to updated report figures to show a continuous relationship between in-channel and floodplain areas, a combined figure will be developed for potential inclusion in the final model report. The results of the upcoming W&AR-21 study may also provide more up-to-date information based upon additional hydraulic modeling at high flows. Should this study produce significantly different results in usable habitat area that affect TRCh model results, revisions or addenda to the final model report will be developed following completion of W&AR-21.

5. *Additional scenario requests*. USFWS made several requests for additional modeling scenarios, including (a) flows to meet the AFRP doubling goal targets for salmon escapement[7], (b) observed La Grange flows, and (c) percent of unimpaired flows evaluated as part of the Substitute Environmental Document[8]. With regard to flows required to meet AFRP doubling goal targets, the Districts have previously submitted comments (FERC No. 2299-053 and 2295-065) that

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[7] USFWS. 2005. Recommended Streamflow Schedules To Meet the AFRP Doubling Goal in the San Joaquin River Basin. U. S. Fish and Wildlife Service, Anadromous Fish Restoration Program, Lodi, CA.

[8] ICF International. 2012. Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary: San Joaquin River Flows and Southern Delta Water Quality. Public Draft. December. (ICF 00427.11) Sacramento, CA. Prepared by State Water Resources Control Board, California Environmental Protection Agency, Sacramento, CA.

showed significant and unquantifiable errors are present in the historical (1967–1991) escapement baseline estimates underlying AFRP doubling goals[9]. For this reason, interpretation of the potential benefits of various flow scenarios should be limited to smolt production. The Districts will schedule a teleconference with USFWS staff to discuss details of the requested scenarios. Following modeling of the water temperature time series corresponding to each of the scenarios, TRCh modeling will be conducted and provided to USFWS and other relicensing participants.

Responses to Comments by Tuolumne River Trust and California Sportfishing Protection Alliance

In their letter of September 20, 2013 (Attachment E), TRT/CSPA provided comments on three issues, (1) model validation and uncertainty, (2) water temperature effects, and (3) modeling of San Joaquin River and Delta conditions.

1. *Model validation and uncertainty*. Comments by TRT-CSPA correctly pointed out that many of the individual sub-models draw upon deterministic functional relationships and indicate that data for several relationships are based on relatively short time series. While the TRCh model includes probabilistic relationships for certain processes (i.e., habitat selection, mortality, emigration) a decision was made to evaluate alternative operational scenarios on the basis of fixed long-term averages for spawning age structure, arrival timing, and size-fecundity relationships. This decision was made to allow examination of the relative effects of in-river conditions without the confounding influences of interannual variations of ocean growth and survival conditions. Although sensitivity testing was used to examine the potential effects of redd size and several other parameters, TRT-CSPA and other relicensing participants are free to use the TRCh model to explore the effects of other variations in model parameters, inter-annual variations in age structure and spawner arrival timing. With regard to the comment related to use of the model as a predictive tool, it should be understood that the TRCh model was not developed specifically as a predictive tool. The model represents documented seasonal rearing patterns well and the resulting fry and smolt RST passage estimates match existing data within an acceptable range over broad variations in hydrologic conditions tested between 2007 and 2012. Therefore, we believe the model can be used as originally intended; that is, as a tool to examine the ***relative*** influences of various factors on: (1) life-stage specific production of Chinook salmon in the Tuolumne River, (2) identification of critical life-stages that may represent a life-history "bottleneck," and (3) to compare ***relative*** changes in juvenile production between alternative flow and habitat management scenarios. Subject to these limits, the TRCh model may be useful in "predicting" these relative changes to in-river production due to river flow as well as other potential non-flow measures.

[9] Newman, K. B. and D. G. Hankin. 2004. Statistical Procedures for Detecting the CVPIA Natural Chinook Salmon production Doubling Goal and Determining Sustainability of Production Increases. Prepared for CH2M Hill (subcontract 73603). June 21, 2004.

2. *Water temperature effects*. TRT/CSPA suggest that the TRCh model assumes environmental tolerances that exceed those documented in the literature, providing comparisons of the TRCh model mortality endpoints with various literature sources, including EPA (2003) 7DADM recommendations for summertime conditions, literature review recommendations by Richter and Kolmes (2005)[10], as well as several life stage specific references to alternative temperature thresholds based upon Central Valley based literature sources previously reviewed as part of the Synthesis Study. Below, we address the identified threshold comparisons by life stage.

    a. **Returning Adults**. Although we were unable to actually find the referenced 20–21°C temperature recommendations attributed to Richter and Kolmes (2005), TRT/CSPA comparisons of these and EPA (2003) recommendations with spawning habitat selection preferences in the TRCh model are inappropriate. As stated in reply to USFWS comments above, no data were identified showing temperature related effects on upmigrant mortality or egg viability. Further, since water temperatures in the South Delta and lower San Joaquin are considerably higher than those in the Tuolumne River, we reasoned that any temperature related impacts to upmigrant spawners would have occurred at locations far downstream of the effects of cold water releases from Don Pedro reservoir.
    b. **Egg incubation**. Whereas references cited by TRT/CSPA are related to upper limits of suitable or optimal temperature conditions, the 14.4°C (58°F) mortality threshold in Table 4-2 of the model report represents the midpoint of the 13.9–15.6°C temperature range corresponding to egg mortality in controlled laboratory experiments of Central Valley Chinook salmon. As these experiments were generally conducted under constant temperature regimes, it is not expected that alternative exposure metrics (e.g., 7DADM, daily maximum) are relevant to the selected parameter.
    c. **Juvenile rearing**. References cited by TRT/CSPA provide temperature ranges for optimal conditions (12–17°C [54–63°F]), sub-optimal conditions (20°C [68°F]), as well as a range of lethal conditions (22–25°C [72–77°F]), none of which are inconsistent with the 25°C (77°F) mortality threshold used in the TRCh model (Tables 4-3 through 4-5). As stated in reply to USFWS' comments, the TRCh model directly incorporates bioenergetic modeling with temperature optima at cooler temperatures than the references cited by TRT/CSPA. For mortality endpoints, model sensitivity testing over a broad range in assumed mortality thresholds (17–25°C [63–77°F]) showed no changes in smolt productivity. Both empirical in-river monitoring data as well as modeling results at various times of year indicate that Chinook salmon life history progression from spawning through smolt emigration occurs at temperatures below identified mortality thresholds.
    d. **Smoltification**. TRT/CSPA provides a comparison of the TRCh smolt mortality threshold of 25°C (77°F) with literature review summaries of

[10] Richter A, and S.A. Kolmes. 2005. Maximum Temperature Limits for Chinook, Coho, and Chum Salmon, and Steelhead Trout in the Pacific Northwest. Rev in Fish Sci, 13:1, p. 23–49.

temperatures corresponding to smoltification impairment. The Districts' Synthesis Study previously summarized all these referenced laboratory study results, including inhibition of smoltification for *Sacramento* fall-run Chinook salmon juveniles reared at 21–24°C (70–75°F) relative to those reared at 13–16°C (55–61°F) and 17–20°C (63–68°F) temperatures. However, because empirical Tuolumne River seining and temperature data as well as modeling results at various times of year indicate the vast majority of Tuolumne River juveniles are reared at temperatures well below these limits, a decision was made to not include a temperature related mechanism for smoltification. Recognizing that small numbers of juveniles remain in the Tuolumne River during summer, a length based smoltification threshold was implemented in the TRCh model (Section 4.1.5.1) based upon sizes at emigration in historical in-river RST monitoring.

3. *Modeling of San Joaquin River and Delta conditions*. TRT/CSPA reference conditions in the San Joaquin River and Delta with broad linkages to Tuolumne River flow that were previously discussed as part of the Synthesis Study. As discussed in the Synthesis Study, linkages of Don Pedro Reservoir releases to dissolved oxygen or temperature conditions in the lower San Joaquin River are not supported by monitoring data or modeling results, nor are they separable from regional variations in seasonal meteorology and basin-wide runoff occurring in "wet" and "dry" water year types. Because of the broad range of out-of-basin effects upon Chinook salmon life history progression that are not under the influence of Project operations, a decision was made during the study planning process undertaken in conjunction with relicensing participants and supported by FERC December 2011 SPD to develop a juvenile production model in order to examine the relative influences of in-river factors upon life-stage production or population levels of Chinook salmon. While the study area included in the approved study plan was limited to the Tuolumne River from La Grange Dam (RM 52) to the Grayson River Ranch RST (RM 5) near the San Joaquin River confluence, the Synthesis Study previously reviewed the out-of-basin considerations raised in the TRT/CSPA comments.

Respectfully submitted,

Noah Hume, PE, PhD
Senior Aquatic Ecologist

Attachments

Attachment A
Final Meeting Notes and Workshop Materials
W&AR-6 Modeling Workshop No. 2

Don Pedro Project Relicensing
W&AR-6 Workshop No. 2
Tuesday, August 6, 2013

Final Meeting Notes

Attendees

Peter Baker – Stillwater	Ramon Martin - USFWS
Steve Boyd – TID	Gretchen Murphey – CDFW
John Devine – HDR	Bill Paris – MID
Karl English – LGL, Ltd.	John Shelton – CDFW, *by phone*
Donn Furman – CCSF Attorney, *by phone*	Chris Shutes – CSPA
Art Godwin – TID	Dale Stanton – CDFW
Jim Hastreiter –FERC, *by phone*	Josh Strange – Stillwater, *by phone*
Noah Hume – Stillwater	Nicola Ulibarri – Researcher, Stanford Univ.
Zach Jackson – USFWS	Amber Villalobos – SWRCB
Bill Johnston – MID	Scott Wilcox – Stillwater
Ellen Levin – CCSF, *in person in morning, phone in afternoon*	Ron Yoshiyama – CCSF
Carin Loy – HDR	

Introductions and Background

Following introductions, John Devine provided some background on the study process to date.

- This is the second Workshop for this W&AR-6 modeling effort, and is being conducted in accordance with the Consultation Workshop protocols.
- The purpose of Workshop No. 2 is to: (1) update Relicensing Participants (RPs) on study progress; (2) demonstrate model functionality through Calibration/Validation and Base Case simulations; (3) provide updated assessment of important factors affecting Chinook salmon; and (4) solicit input on potential scenarios for evaluation.
- Other studies incorporated in this modeling effort include W&AR-4 (spawning gravel), W&AR-5 (salmonid information synthesis), W&AR-8 (redd mapping), W&AR-16 (water temperature); the one-dimensional (1D) Instream Flow study, and the two-dimensional (2D) Pulse Flow study.
- The *Lower Tuolumne Floodplain Hydraulic Assessment* study plan (W&AR-21) will be released shortly (*Note: this study plan was subsequently released to RPs for 30-day review and comment on August 9, with comments due on or before September 9*). Districts must file the study plan with FERC by September 16, 2013.

USFWS asked if the draft report should be considered a final draft for purposes of RP's review and comment.

- John Devine responded yes, the report should be considered a final draft with comments due 30 days after issuance of the Workshop Meeting notes in accordance with Consultation Workshop protocols.

Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production

- Noah reviewed and discussed the relationship of the W&AR-6 model to the W&AR-5 Synthesis Study completed in 2012.
- Model structure: the model is largely individually based, spatially explicit, with a simulation period of fall through spring to cover habitat use by in-river life stages.
- Model structured as linked sub-models addressing individual life stages. Allows use of available empirical data for calibration and validation.
- Noah reviewed slides on represented life stages, processes and parameters that are included in the model, and described its modular structure (slide 6).
- The modeled reach (RM 52.2–RM 0) was subdivided into smaller sub-reaches representing uniform habitat conditions. Spatial resolution may be changed by individual life stage.
- Key sub-model relationships by life stage were presented and discussed. These included:
    - Upmigration and spawning: timing (slide 9)
    - Upmigration and spawning: habitat suitability (slide 10)
        - Superimposition effects were noted (e.g., spawners tend to concentrate further upstream)
    - Spawner preference to upstream spawning sites (slide 11)
        - Fitted curve (red) to single-year data (black) from *Redd Mapping Study* (W&AR-8). Cumulative curve (grey) shows 3-year totals of redd counts by RM.
    - Upmigration and spawning: fecundity and mortality (slide 12)
        - No pre-spawning mortality for high water temperature included, since spawners had already passed high water temperature threats further downstream in the San Joaquin River and South Delta.
    - Egg incubation (slide 13)
        - Standard degree-day relationship to hatching with modifications to account for variable temperatures during incubation.
    - Fry rearing: movement (slide 14)
        - Gray contours are density of fry-sized fish, green contours are density of smolt-sized fish. Graphics depict more concentrated upstream rearing under low flow conditions than under high flow conditions, and show a season-long "drift" of the rearing juvenile populations downstream.
    - Fry rearing: habitat use (slide 15)
        - Fry use of both in-channel and overbank areas in the model in proportion to available habitat at a given location and flow condition.
        - Overbank habitat estimate in Shiloh Bridge to San Joaquin River sub-reach is probably an artifact of agricultural field flooding and backwater effects from the San Joaquin (slide 16). Figures to be modified in Final Report to keep the color of the lines for each reach consistent between the two graphics.
        - Carrying capacity is established for each sub-reach on the basis of usable area and maximum rearing density estimates. Fish in excess of carrying capacity are moved downstream to the next sub-reach that has suitable habitat available.
    - Fry rearing: growth (slide 17)
        - Ration is incorporated as a bioenergetic input, not further divided by quantity vs. quality of the food (i.e., existing ration estimates from Tuolumne River reflect stomach contents of Tuolumne River prey items).

    - Ration is assumed to be consistent among different floodplain locations.
    - Noah to provide Stauffer (1973) reference to Ramon
  - Fry rearing: mortality based upon fitting to RST data (slide 19)
  - Juvenile rearing: habitat use and growth (slides 20-22)
    - Follows same approach as for fry described previously
  - Smolt emigration (slides 23-24)
    - Primarily based on size threshold (i.e., developmental), water temperature, historical data documenting size at emigration.
    - Fish generally tend to emigrate at larger sizes in wet year types, smaller in dry year types, later in wet year types, earlier in dry year types.
  - Smolt mortality and survival (slides 25-26)
    - Prior TRTAC smolt survival relationship found to be inconsistent with observed RST data that show lower apparent survival at all flows.
    - The updated smolt survival relationship determined from RST data in Attachment C of the report was used to identify representative periods for smolt movement between the upper and lower RSTs in response to specific flow conditions.
    - QA/QC review identified anomalous conditions on some RST days (e.g., breaking loose from moorings during highest flows).
    - The relationship is sensitive to flow and reflects the observed RST results fairly well.

Model Calibration and Validation Results

- Upmigration and spawning timing
  - There is a time lag of approximately two weeks between weir passage and spawning activity (slide 27) represented as up migration speed. Note that this only applies when using spawner arrival via weir counts vs. redd count data.
- Rearing patterns (slide 28)
  - Note: Upper x-axis on slide should be showing 2010-11 dates, not 2009-10.
  - Contour plots represent density of fish by river mile
  - Model generally reproduces wet/dry pattern of fish distribution in the river
- RST passage (slides 31-36)
  - Grayson fry and smolt timing are reproduced by the model reasonably well, as well as fry passage at Waterford
  - Timing of Waterford smolts are not as well modeled, in part because model is rearing more fry in lower river
  - Modeled annual passage totals for fry and smolts at Grayson match RST data well (slides 37 and 38), demonstrating good model performance over a range of flow conditions
  - Model can be run using either carcass survey or weir data. Further comparisons can be made as additional spawning data become available (2010–2012).

Model Sensitivity Testing

- Noah and Peter reviewed the general approach to sensitivity testing (slide 39)
  - Different water year and escapement combinations considered along with variations in individual parameter values.
  - Evaluation metric is “smolt productivity”, defined as the number of smolts produced per female spawner.

    - Sensitive parameters result in a diagonal (sloped) line, showing a change in productivity with change in the parameter. Less sensitive parameters have a more horizontal line, showing little change in response to different parameter values.
    - Results (smolt productivity) presented for wet/dry conditions~~,~~ and for more/fewer spawners (slides 40-41)
- Modeling Sensitivity Tests (slide 42)
    - 13 relationships show the greatest sensitivity
    - Most sensitive parameters presented in slides 43-44.
    - Animation example of a model run
        - Peter walked the group through an animated example of model run results
        - Smolt emigration travel speed was discussed but is currently not used in the model to assess exposure to predation. Rather than using movement, smolt survival is represented as a direct function of flow based on RST data. Regardless, data indicate smolts move out of the river very quickly (1–2 days); this is consistent with physiological requirements as well.

Lunch Break

Discussion of Base Case (1971–2009) Scenario Results

- Noah introduced the base case simulations (slides 45–47)
    - Run for three reference spawning run sizes
        - Demonstrates a spawner density-dependent effect, with productivity per spawner going up when spawner numbers go down.
        - Demonstrates a positive relationship of smolt productivity with flow
        - Reservoir refilling effects after very dry water years are apparent in 1978 and 1993, where La Grange gage flows are low even though the water year meets a Wet WY designation.
    - There was a question from Chris Shutes about the slide 46 results for 1982 vs. 1983.
        - Subsequent examination of the individual hydrographs showed an average of 8,500 cfs during the pulse flow period (4/15-5/15) in 1982 vs. 10,000 cfs in 1983. In addition, discharge in 1983 drops after the pulse flow period, which did not occur in 1982. This may result in a stronger interaction with escapement size effects upon superimposition and subsequent smolt emigration timing in 1983 than in 1982.
    - Emigration timing (slide 47) shows earlier emigration in drier years, later in wetter years. It also shows variation in timing within each water-year type.
    - Ramon asked if VAMP-year flows were excluded from slide 47.
        - John Devine responded that VAMP flows are not included in the Base Case flows to the lower Tuolumne River.
        - Noah stated that including VAMP flows above Pulse Flow amounts would have marginally higher smolt productivity in years that VAMP was implemented, but would not be expected to alter the observed emigration timing significantly.

Discussion of Factors Affecting Chinook Production

- Model can be used to look at how different factors affect production. Some of these effects include the following (slides 48- 51)
- Spawning habitat
  - Redd superimposition effects: smolt productivity per spawner declines with increased escapement
- Rearing habitat
  - There is low model sensitivity to rearing density (e.g., quantity of rearing habitat area) or increased food availability
  - The assumption of greater food availability in lower reach overbank areas causes some improvement in rearing capacity there during high flows, although not that many fish rear that far downstream.
  - A question was raised regarding whether the carrying capacity and rearing may obscure any important indirect effects such as increased exposure to predation (Dale Stanton, John Shelton). Actual fish habitat use is patchy, and although fish movement and thus predator exposure may vary on smaller scales, the current treatment of rearing habitat in the model reproduces RST passage well.
- Flow effects
  - Increased smolt productivity with spring discharge. Model is reproducing observed historical results (slide 50)
- Water temperature
  - Little sensitivity to temperature during the times of year the fish are present (slide 51)
  - Mortality thresholds came from guidance documents and literature reviews prepared as part of the EPA (2003) development.
    - Peter mentioned that even lowering the mortality threshold (UUILT) to 18C in sensitivity testing did not produce significant change in productivity.
  - Question raised by John Shelton regarding microhabitat distribution of temperature and behavioral responses and potential effects.
    - John Devine mentioned the recent deployment of numerous in-river thermographs to provide more information about local temperature refugia as compared to broader longitudinal patterns in historical thermograph data and model output.
    - Noah noted that 2-dimensional temperature variations are below the resolution of the current model. .

Discussion of Modeling Scenarios

- John Devine introduced the concept of modeling scenarios and opportunity to run alternative scenarios proposed by the group.
- Noah discussed the 300 cfs Test Case run that was completed as part of the *Operations Model* training (slides 52-53)
  - Small increase in productivity in drier water year types relative to Base Case.
  - Up-migration timing is not significantly affected by flow or temperature factors. However, year-to-year variations in up-migration timing can affect when smolts go out and how that overlaps with scheduled pulse flows, which can substantively affect overall productivity.
  - Results differ based on numbers of spawners, and water year type

- A concern was expressed (Gretchen) that smolts/spawner might be a misleading metric, and for some presentations the total smolt production might be a more helpful metric. Others noted that this is simply a matter of multiplying by the sizes of the represented reference runs.

Requests for Additional Scenarios

- Model can be run using alternate input data, such as operations model output and river temperature model output.
- Dale Stanton suggested experimenting with timing of spring pulses to match emigration peaks.
- A second alternative included the 35 % unimpaired flow scenario developed as part of the *Operations Model* (W&AR-2). Model runs will be made with 2,000 and 10,000 spawners.
- John encouraged RPs to call Noah with questions or other scenario ideas, in addition to putting them in writing.
- As a sensitivity evaluation, Ramon requested substitution of the 7-day average daily max (7DADM) and Daily Maximum temperatures as input data for the Base Case. These alternate input data will be evaluated at the 25C UUILT or other mortality thresholds from EPA (2003) that are relevant to the averaging periods of the water temperature input data.

Next Steps/Action Items (slide 56)

- A user interface is in development to make model runs simpler for others to execute
- An offer for model training was made, no RPs are currently requesting training.
- Any other scenario requests will be provided by RPs along with their comments on the report.
- Noah to provide Stauffer (1973) reference to Ramon. [*Note: This was transmitted by e-mail on 8/9/2013*]
- Figures represented in Slide 16 graphics to be modified in Final Report to keep the color of the lines for each reach consistent between the two graphics.
- RP comments should be provided on the Final Draft Report. Although the report may be potentially be updated on the basis of RP comments and any 2014 Study results, RPs should consider the W&AR-6 report as a "Final" report.
- Ramon will likely wait for the floodplain inundation study before focusing on results of runs of the salmon model. Noah indicated that he would not expect significant changes to model results coming from the floodplain inundation study. Model runs performed with the current parameterization will provide very useful comparisons between the Base Case and other operations scenarios.

Attachments

Attachment 1: Agenda

Attachment 2: Modeling Workshop No. 2 Slides. *Note the slides below were revised following the meeting*:

- Slide 15 (Usable Area for Fry) – Re-formatted data series to match colors by sub-reach
- Slide 17 (Fry Rearing (Growth) – Insertion of Stauffer (1973) reference.
- Slide 15 (Usable Area fo r Juveniles) – Re-formatted data series to match colors by sub-reach
- Slide 28/29 (Fry and Juve nile Rearing Patterns) – Correction of date scale in WY 2011
- Slide 39 (Param eters Affecting Juvenile Productivity) – Deletion of repeated bullet.
- Slide 44 (Sensitive parameters) – Inserte d bullet Re: sensitivity to lower food-ration on in-channel and floodplain habitats for fry.

Attachment 1

Agenda

Chinook salmon Population Model Workshop No. 2
Don Pedro Relicensing Study W&AR-6
August 6, 2013 – HDR Offices, Sacramento
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994

Join online meeting

https://meet.hdrinc.com/carin.loy/HM5F42M3

First online meeting?

Agenda

9:00 a.m. – 9:15 a.m.	**Introductions and Background**
9:15 a.m. – 10:30 a.m.	**Modeling Approach for Key Issues Affecting Tuolumne River Chinook salmon juvenile production** **1. Relationship to W&AR-5 Synthesis Study** **2. General assumptions and model structure** **3. Key Sub Model Relationships by Life-Stage**
10:30 a.m. – 11:00 a.m.	**Model Calibration and Validation Results**
11:00 a.m. – 12:00 p.m.	**Modeling Sensitivity Testing**
12:00 p.m. – 1:00 p.m.	**Lunch (on your own)**
1:00 p.m. – 2:00 p.m.	**Discussion of Base Case (1971–2009) Scenario Results**
2:00 p.m. – 3:00 p.m.	**Discussion of Factors Affecting Chinook Production**
3:00 p.m. – 3:45 p.m.	**Discussion of Modeling Scenarios** - **300 cfs Test Case Run** - **Requests for Additional Scenarios**
3:45 p.m. – 4:00 p.m.	**Next Steps**

Attachment 2

Modeling Workshop No. 2 Slides

Tuolumne River Chinook salmon (W&AR-6) study

Modeling Workshop No. 2

August 6, 2013

Don Pedro Project Relicensing
FERC No. 2299

Agenda/Overview

Introductions and Background

1. Purpose of Meeting
2. Relationship to Other Studies

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Salmon Juvenile Production

1. Relationship to W&AR-5 Synthesis
2. General Assumptions and Model Structure
3. Key Sub Model Relationships by Life-Stage

Modeling Calibration and Validation

1. Upmigration and Spawning
2. Fry and Juvenile Rearing
3. RST passage of Fry and Smolts

Agenda/Overview

Sensitivity Testing of Parameters by Life Stage

1. Upmigration and Spawning
2. Egg Incubation
3. Fry Rearing
4. Juvenile Rearing
5. Smolt Emigration

Base Case Scenario Results

Factors Affecting Chinook Production

Discussion of Modeling Scenarios

1. 300 cfs Test Case (Example Scenario) Run
2. Requests for Additional Scenarios

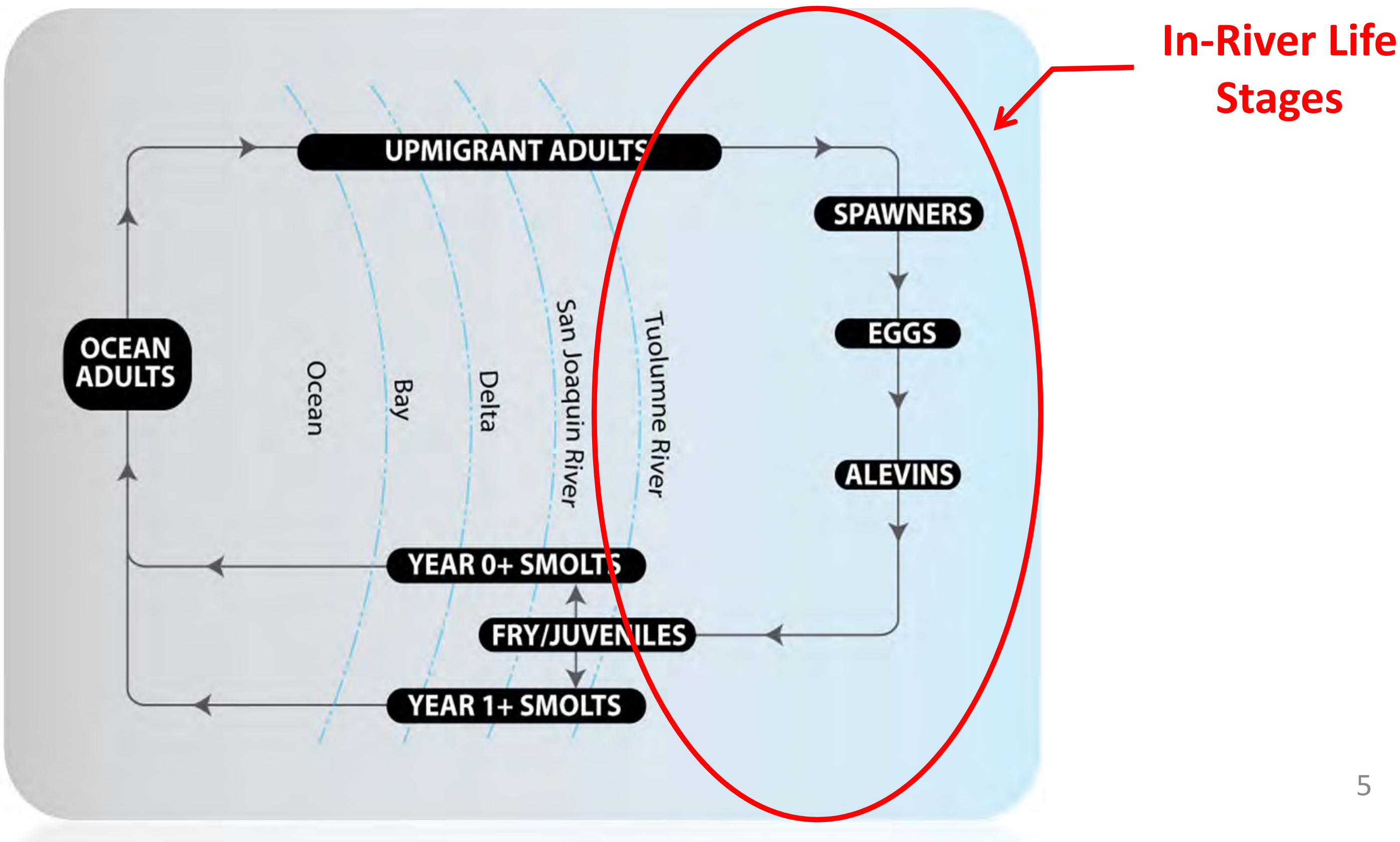
Next Steps

Relationship to W&AR-5 Synthesis

- Literature Review
- Initial assessment of in-river and out-of-basin factors affecting overall population levels
- Production models intended to examine relative importance of identified ***in-river factors upon juvenile production***
- Inclusion of some factors for modeling not recognized as important in initial W&AR-5 assessment
- Recognition that some factors may not be feasibly modeled

General Assumptions and Model Structure

- Independent sub-models separate life-history transitions
  - calibration and verification (e.g., weir counts, redd counts, egg-survival, RST passage)



Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Events	Life stages	Life stanzas	Processes (Parameters)
arrival at weir location	spawner →	upstream migration, habitat selection, redd construction	gravel area (flow, water temp.) gravel preference redd dimensions, redd defense times
burial of fertilized eggs	redd →	embryo development	development rate (water temp.) acute mortality (water temp.) superimposition mortality gravel quality-related mortality
emergence from gravels	swimup →	fry rearing	displacement (flow) migration mortality habitat area (flow, water temp.) development rate (water temp.)
arrival at RST locations	passage fry →		
exit from Tuolumne River	emigrant fry →		
attainment of dev. threshold (fork length = 50 mm)	parr →	juvenile rearing	habitat area (flow, water temp.) development rate (water temp.) acute mortality (water temp.) background mortality smoltification criteria
arrival at RST locations	passage juvenile →		
exit from Tuolumne River	emigrant juvenile →		
smoltification	smolt →		
remaining after the spring outmigration	summer →		

Modeling Approach for Key Issues Affecting Tuolumne River Chinook Juvenile Production

Don Pedro Project
FERC No. 2299

Events	Life stages	Life stanzas	Processes/Parameters
	smolt		
arrival at RST locations	passage smolt	smolt emigration	acute mortality (water temp.) background mortality (flow)
exit from Tuolumne River	emigrant smolt		

Model Structure

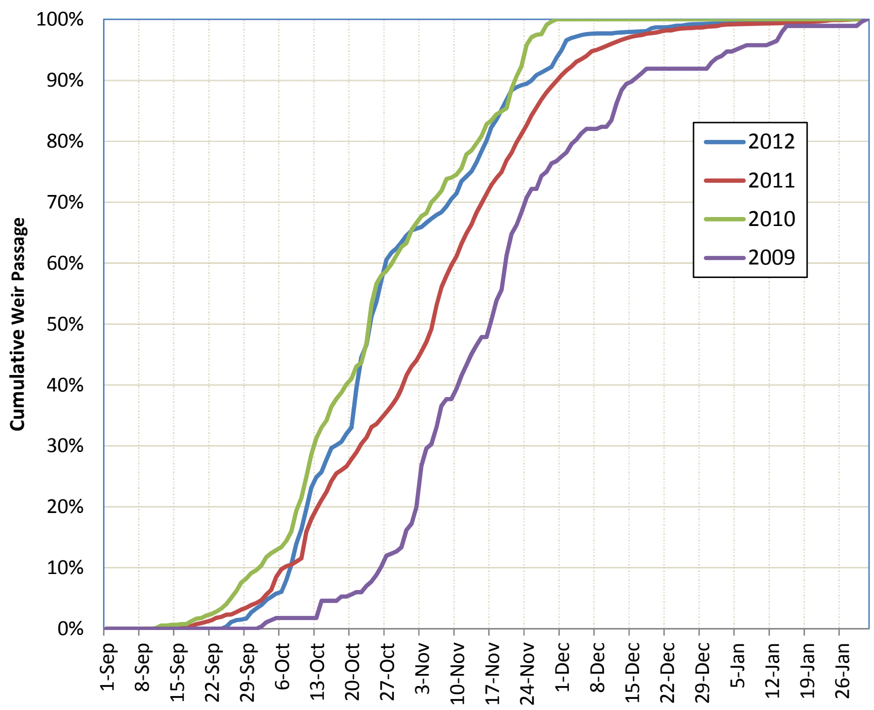
- Subdivision of river into smaller sub-reaches
  - longitudinal variation in habitat composition and availability
- Sub-reach resolution may be altered by sub-model
  - (e.g., spawning vs. rearing, temperature variations, etc.)

W&AR-6 Model Reaches

La Grange dam to OLGB	52.0-50.7
OLGB to TLSRA	50.7-42.0
TLSRA to Hickman Bridge	42.0-31.6
Hickman Bridge to Charles Road	31.6-24.8
Charles Road to Legion Park	24.8-17.6
Legion Park to Riverdale Park	17.6-12.4
Riverdale Park to Shiloh Bridge	12.4-3.5
Shiloh Bridge to mouth	3.5-0.0

Key Sub Model Relationships by Life-Stage

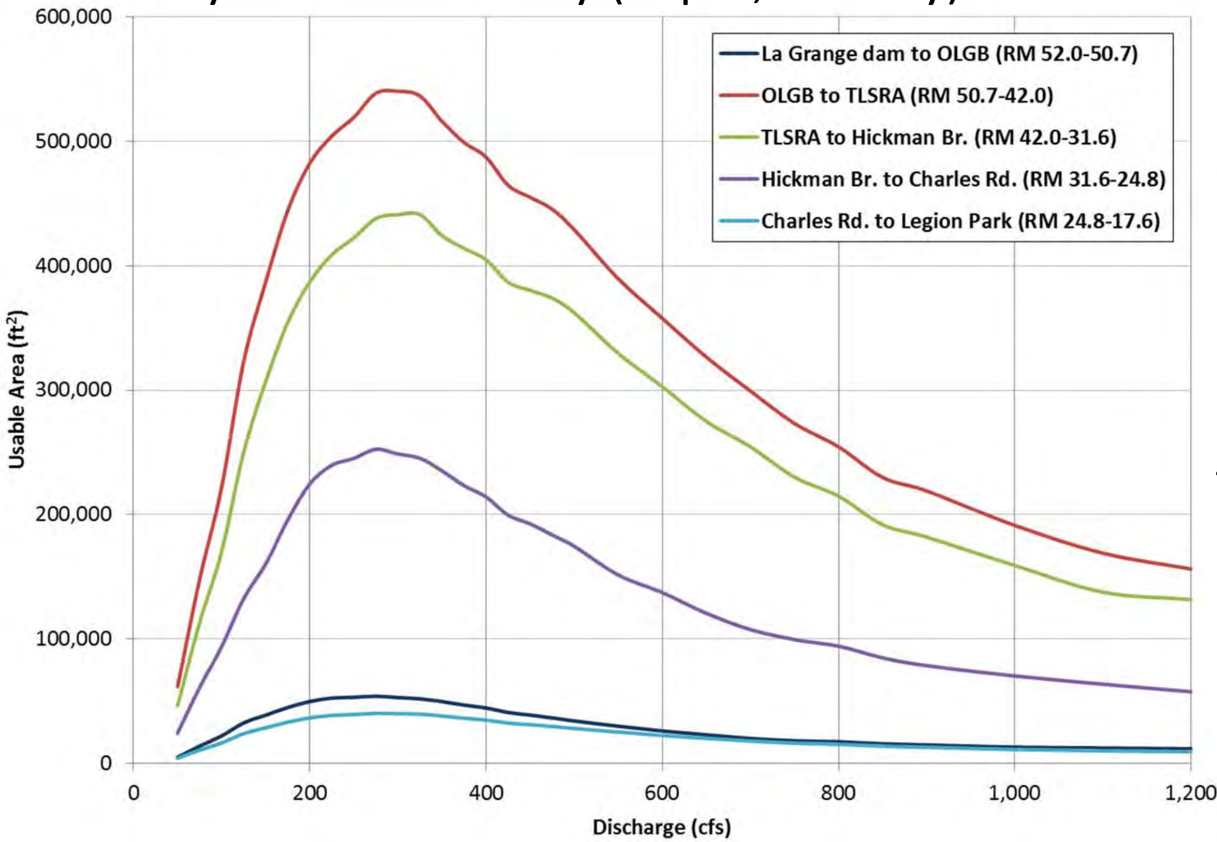
- Upmigration and Spawning (Timing)
  - Migration timing and spawner movement from weir counts
  - Historical spawner survey statistics (e.g., run size, age composition, sex ratio by age, arrival times mean and standard deviation)



Tuolumne River weir passage
2009–2012

Key Sub Model Relationships by Life-Stage

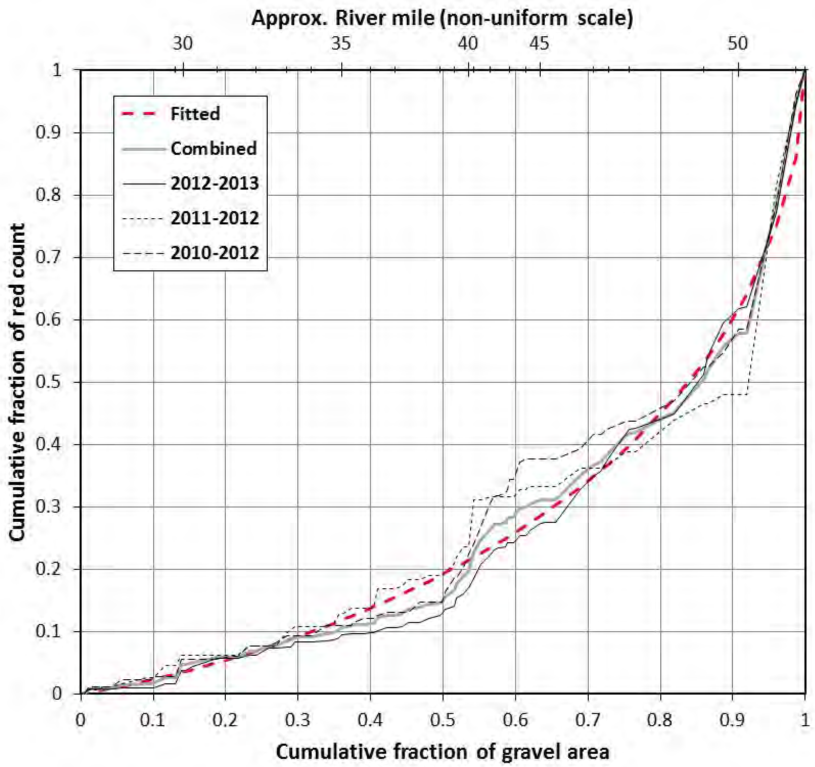
- Upmigration and Spawning (Habitat Suitability)
  - Spawning habitat suitability combines gravel suitability (W&AR-4) with hydraulic suitability (depth, velocity) from IFIM Study.



Weighted usable area estimates for Chinook salmon spawning in sub-reaches of the lower Tuolumne River

Key Sub Model Relationships by Life-Stage

- Spawning (Habitat Suitability)
  - Habitat use of suitable spawning areas as a “preference” function of RM based upon recent redd mapping (W&AR-8)
  - Superimposition onto undefended redds allowed



$$\Phi^{-1}(G(i)) = b_0 + b_1\Phi^{-1}(F(i)),$$

$$\Phi(z) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{z} e^{-t^2/2}\,dt$$

$\Phi(z)$ = probit transform

Φ^{-1} = inverse of the probit transform

$F(i)$ = cumulative fraction of gravel area within and downstream of a mapped riffle number (i)

$G(i)$ = cumulative fraction of the female spawners expected to spawn within and downstream of riffle number (i)

Key Sub Model Relationships by Life-Stage

- Upmigration and Spawning (Fecundity)
  - Egg deposition based upon historical fecundity relationships

$$Eggs = 158.45 \times L - 6138.91$$ *L* = fork length

- Upmigration and Spawning (Mortality)
  - No pre-spawn mortality applied due to high water temperature (W&AR-5).

Key Sub Model Relationships by Life-Stage

- Egg Incubation
  - Embryo development based upon temperature and incubation time (Rombough 1985)
  - Mortality due to superimposition, excess fines, and water temperature

$$\sum_{i=1}^{D} \mathrm{WTU}_i \geq 1, \text{ with}$$

$$WTU_i = \exp(-5.88 - 0.000513W + 0.152T_i)$$

WTU_i = weighted thermal units on day (i)

D = days after fertilization that fry hatching occurs

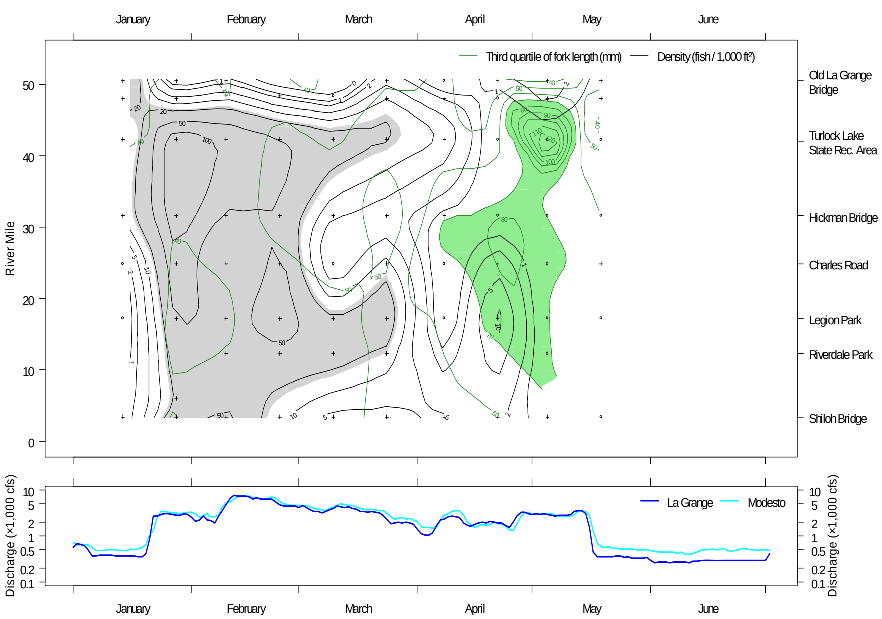
W = estimate of initial egg weight

T = temperature on day (i)

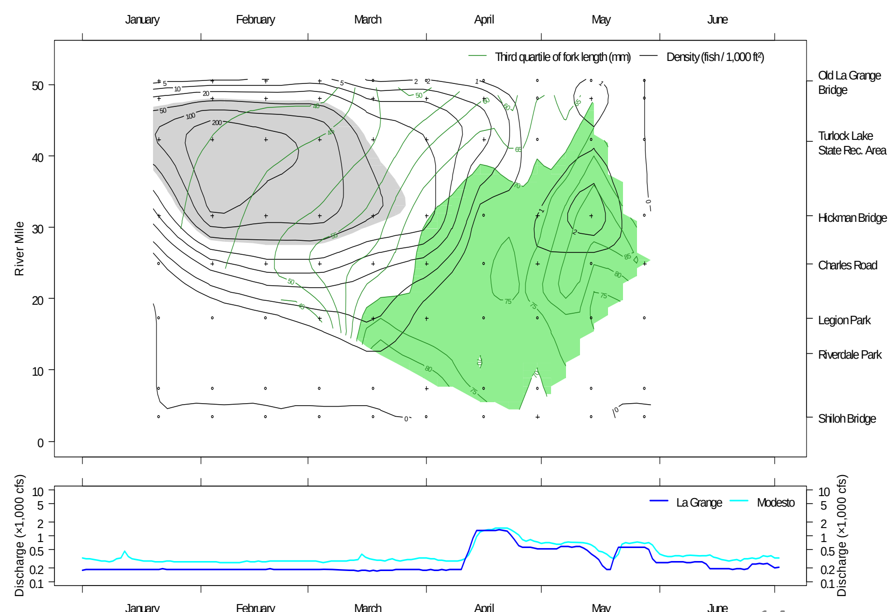
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Movement)
  - Downstream (volitional) movement of fry shortly after emergence (RST data)
  - Riverwide distribution at high/low flows (seine data)

1999 Seine Density



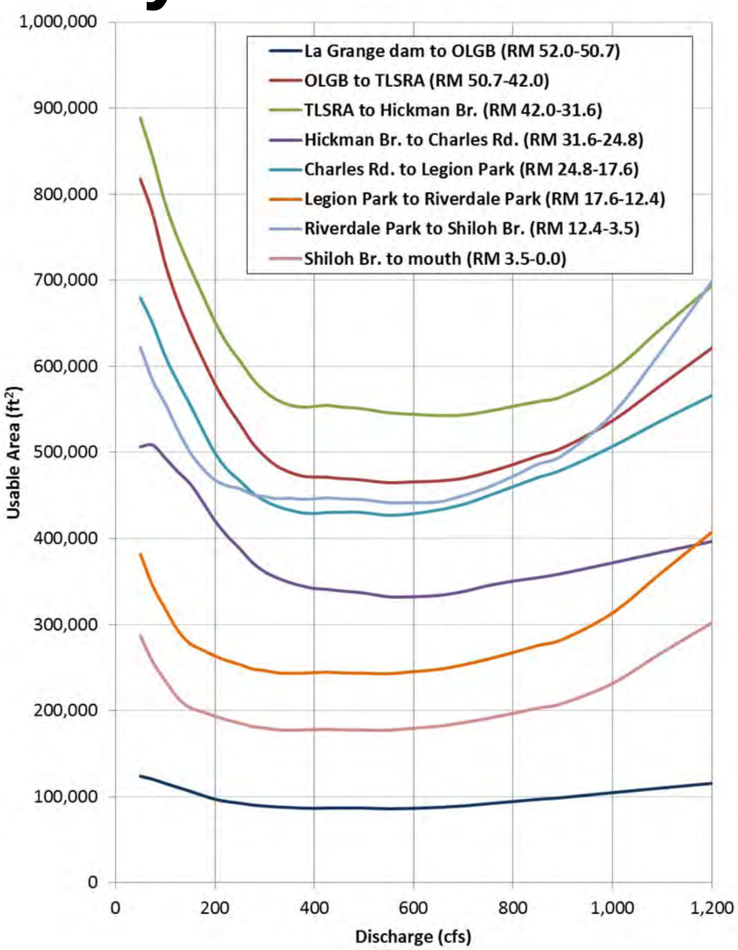
2003 Seine Density



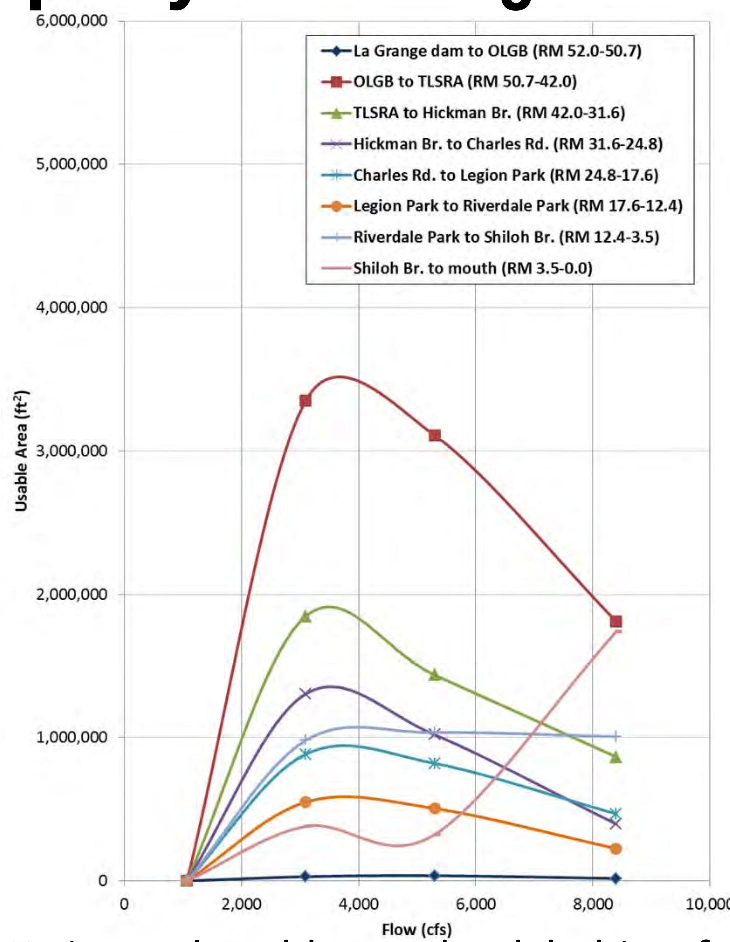
Key Sub Model Relationships by Life-Stage

- Fry Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping (TID/MID 1997) scaled by WUA vs flow relationships from 2D Pulse Flow study .
  - Overbank rearing density in proportion to in-channel and overbank usable area estimates by sub-reach
  - Displacement of resident fry when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon fry rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon fry

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Growth)
  - Growth based upon fish size, ration, and water temperature by Stauffer (1973)

$$W^{+} = W e^{g\Delta t}, \text{ where} \qquad g = \text{GMAX} \sin\left(\frac{\pi}{2} \frac{R - \text{RMAINT}}{\text{RMAX} - \text{RMAINT}}\right)$$

$$\text{GMAX} = (a_1 + a_2 T + a_3 T^2 + a_4 T^3 + a_5 T^4)(a_6 W^{-a_7})$$
$$\text{RMAINT} = (l_1 10^{l_2 T})(l_3 W^{-l_4})$$
$$\text{RMAX} = (-l_5 + l_6 \ln T)(l_7 W^{-l_8})$$

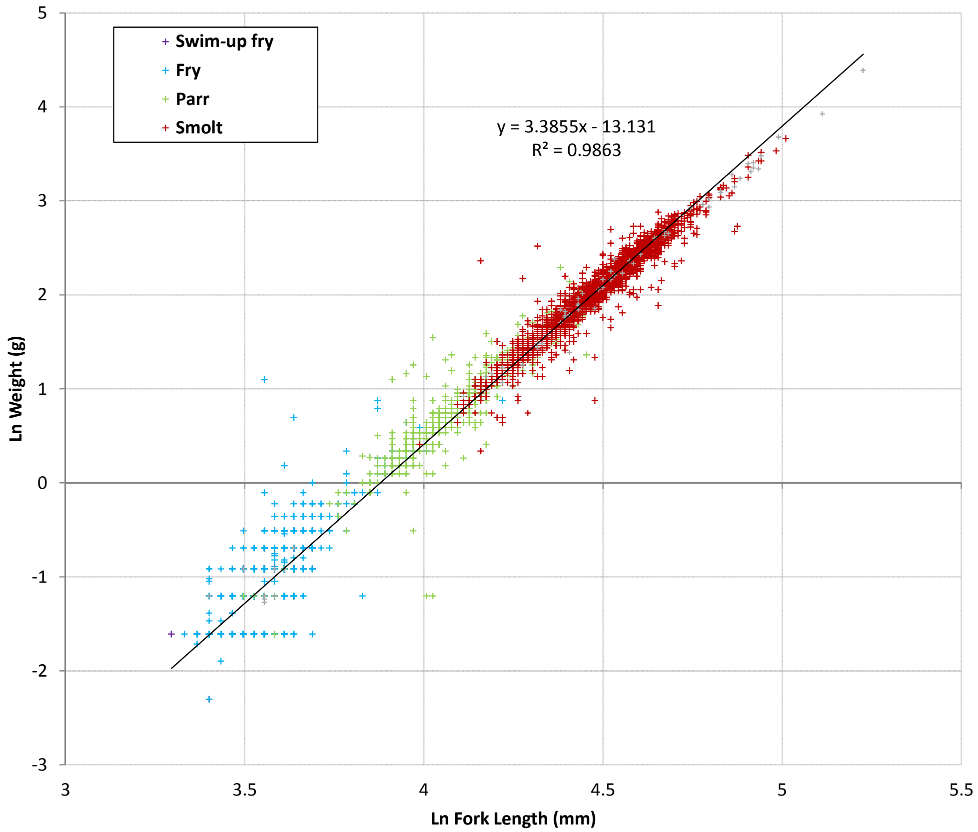
W = starting weight

T = water temperature

R = ration level

weight-length conversions obtained by linear regression of log-weight and log-length of fish from RST sampling

Key Sub Model Relationships by Life-Stage



Length vs. Weight relationship for juvenile Chinook salmon in the Tuolumne River (2004–2010)

Key Sub Model Relationships by Life-Stage

- Fry Rearing (Mortality) sources
  - Background (fixed) daily mortality
  - Movement mortality (e.g., predation, other factors) represented as exposure time (distance)

$$Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt}$$

Survival = the probability of fry survival for any incremental exposure time from t_1 to t_2

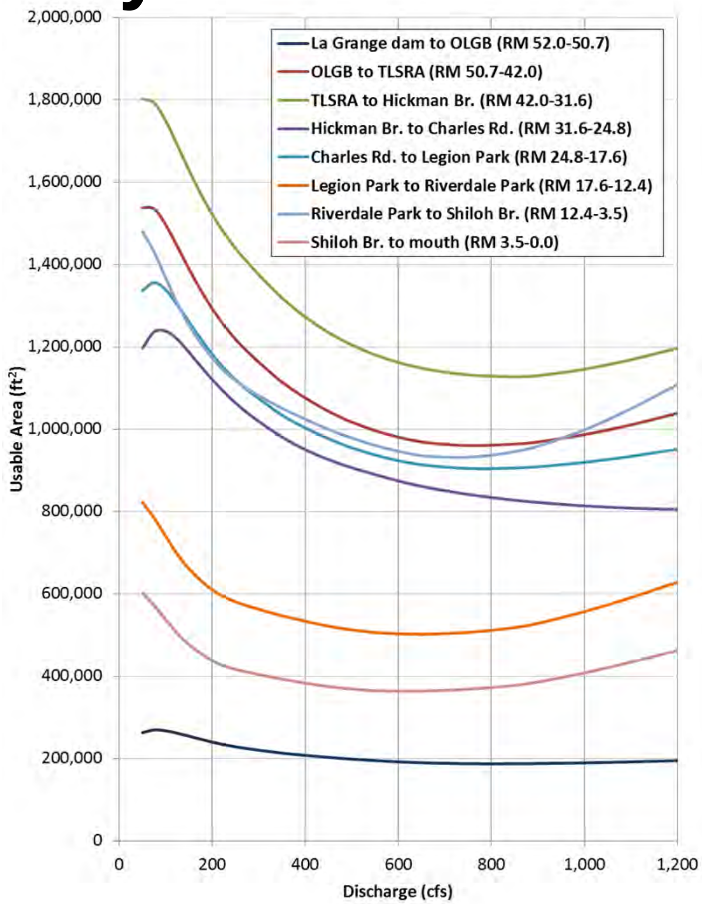
m(t)dt = instantaneous mortality in the main channel

  - Acute mortality due to daily average water temperature exceedance UUILT (T >25°C)

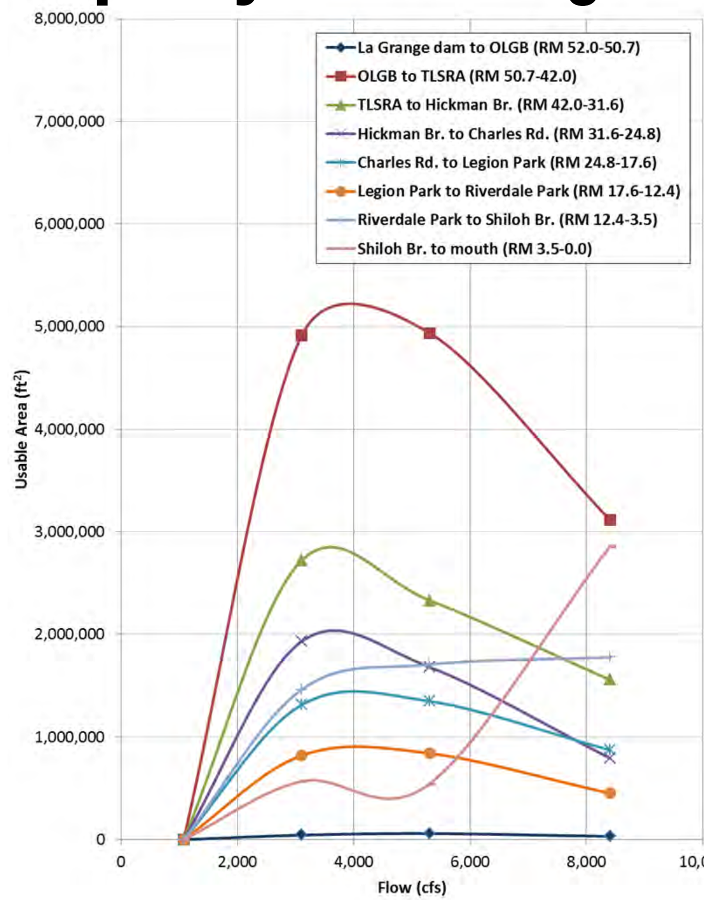
Key Sub Model Relationships by Life-Stage

- Juvenile Rearing (Habitat Use)
  - In-channel habitat availability across all habitat types scaled by WUA vs flow relationships from IFIM Study.
  - Overbank habitat availability from historical inundation mapping scaled by WUA vs flow relationships from 2D Pulse Flow study.
  - In-channel and Overbank rearing density in proportion to usable area estimates by sub-reach
  - Displacement of juveniles when habitat carrying capacity exceeded

Key Sub Model Relationships by Life-Stage



Usable area estimates for Chinook salmon juvenile rearing in sub-reaches of the lower Tuolumne River



Estimated usable overbank habitat for Tuolumne River Chinook salmon juveniles

Key Sub Model Relationships by Life-Stage

- Juvenile growth (same as for Fry)
- Juvenile mortality (same as for Fry):
  - Background mortality
  - Exposure Time $Survival = \mathrm{e}^{-\int_{t_1}^{t_2} m(t)dt}$
  - UUILT Exceedance (T > 25^{o}C)

Key Sub Model Relationships by Life-Stage

- Smolt Emigration (Size)
  - Emigration of smolt-ready juveniles based upon suitable water temperatures, exceedance of minimum size threshold and probability around historical median size at emigration

$$P = \frac{\frac{1}{\sqrt{2\pi\sigma^2}} e^{-(L-\mu)^2/2\sigma^2}}{\int_L^{\infty} \frac{1}{\sqrt{2\pi\sigma^2}} e^{-(\lambda-\mu)^2/2\sigma^2} d\lambda} \frac{\Delta L}{\sigma}.$$

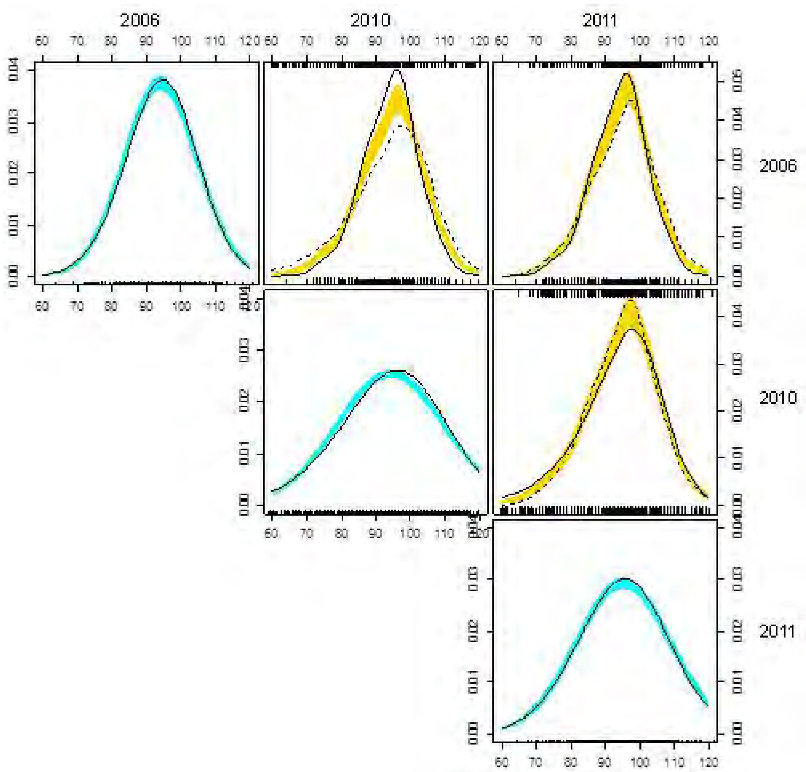
ΔL = the daily growth increment

P = the probability that an individual will smolt at a length between L and $L+\Delta L$

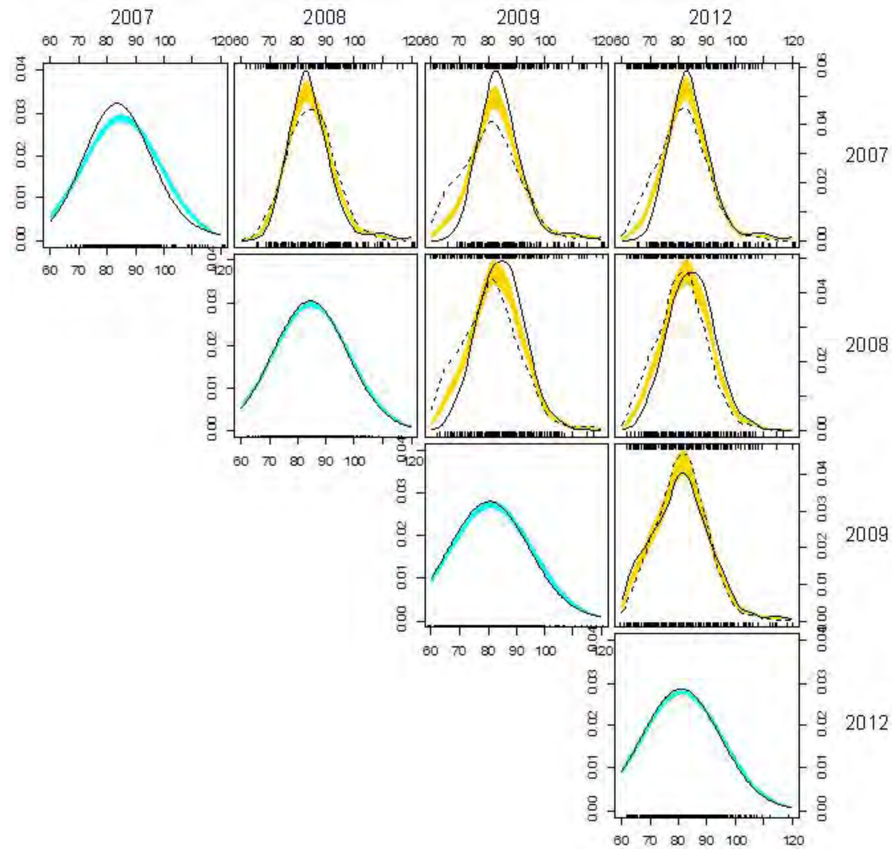
(μ) = mean length

  - Smolt emigration event cues (i.e., pulse flow effects on day-to-day variations in smolt passage) not presently modeled.

Key Sub Model Relationships by Life-Stage



Comparisons of smolt size at emigration in **above average** water year types (2006, 2010, and 2011) in the Tuolumne River



Comparisons of smolt size at emigration in **below average** water year types (2007–2009, and 2012) in the Tuolumne River

Key Sub Model Relationships by Life-Stage

- Smolt Mortality
  - Mortality due to predation and other factors represented as distance travelled (Equation), as well as temperature (T > 25C).
  - Smolt Survival Relationship based upon RST passage data

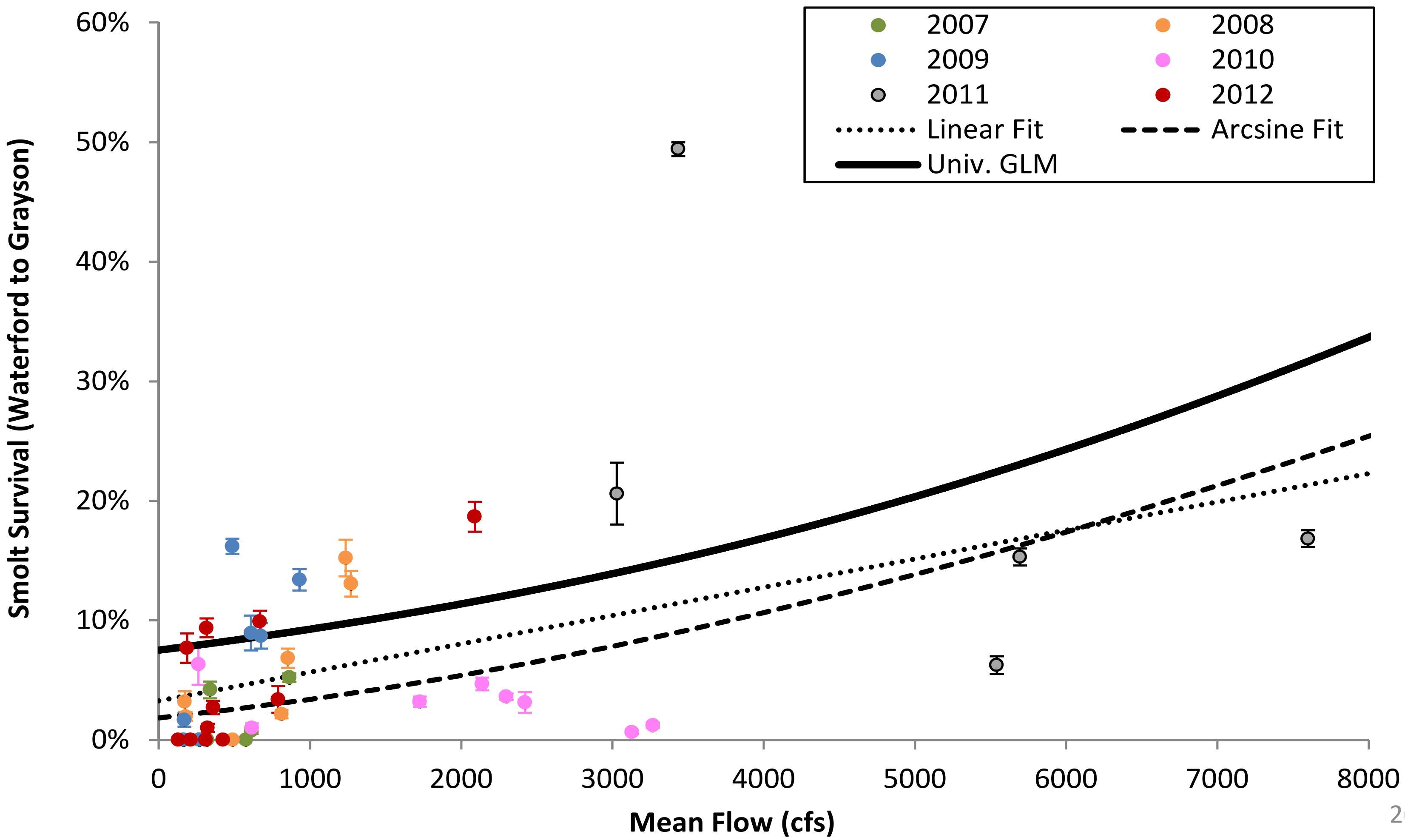
$$S_{RST} = \min(0.03287 + 2.347 \times 10^{-5} \times Q_{LaGrange}\ , 1)$$

$$S_D = e^{-mD}, \text{ where } m = -\frac{\log S_{\mathrm{RST}}}{29.8-5.2}$$

Survival = the probability of smolt survival at flow rate, *Q*

D = Distance (RM)

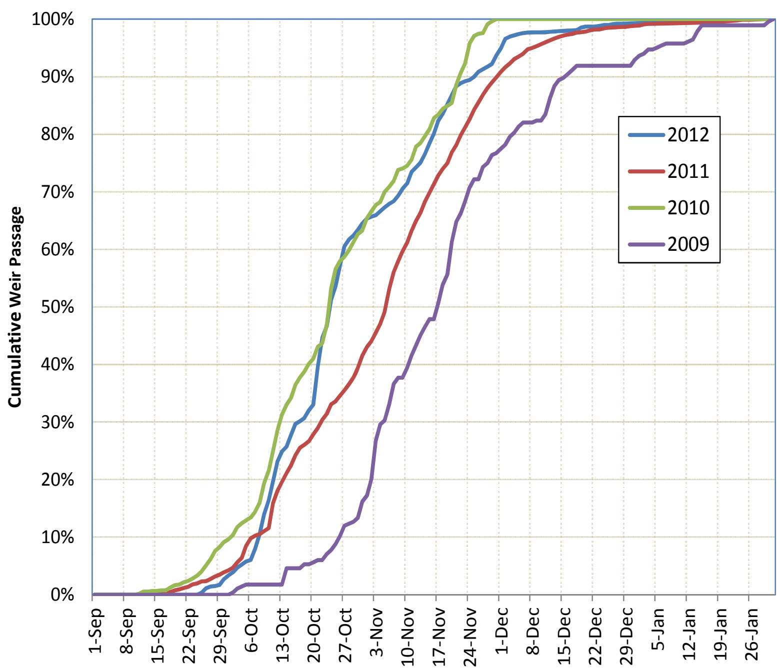
Smolt survival measured by RST passage



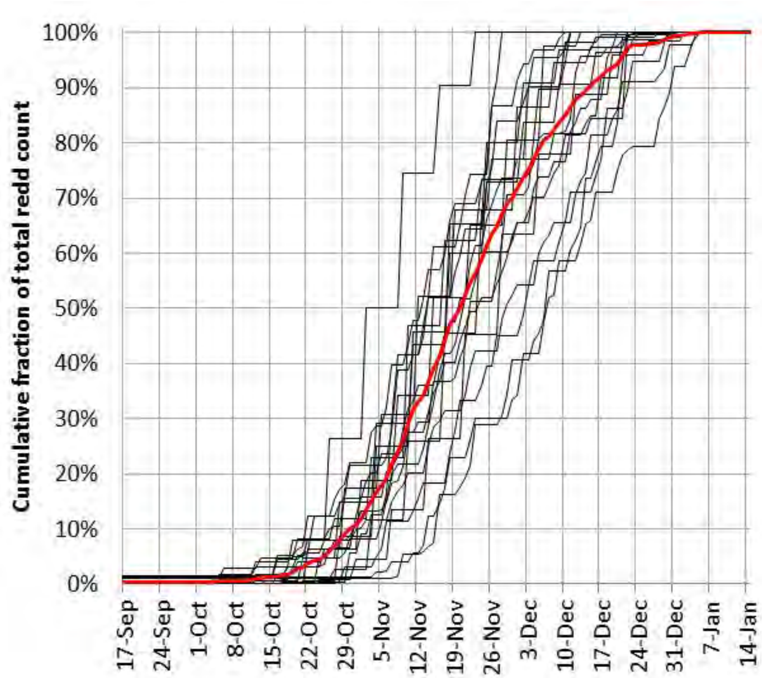
Upmigration and Spawning Timing

- Time lag between weir passage (2009-2012) and spawning activity represented as upmigration speed and not holding

50% weir passage (2009-2012)
Approx. November 5th

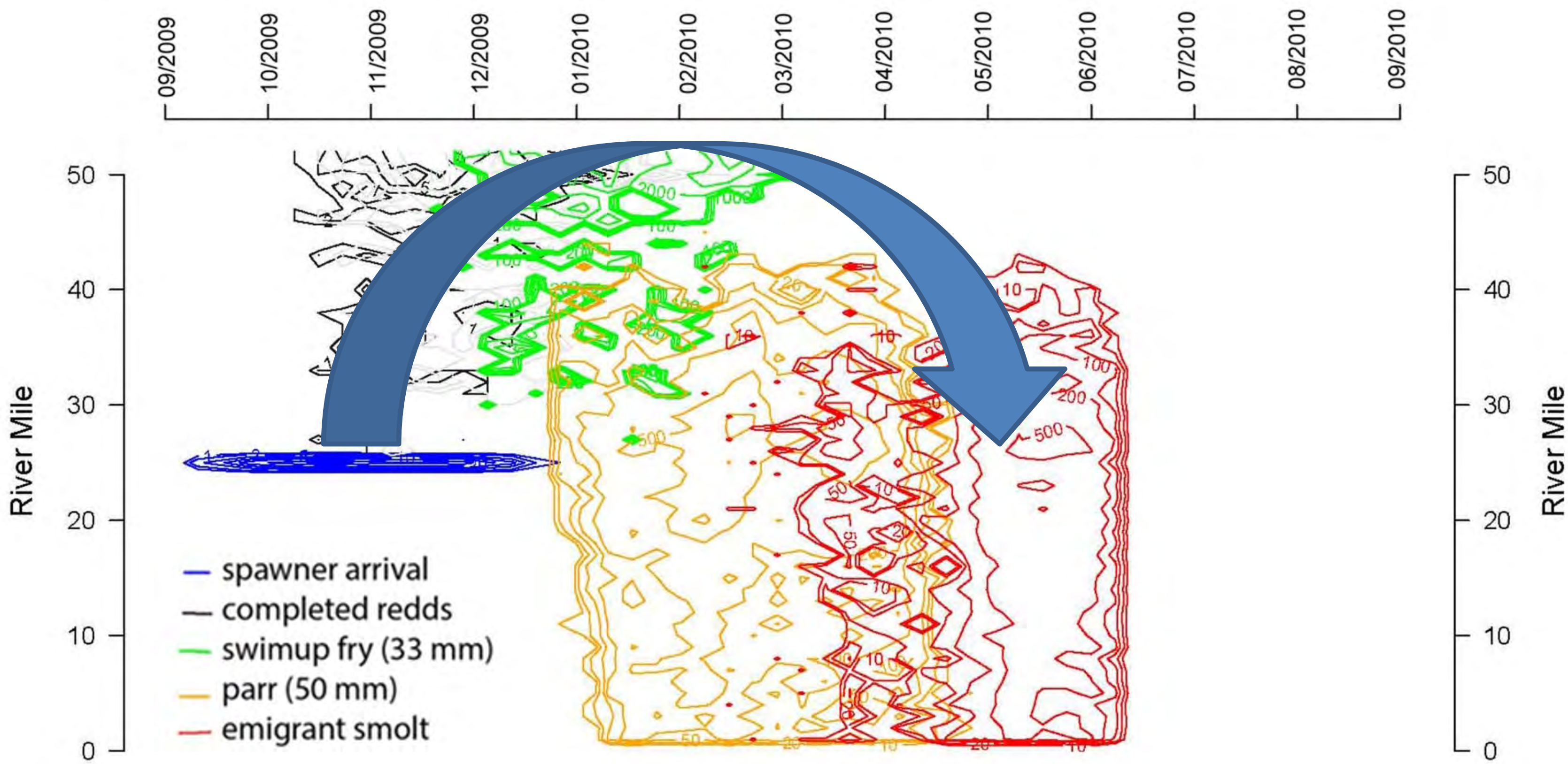


50% redd counts (1992-2010)
Approx. November 20th



Fry and Juvenile Rearing Patterns

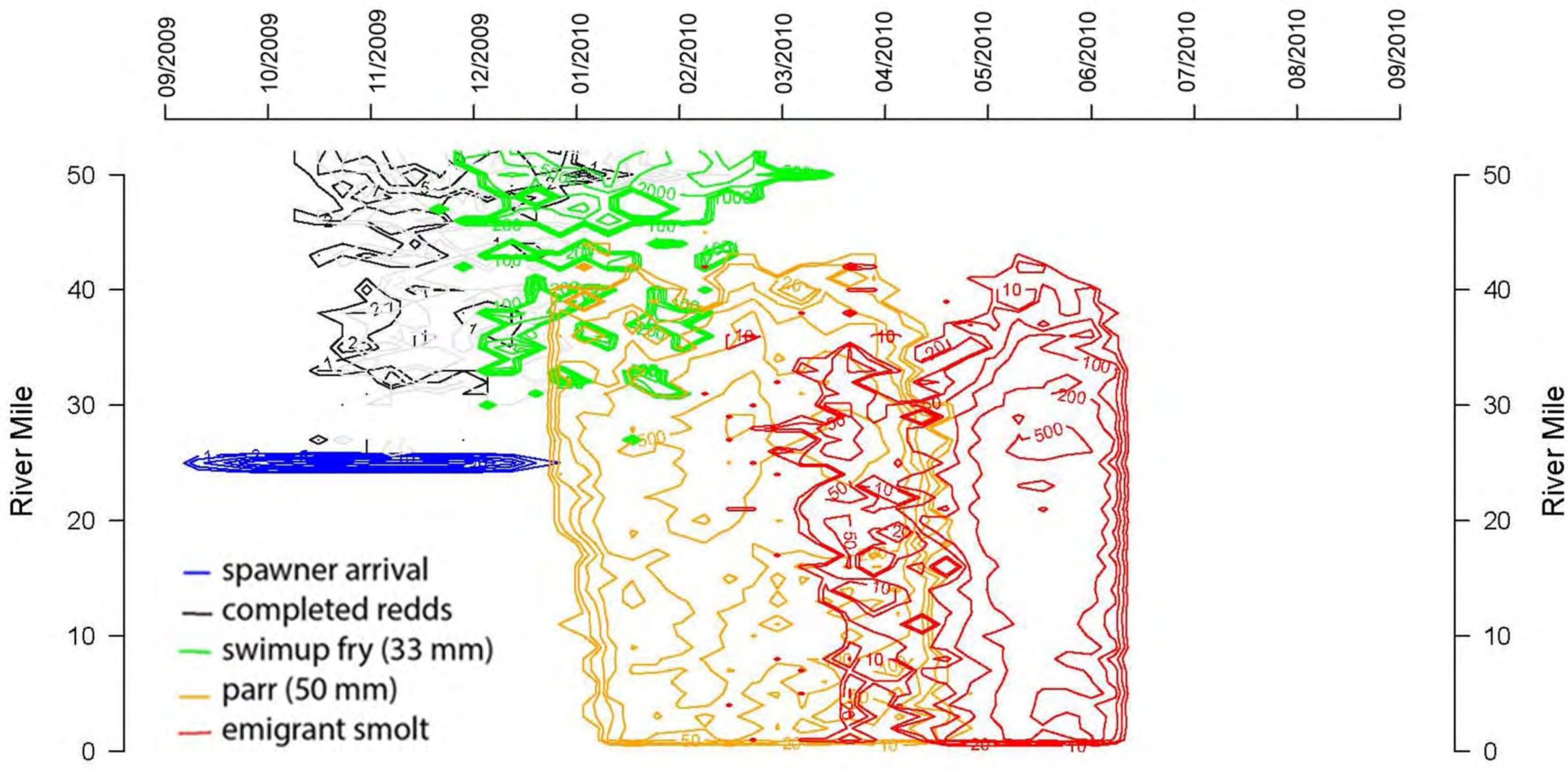
- Matching of life history transition locations and timing



Water Year 2011 (Wet)

Fry and Juvenile Rearing Patterns

- Matching of life history transition locations and timing

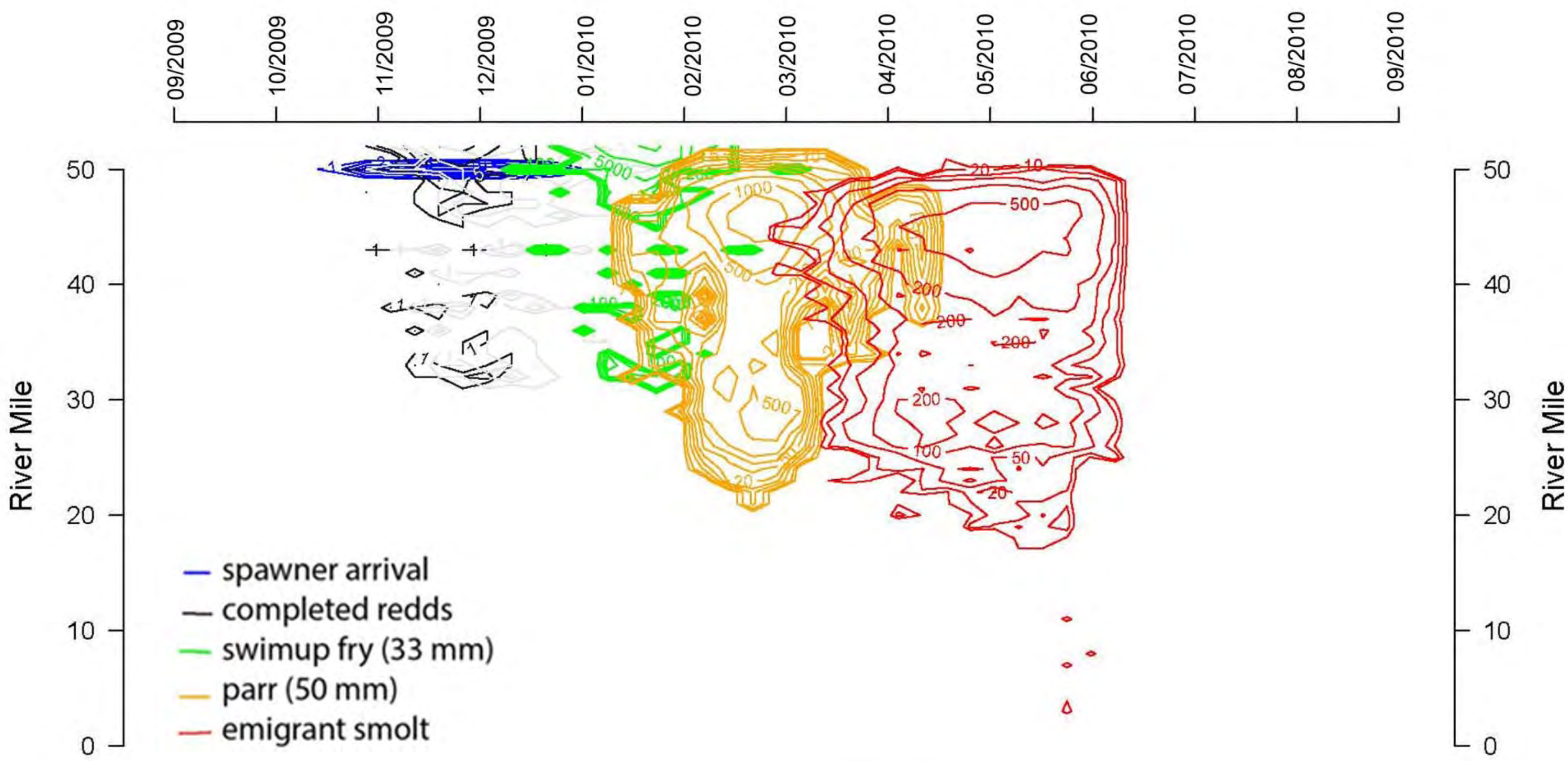


Water Year 2011 (Wet)

Modeling Calibration and Validation

Fry and Juvenile Rearing Patterns

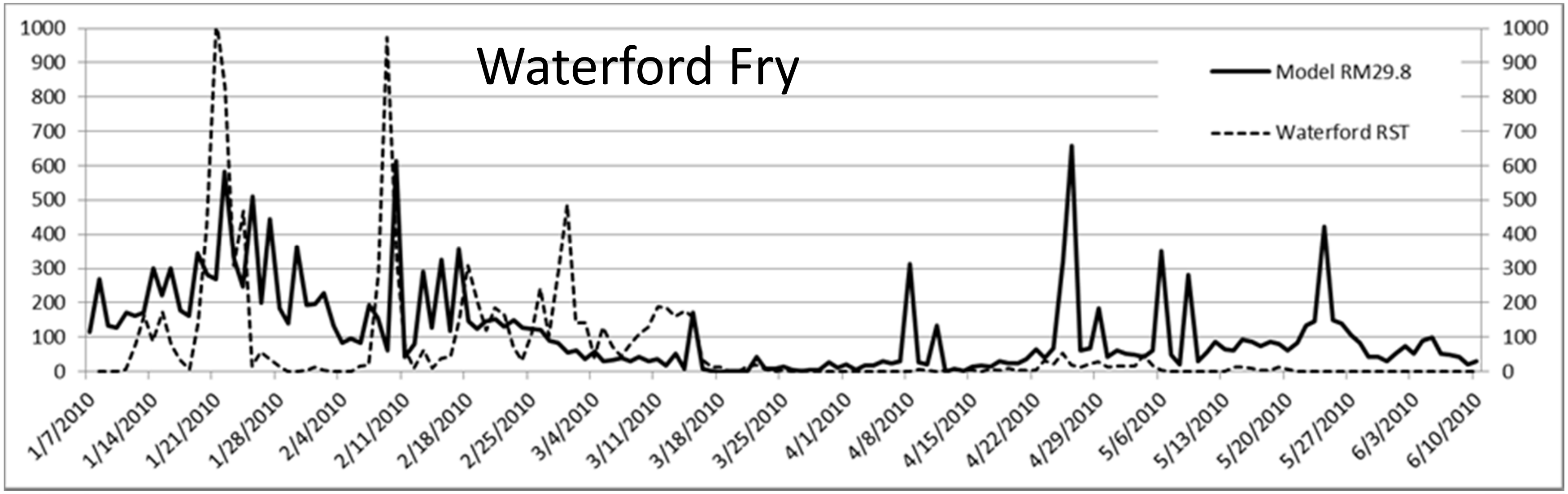
- Matching of life history transition locations and timing

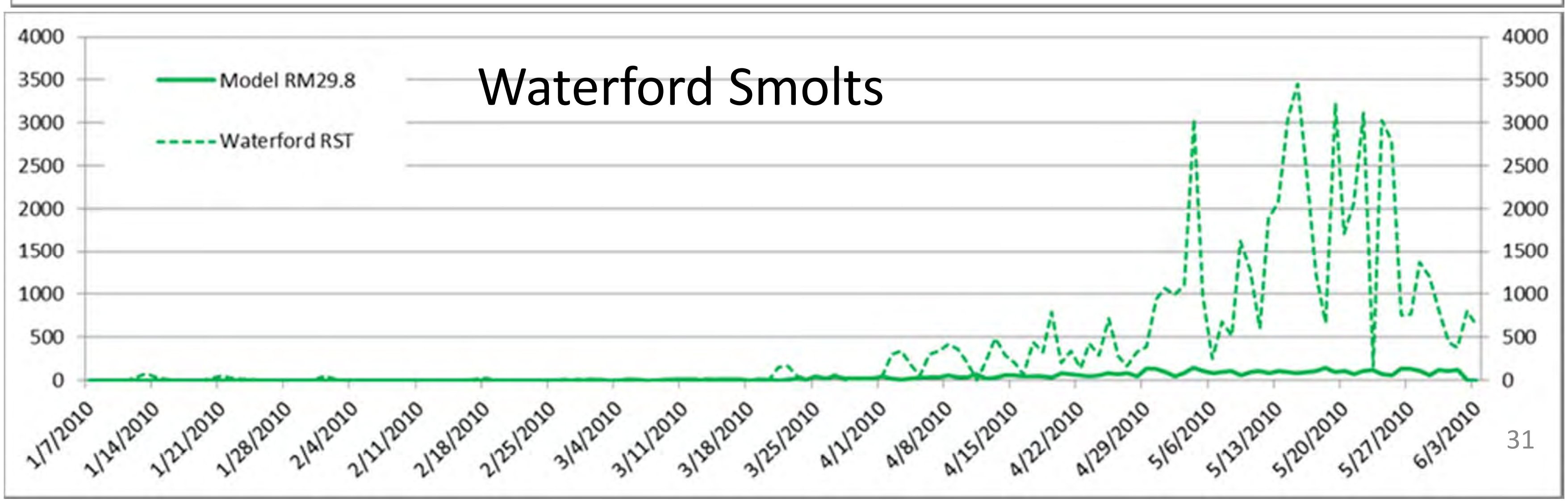


Water Year 2009 (Dry)

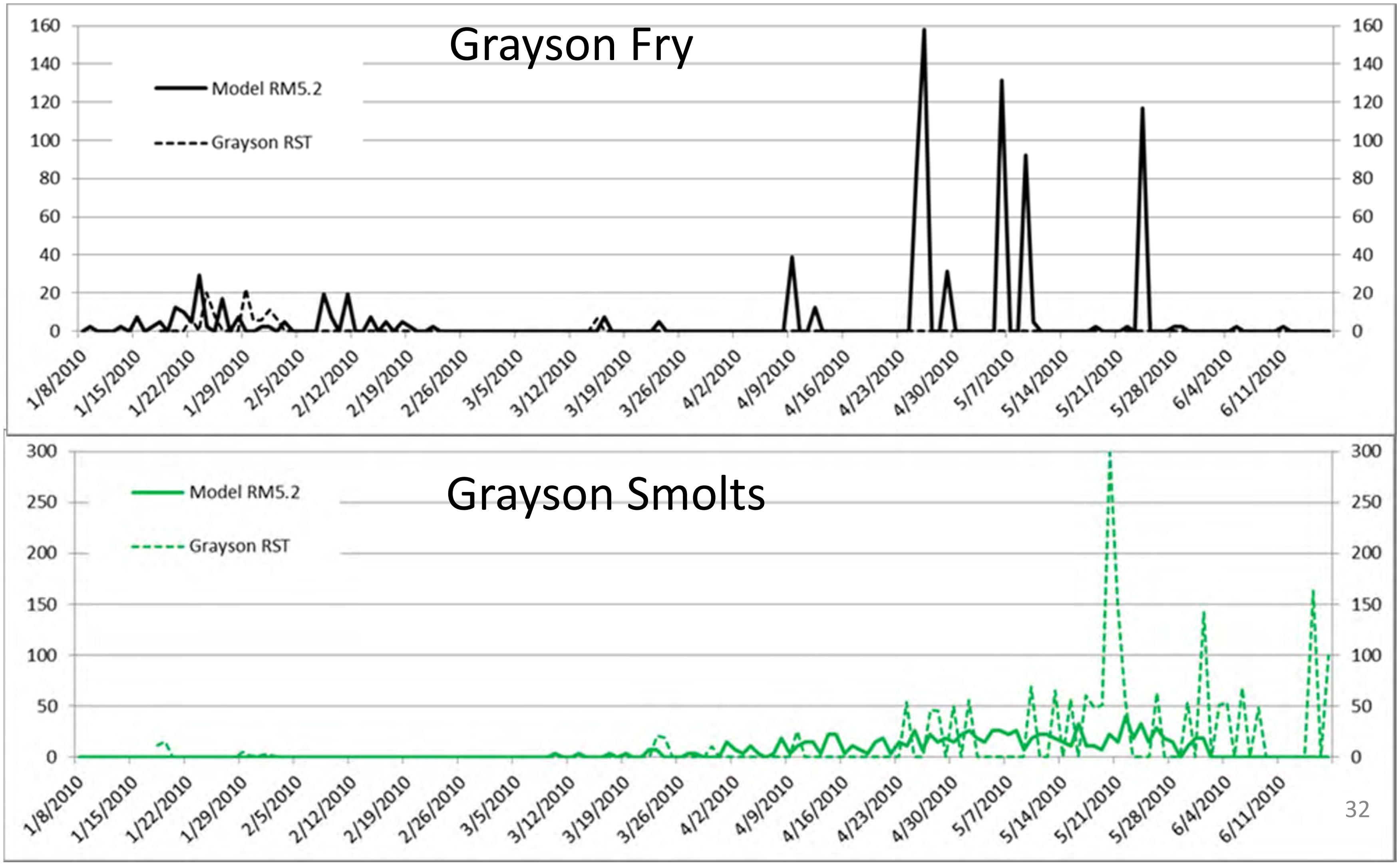
Modeling Calibration and Validation

RST passage of Chinook salmon (Fry, Smolt) in 2010

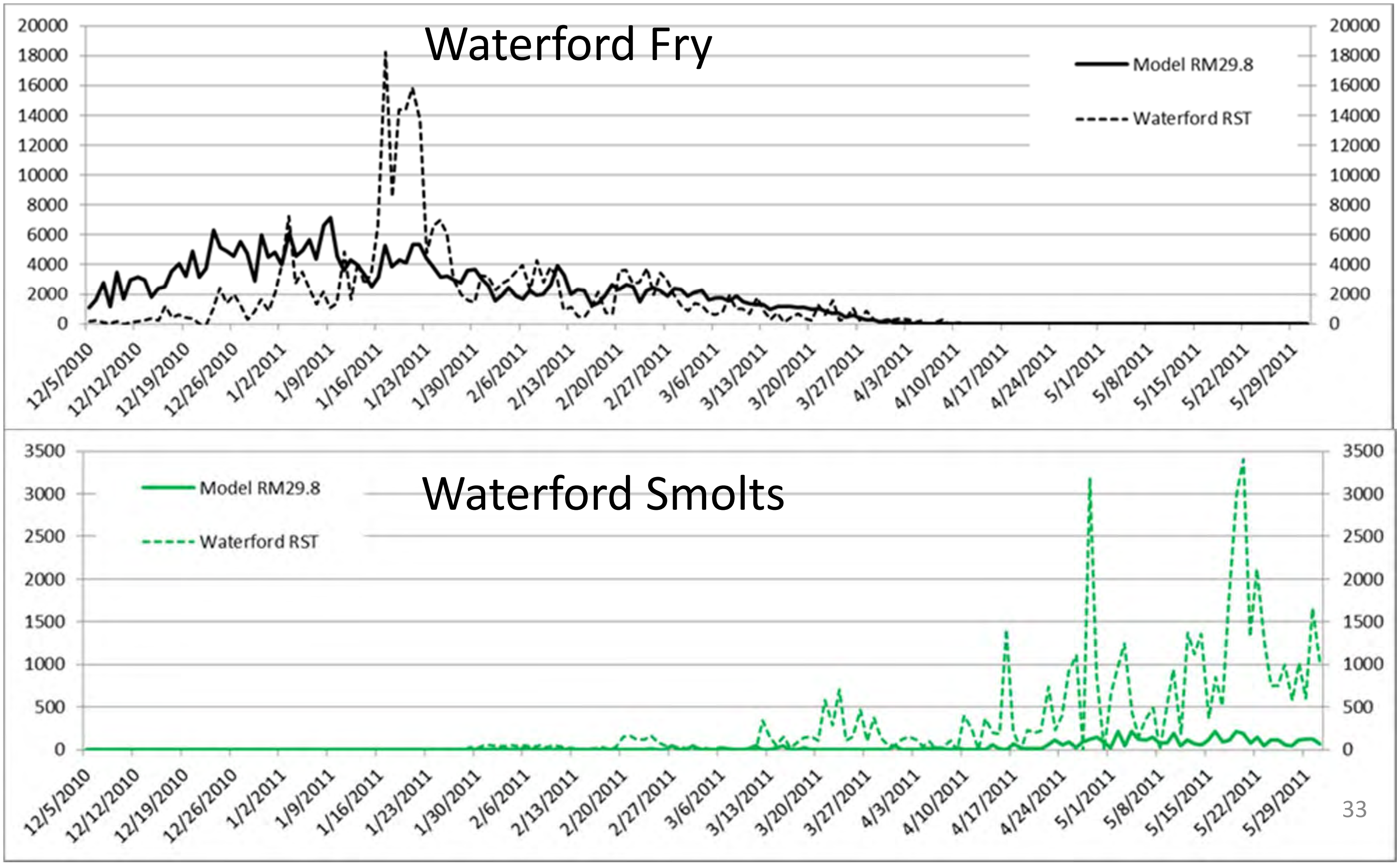




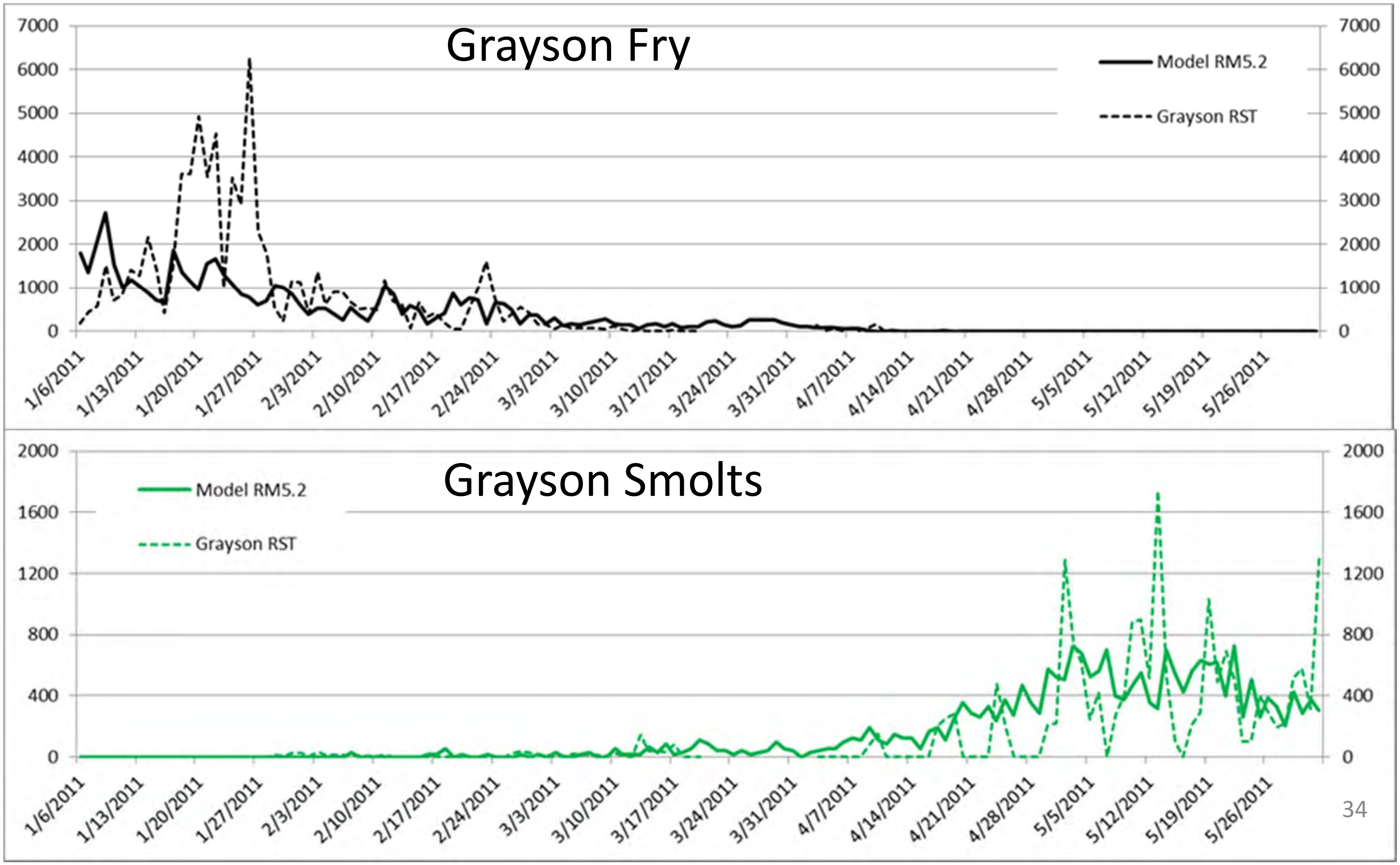
RST passage of Chinook salmon (Fry, Smolt) in 2010



RST passage of Chinook salmon (Fry, Smolt) in 2011



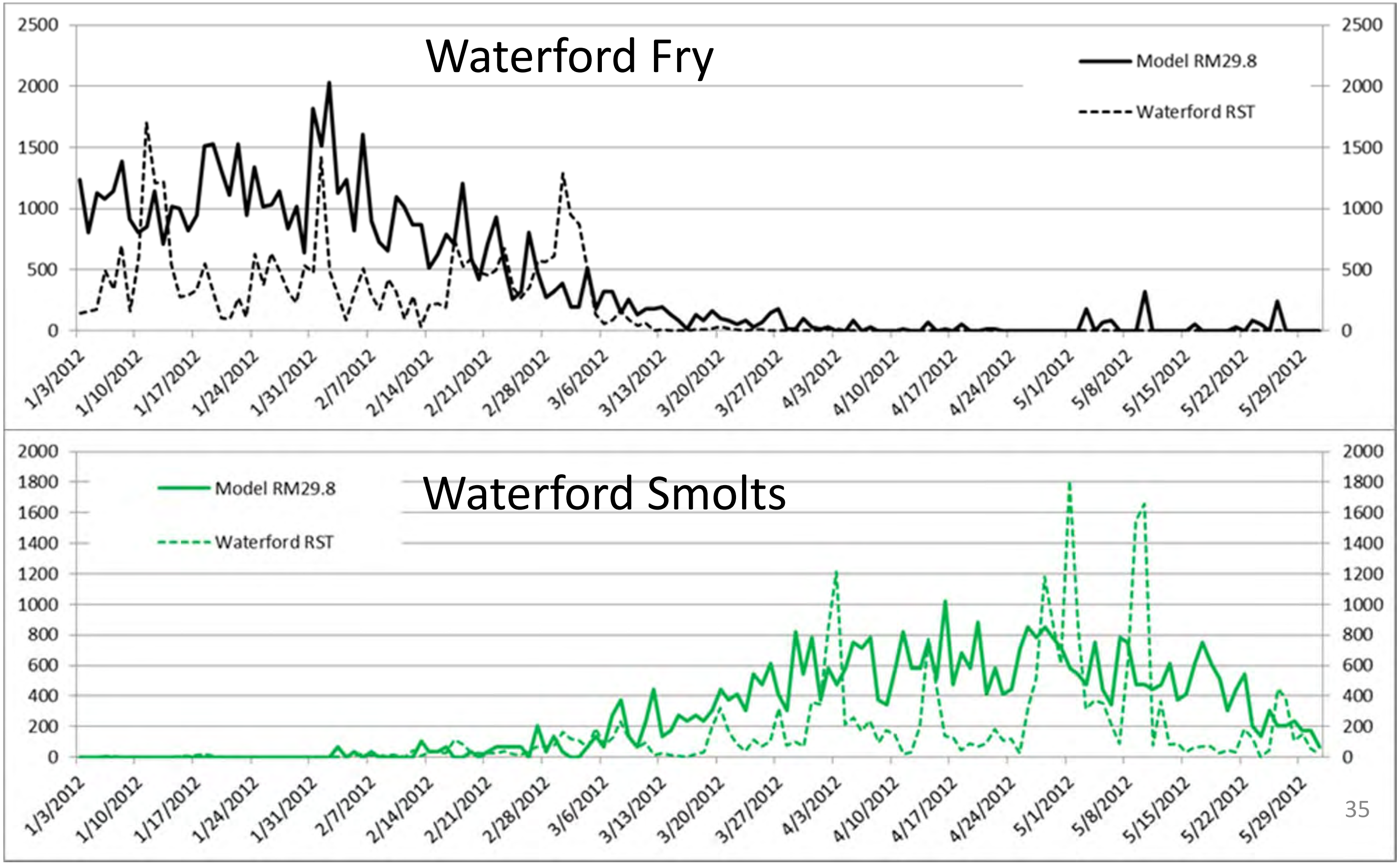
RST passage of Chinook salmon (Fry, Smolt) in 2011



Modeling Calibration and Validation

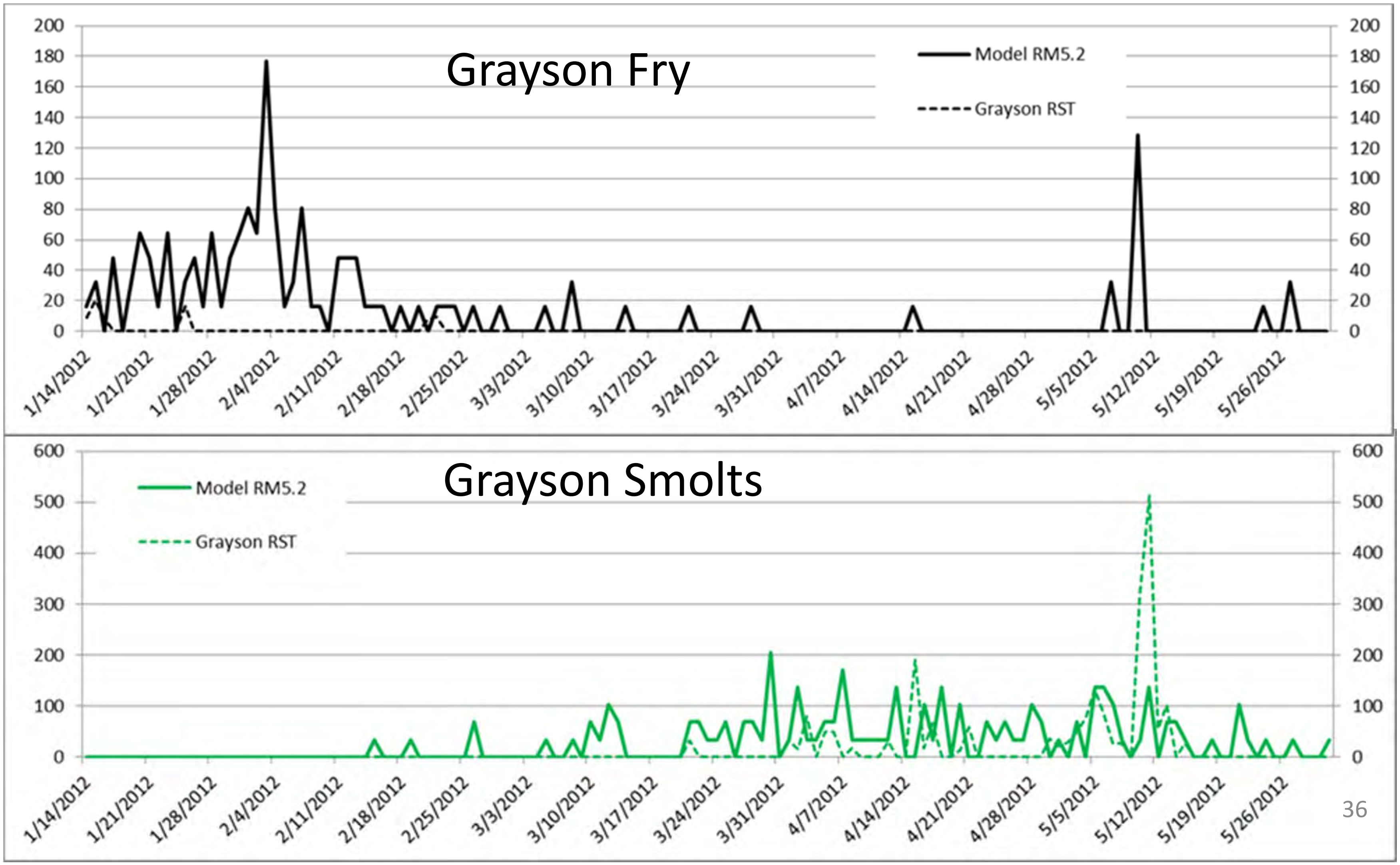
Don Pedro Project
FERC No. 2299

RST passage of Chinook salmon (Fry, Smolt) in 2012



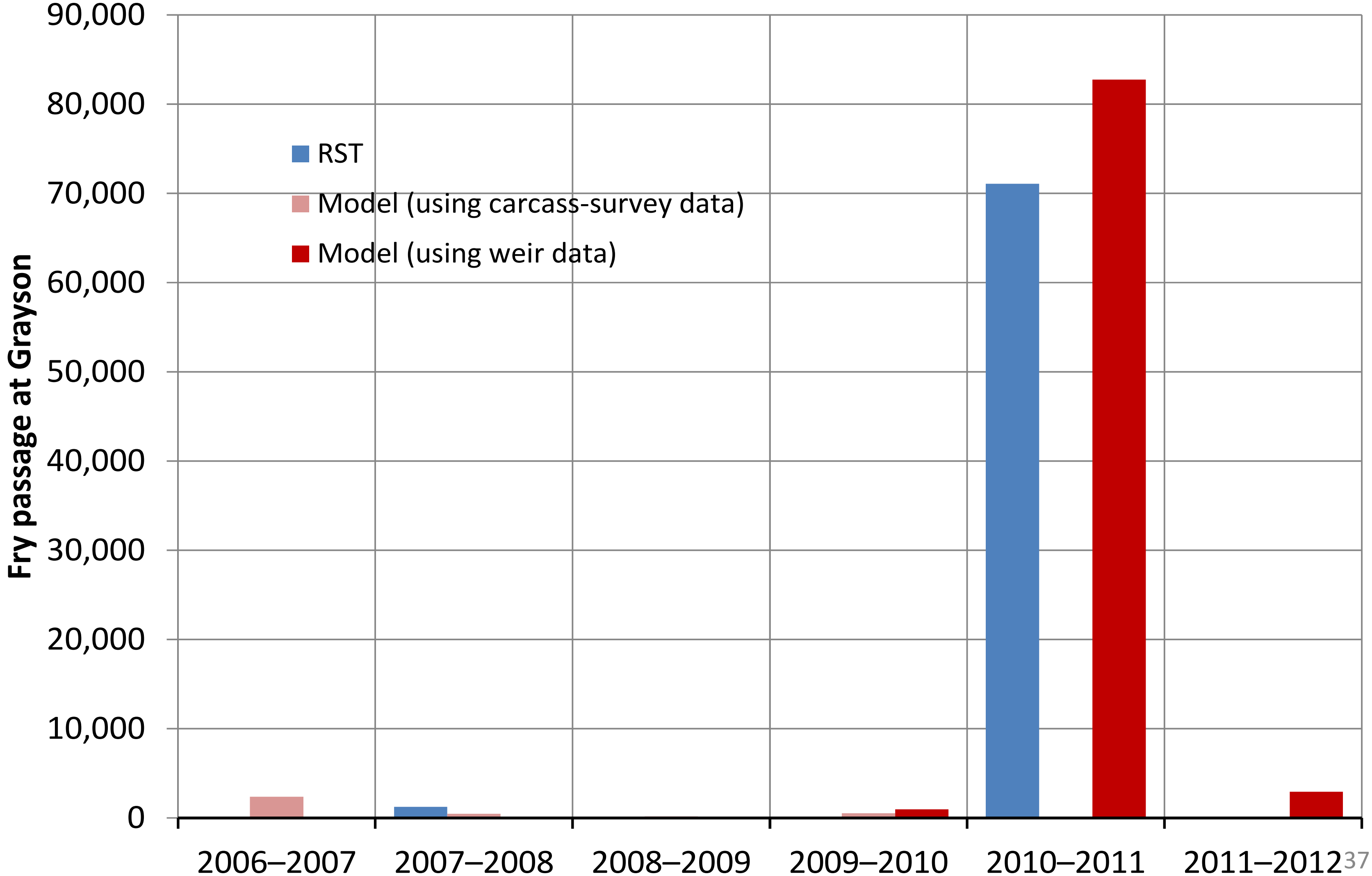
Modeling Calibration and Validation

RST passage of Chinook salmon (Fry, Smolt) in 2012



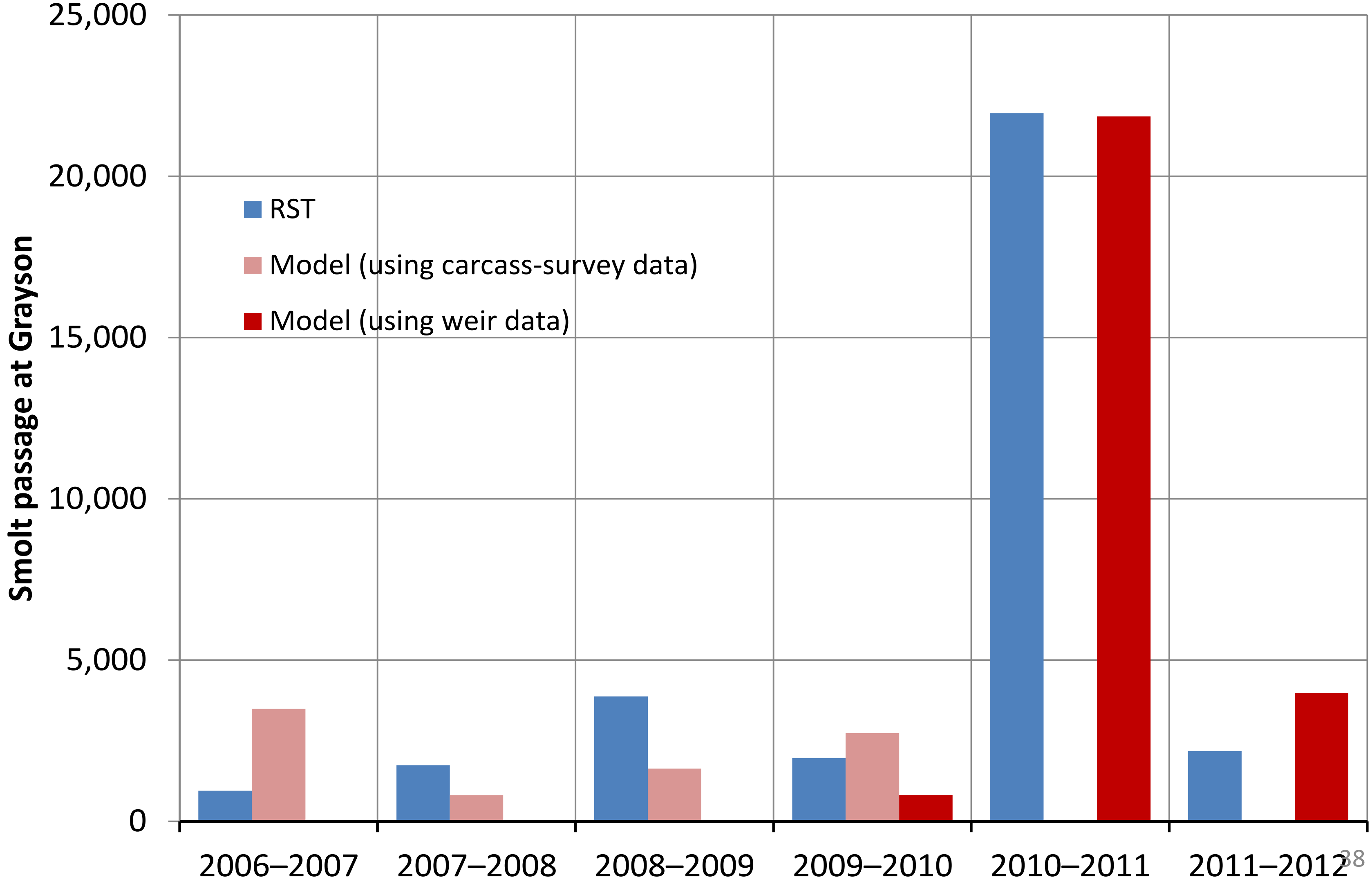
Modeling Calibration and Validation

Annual Fry Passage at Grayson (2007-2012)



Modeling Calibration and Validation

Annual Smolt Passage at Grayson (2007-2012)

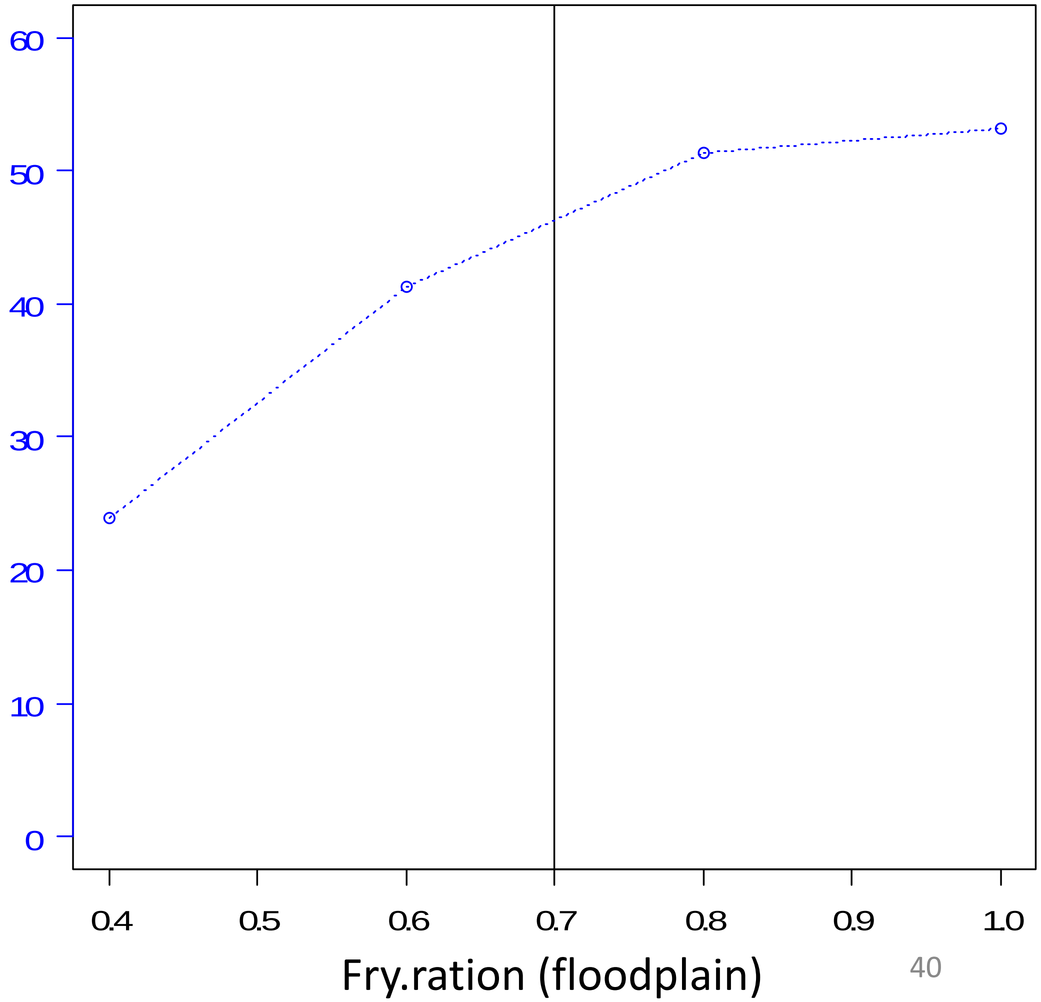


Parameters Affecting Juvenile Productivity

- Vary each parameters around calibrated value
  - Reasonable Range vs. +/- 25% or more around calibrated value
  - All other parameters held constant
- Examine smolt productivity change
  - Evaluation Metric = smolts/female spawner
- Test under broad range in hydrology
  - WY 2009 (Drier WY Type) = Low Discharge
  - WY 2011 (Wetter WY Type) = High Discharge
- Test under broad range in spawning escapement
  - Reference runs of 200 and 10,000 female spawners
- 1,920 model simulations performed

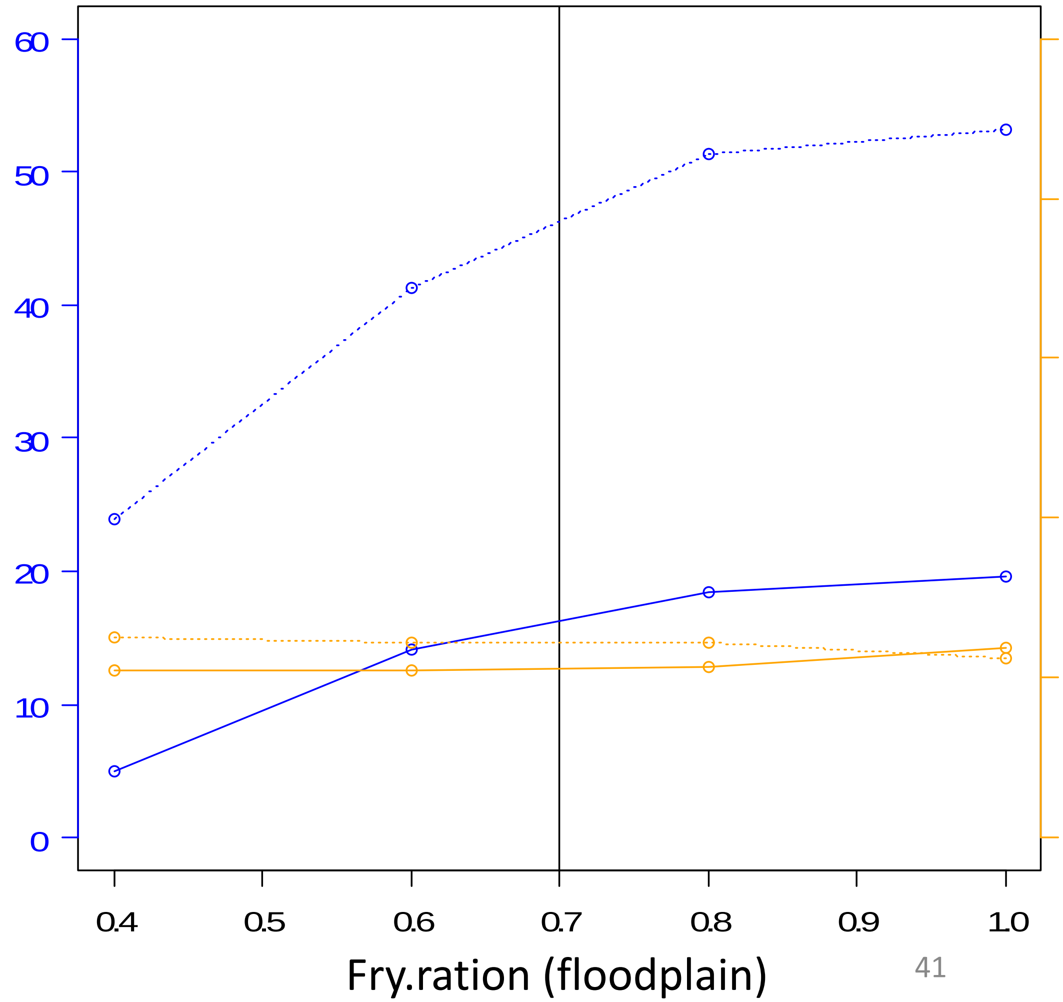
Fry feeding ration on floodplain (Example)

- Smolt productivity vs fry feeding ration on the floodplain.
  - Results for WY 2011 (Wet) shown at 200 spawners
  - Vertical line represents calibrated value = 0.7
  - Moderate sensitivity to reductions in food ration

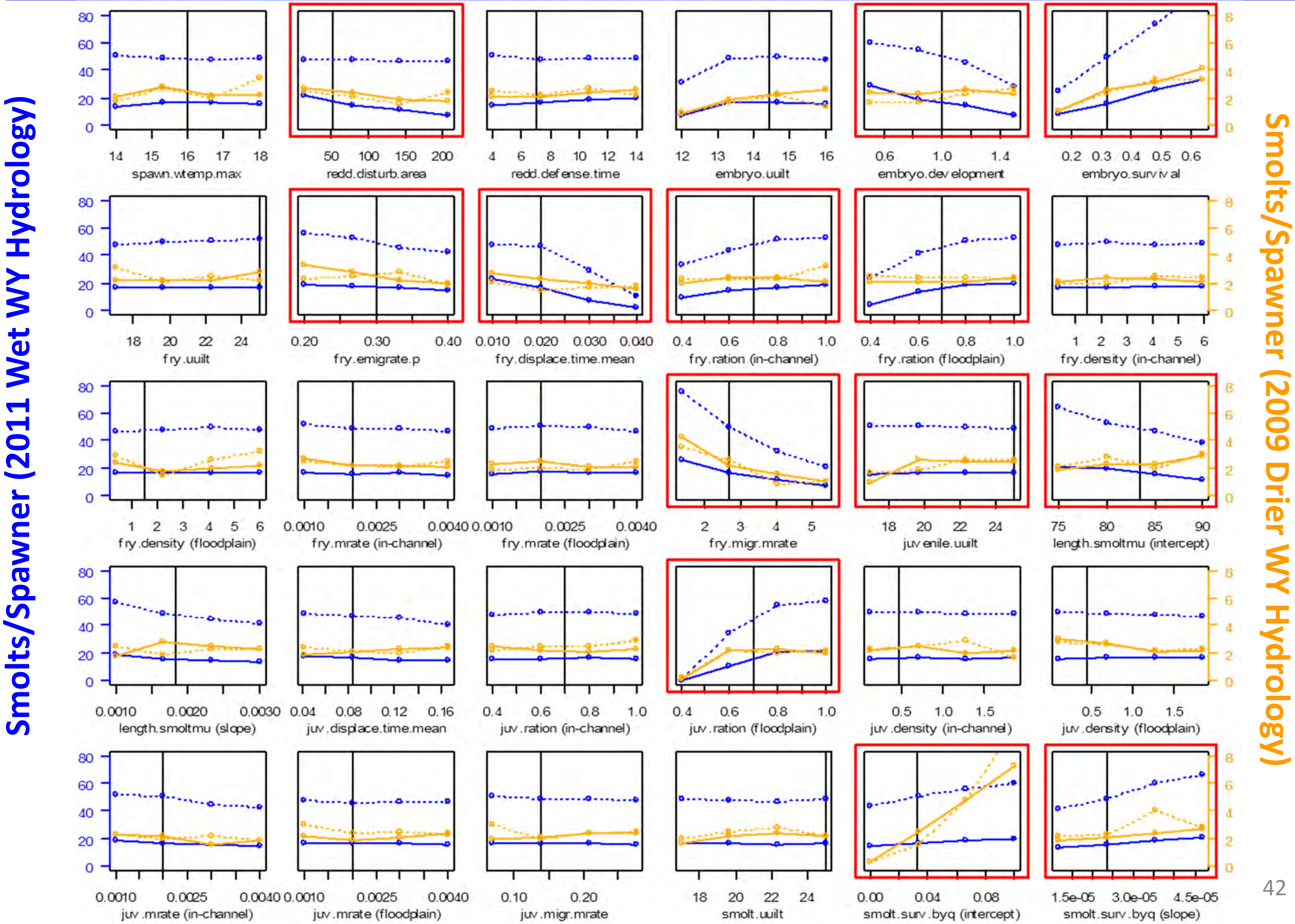


Fry feeding ration on floodplain (Example)

- Blue Lines = High Discharge (2011 “Wet”)
- Orange Lines = Low Discharge (2009 “Drier”)
- Dashed Lines = 200 spawners (“Low”)
- Solid Lines = 10,000 spawners (“High”)
- **Moderate sensitivity in Wet WY type**
- **No sensitivity in Dry WY Type**



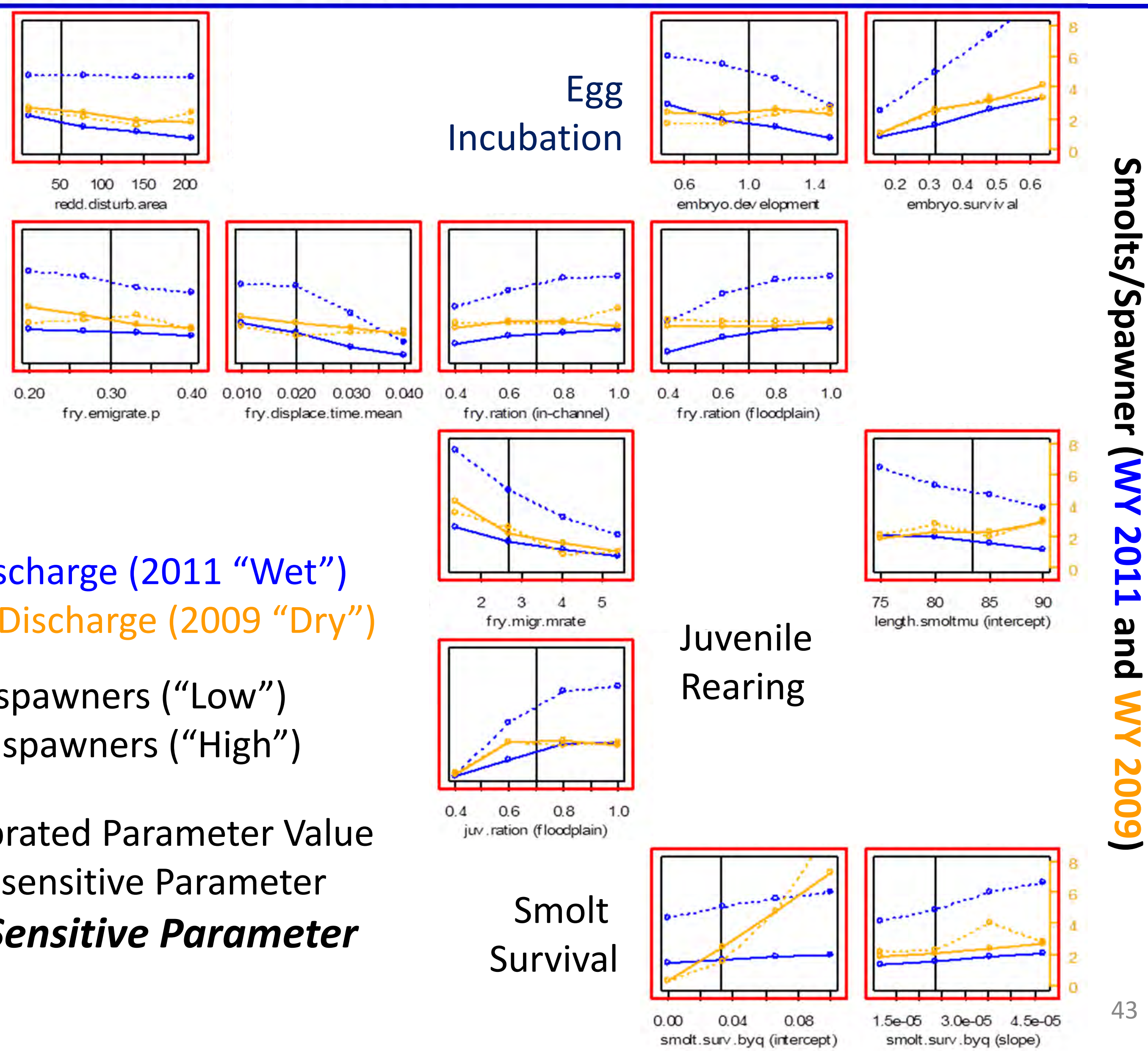
Modeling Sensitivity Testing



Modeling Sensitivity Testing

Redd Superimposition

Fry Rearing



Blue Lines = High Discharge (2011 "Wet")

Orange Lines = Low Discharge (2009 "Dry")

Dashed Lines = 200 spawners ("Low")

Solid Lines = 10,000 spawners ("High")

Vertical Lines = Calibrated Parameter Value

Horizontal Lines = Insensitive Parameter

Diagonal Lines = Sensitive Parameter

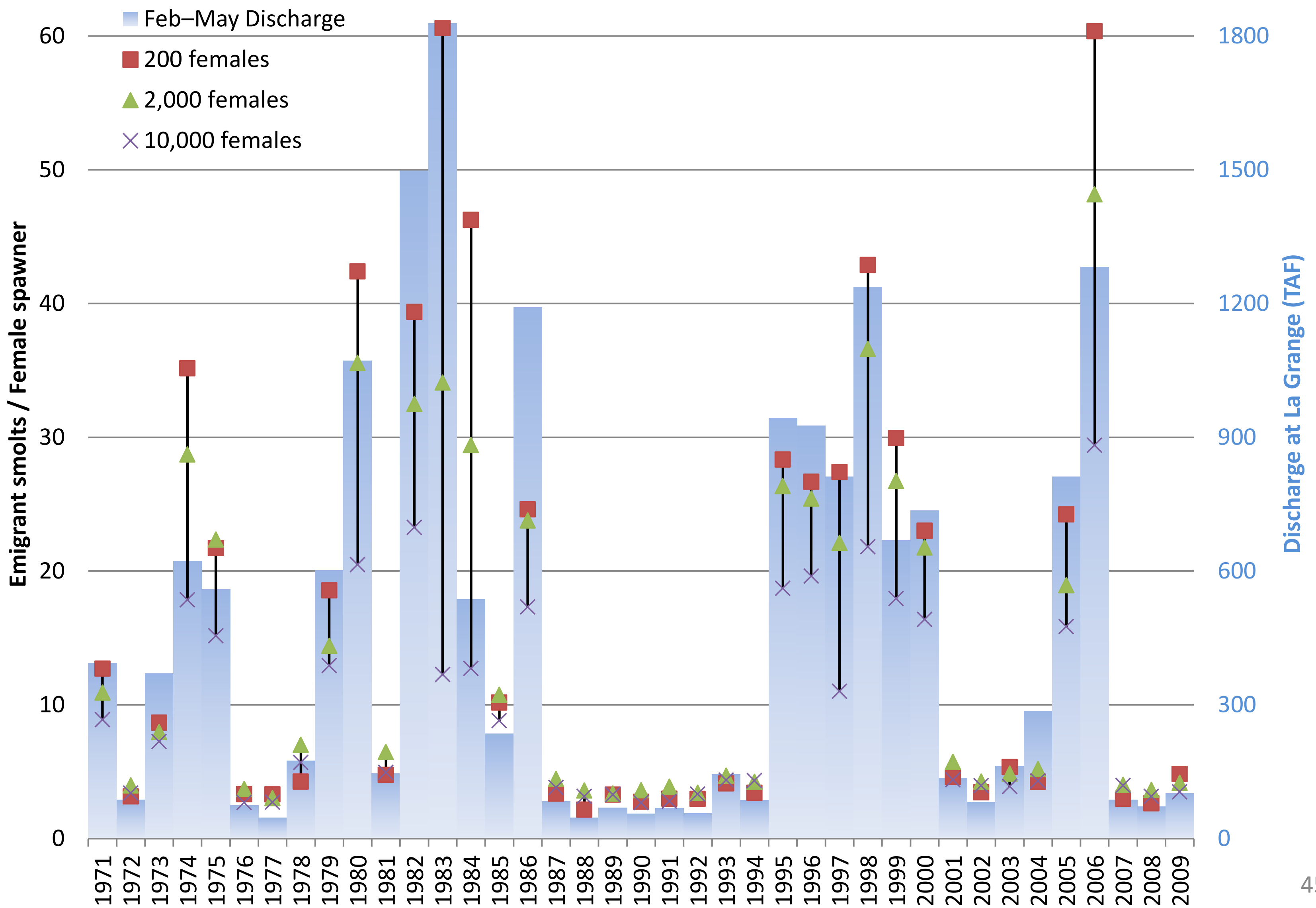
Modeling Sensitivity Testing

Sensitive parameters affecting smolt productivity:

- Upmigration and Spawning
  - Larger vs. smaller redd size (redd.disturb.area)
- Egg incubation and fry emergence
  - Slower vs. faster incubation rates (embryo.development)
  - Lower vs higher survival-to-emergence due to gravel quality (embryo.survival)
- Fry rearing
  - Greater or lower proportions of emigrant fry upon emergence (fry.emigrate.p)
  - Lower vs. higher food (fry.ration) within in-channel and floodplain areas
  - Changes in movement (fry.displace.time.mean) and predation rates (fry.mrate)
- Juvenile rearing
  - Lower vs. higher food (juv.ration) within floodplain areas
  - Smaller vs. larger size at smoltification (length.smoltmu)
- Smolt emigration
  - Smolt survival as a function of flow (smolt.surv.byq)

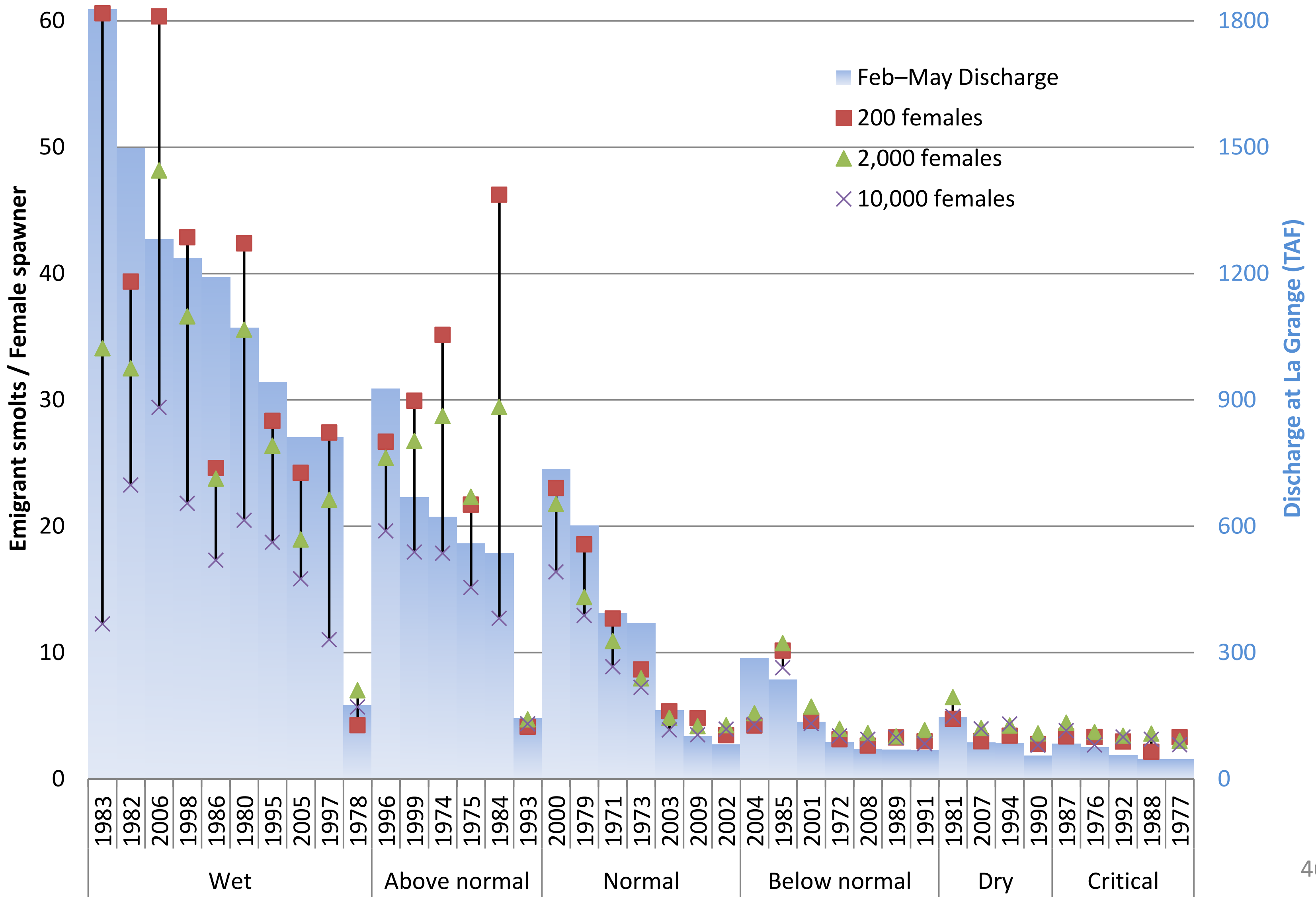
Base Case Simulations (1971-2009)

Don Pedro Project
FERC No. 2299

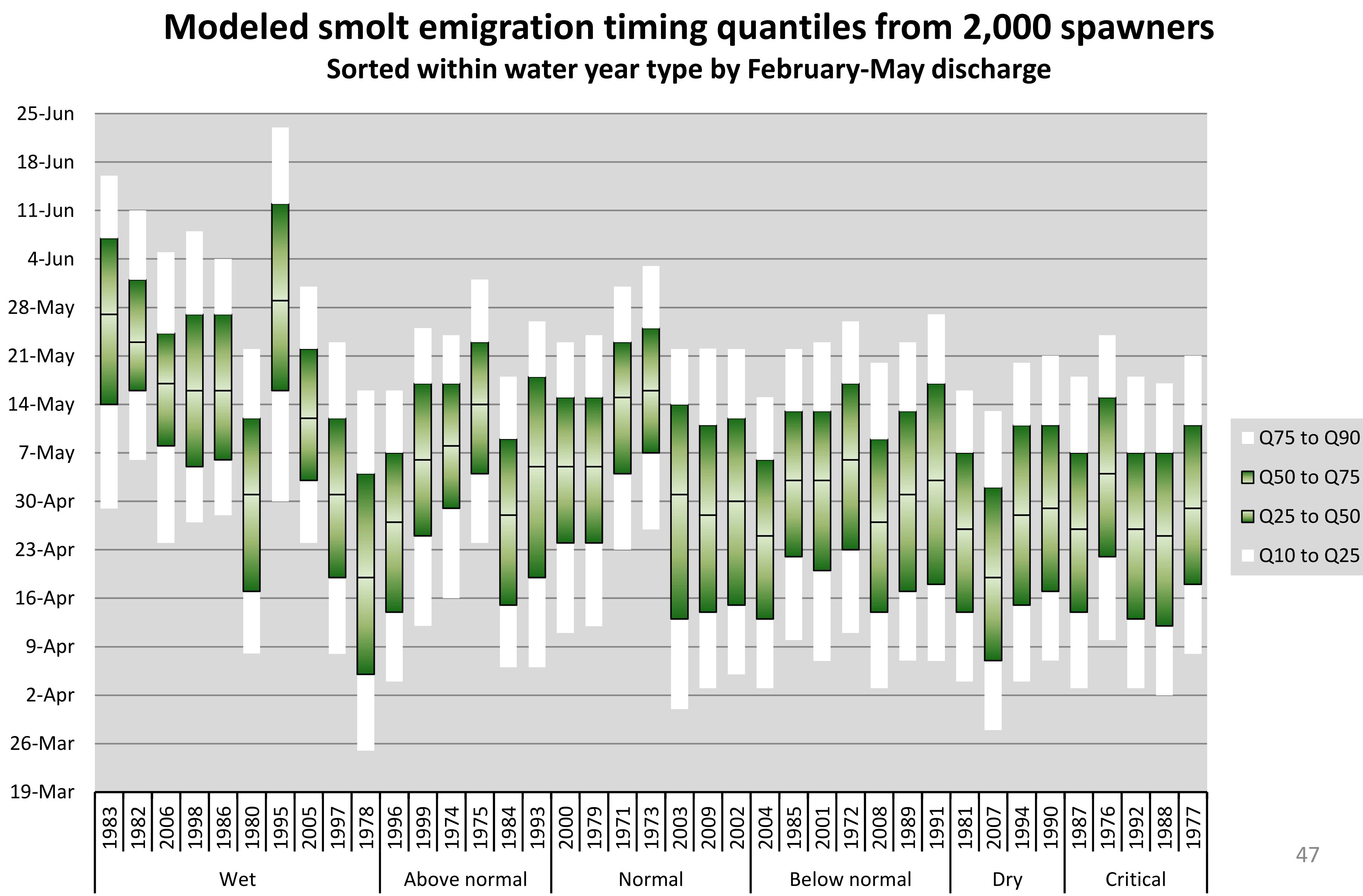


Base Case Simulations (1971-2009)

Don Pedro Project
FERC No. 2299



Base Case Simulations (1971-2009)



Factors Affecting Production

Spawning Habitat

1. **Redd superimposition effects**
   - Reductions in smolt productivity with increasing escapement for the Base Case
   - Model sensitivity to redd area
   - Model sensitivity to increased incubation times
2. **Consistent with previous and ongoing studies**
   - Superimposition observations (W&AR-8, TID/MID 1992)
   - Increased "preference" for upstream spawning sites (W&AR-5, W&AR-8)
   - Loss of upstream riffles in 1997 flood (W&AR-4, McBain & Trush 2004, TID/MID 1992)

Factors Affecting Production

Fry/Juvenile Rearing Habitat

1. No identified rearing habitat limitation
   - Low model sensitivity to rearing density
   - Low model sensitivity to increased food availability
   - Some sensitivity to reduced food availability below calibrated values
2. Consistent with previous studies
   - High food ration estimates from direct stomach content analyses (TID/MID 1997)
   - USFWS (2001, 2002) smolt condition assessments

Factors Affecting Production

Flow Effects

1. **Increased smolt productivity with discharge**
   - Flow linkages with habitat suitability (WUA) and Water Temperature
   - Sensitivity to fry movement and predation mortality parameters
   - Sensitivity of smolt size and emigration timing with rearing temperatures
   - Sensitivity of smolt survival with flow
2. **Consistent with previous studies**
   - Relationships between spring discharge and subsequent escapement 3-years later (W&AR-5 and W&AR-6 citations)
   - Relationships between RST passage and spring discharge (Mesick et al. 2008)

Factors Affecting Production

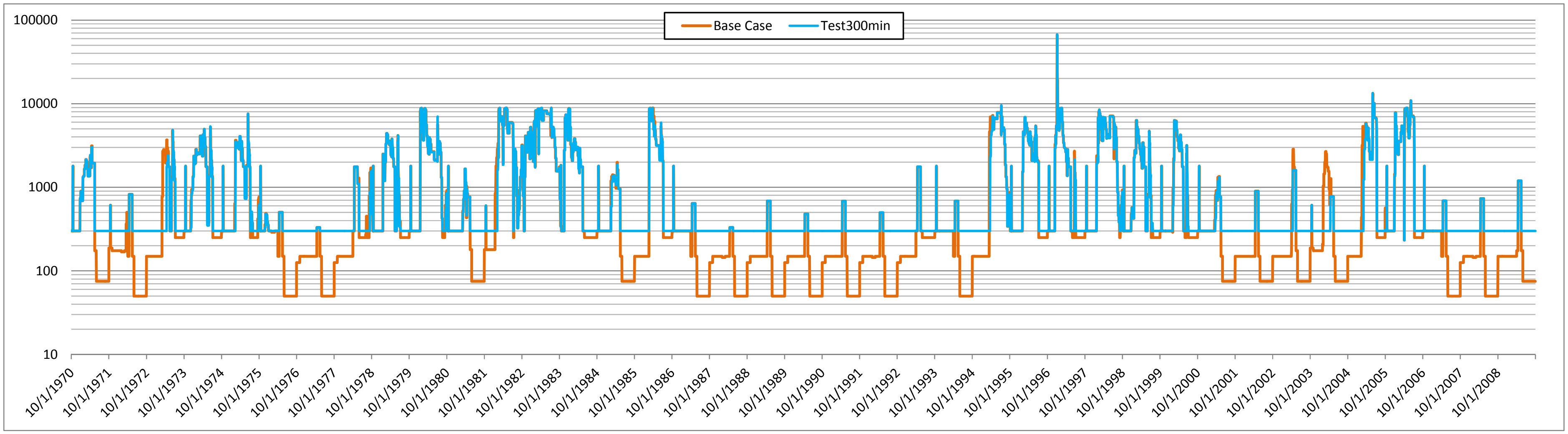
Water Temperature Effects

1. **Spawning and Egg Incubation**
   - No sensitivity to maximum spawning temperature (14-18°C)
   - No sensitivity to egg mortality threshold (13-16°C)
   - Sensitivity to incubation rate (i.e., slower at lower temps, etc.)
2. **Fry/Juvenile Rearing**
   - No sensitivity to mortality thresholds (18-25°C)
   - Growth rates affected by water temperature
3. **Smolt Emigration**
   - No sensitivity to mortality thresholds (18-25°C)
4. **Consistent with existing data (W&AR-5)**
   - Suitable spawning temperatures by mid- to late-October
   - Suitable rearing temperatures from January through mid-May
   - Peak emigration occurs during mid-to late-April of most years
   - Unsuitable emigration temperatures by early June in most years

Modeling Scenario Example

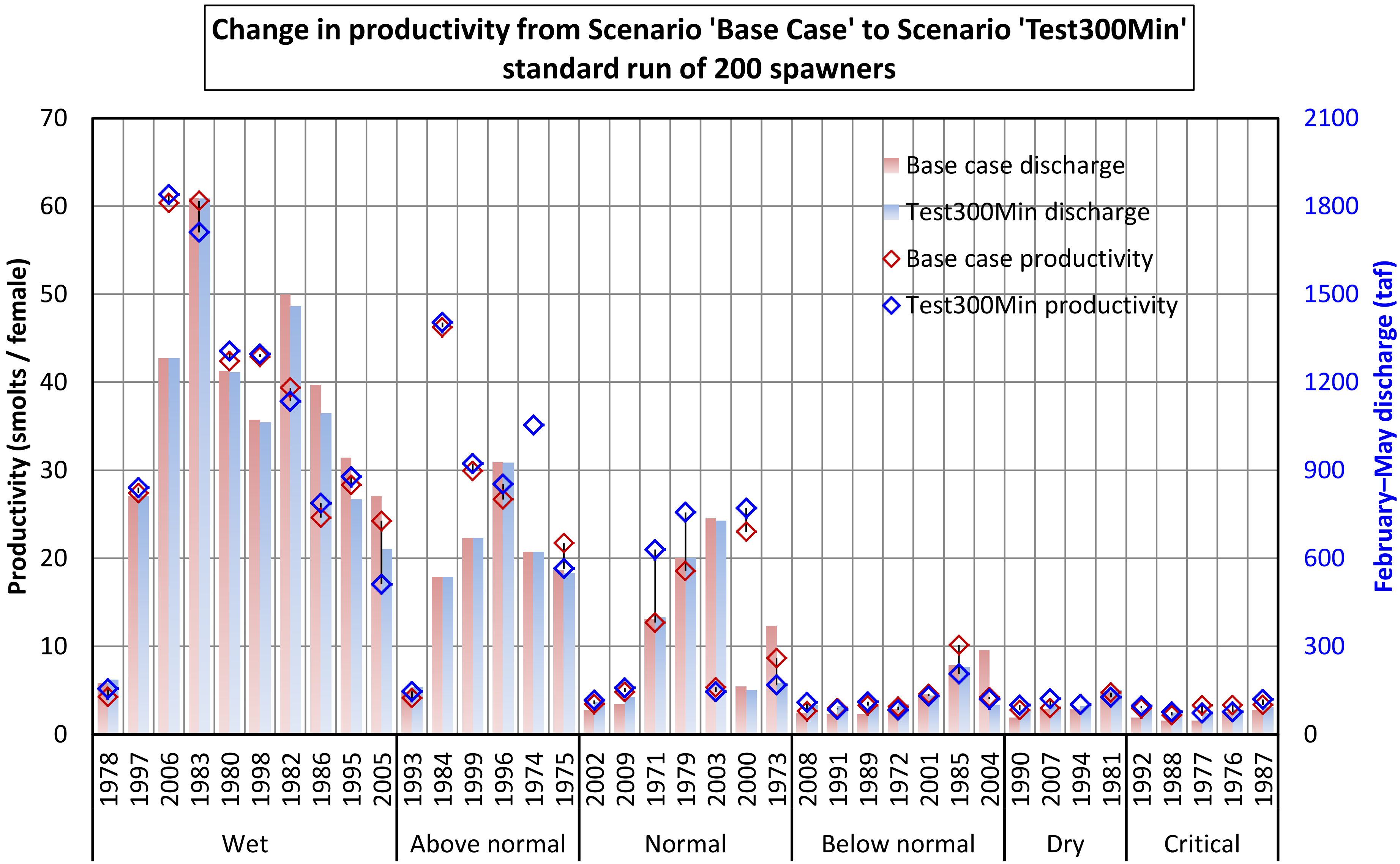
1. 300 cfs Test Case

- Provides 300 cfs or FERC (1996) minimum flows, whichever is greater



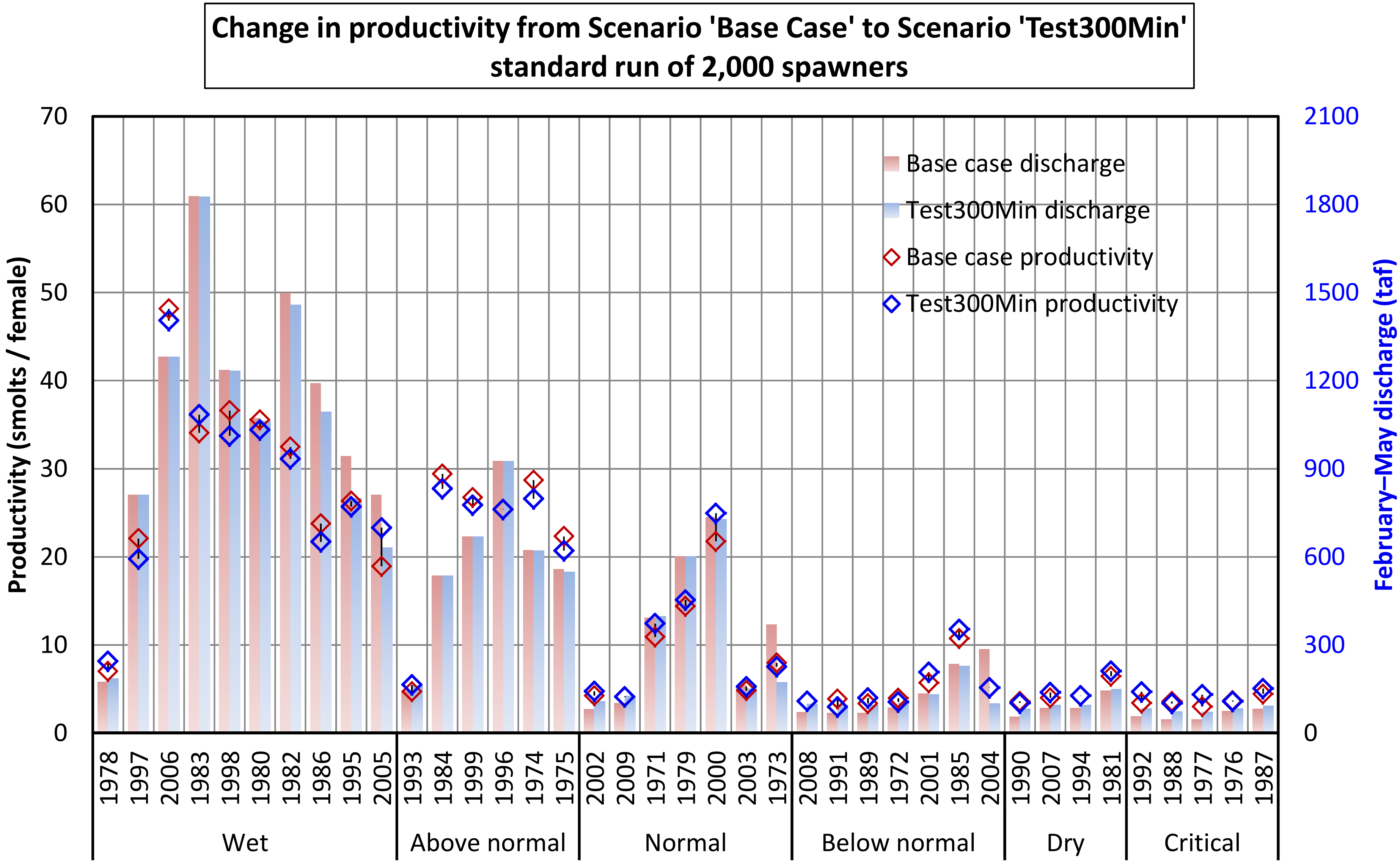
- Smolt productivity results shown for 200 and 2,000 spawners

300 cfs Test Case (Example Scenario)



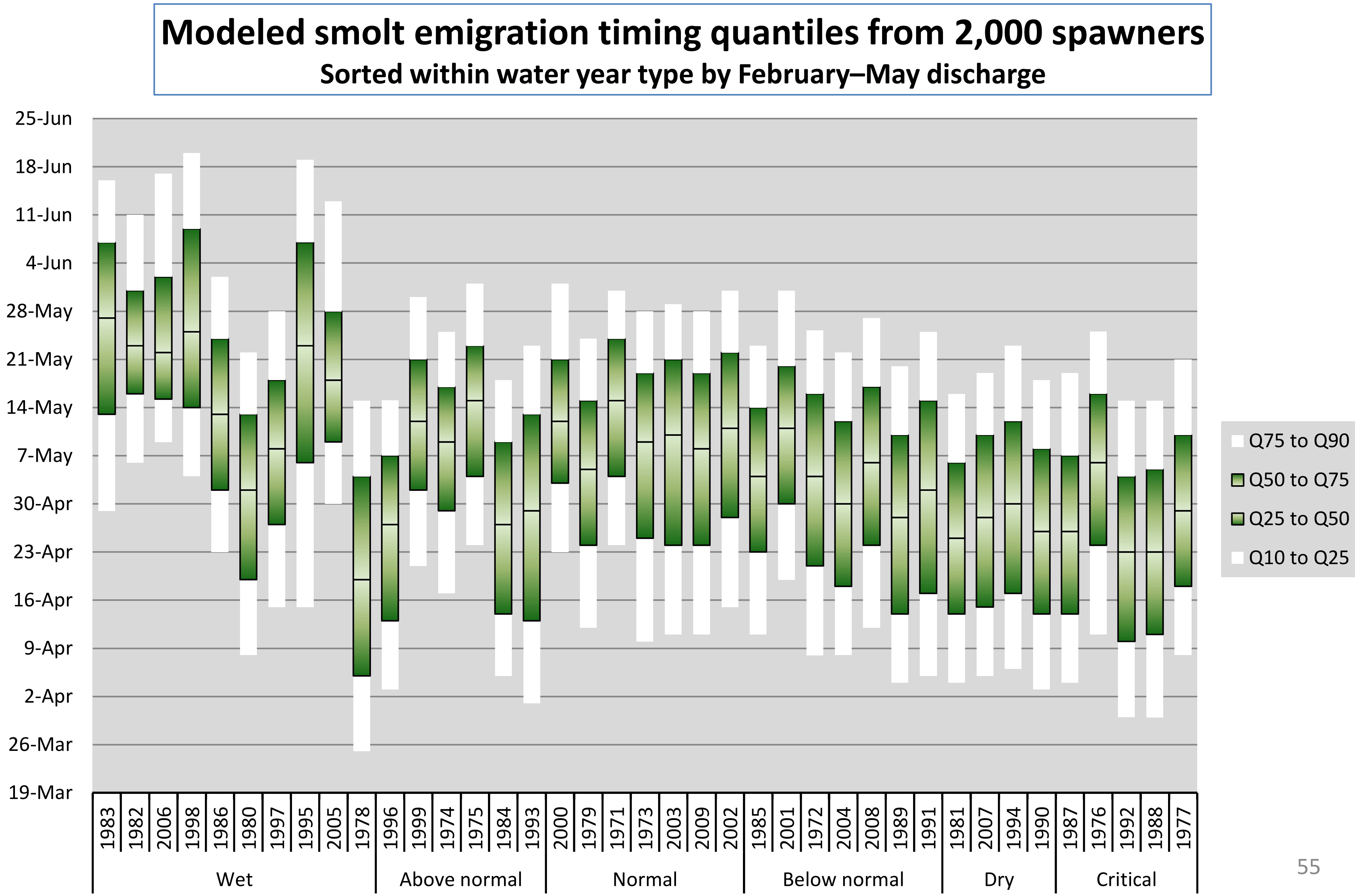
300 cfs Test Case (Example Scenario)

Don Pedro Project
FERC No. 2299



300 cfs Test Case (Example Scenario)

Don Pedro Project
FERC No. 2299



Next Steps

1. Relicensing Participant comments on report and model
2. Scenario testing
3. User-interface model code availability
4. Model training?
5. Future model refinements
   – 2014 Studies (W&AR-7, W&AR-21)
   – RP Comments
   – Other Refinements

Attachment B
California Department of Fish and Wildlife Comments on
Draft Meeting Notes and W&AR-6 Workshop No.2,
Don Pedro Hydroelectric Project (Project) No. 2299, Tuolumne River

State of California – Natural Resources Agency
DEPARTMENT OF FISH AND WILDLIFE
Central Region
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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

September 17, 2013

Via Electronic Submission

Kimberley D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

Subject: California Department of Fish and Wildlife Comments on Draft Meeting Notes and W&AR-6 Workshop No. 2, Don Pedro Hydroelectric Project (Project) No. 2299, Tuolumne River

Dear Secretary Bose:

The California Department of Fish and Wildlife[1] (CDFW) has reviewed the draft Meeting Notes from the August 6, 2013 W&AR-6 Workshop No. 2 distributed by the Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) to all relicensing parties on August 21, 2013, for a 30-day review. By this letter, CDFW provides the following comments on the W&AR-6 Workshop No. 2 and draft Meeting Notes.

Consistency with Previous Studies / Existing Data

During the workshop, the Districts' representatives presented an analysis of factors affecting Chinook salmon production based on preliminary W&AR-6 model results. There was discussion of four main categories: 1) Spawning Habitat, 2) Fry/Juvenile Rearing Habitat, 3) Flow Effects, and 4) Water Temperature Effects. Each of these discussions concluded with a determination that the model results were consistent with previous studies or existing data. CDFW concurs that existing information strongly supports the flow effects concept and that spring flows are highly correlated with both smolt survival and adult escapement. The following excerpt from the State Water Resources Control Board (SWRCB) 2011 Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives (Technical Report) cites multiple sources that have examined the relationship of flow and Chinook salmon populations in the San Joaquin River basin generally and the lower Tuolumne River in particular.

[1] Please note that as of January 1, 2013, our new name is the California Department of Fish and Wildlife (CDFW).

"Studies that examine the relationship between fall-run Chinook salmon population abundance and flow in the SJR basin generally indicate that: 1) additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and 2) the primary influence on adult abundance is flow 2.5 years earlier during the juvenile rearing and outmigration life phase (AFRP 2005, DFG [2005], Mesick 2008, DFG [2010], USDOI 2010). These studies also report that the primary limiting factor for tributary abundances are reduced spring flow, and that populations on the tributaries are highly correlated with tributary, Vernalis, and Delta flows (Kjelson et al. 1981, Kjelson and Brandes 1989, AFRP 1995, Baker and Mohardt 2001, Brandes and McLain 2001, Mesick [2001], Mesick and Marston 2007, Mesick 2009, Mesick 2010 a-d)." (SWRCB, 2011, p. 3-26)

CDFW does *not* agree that the preliminary W&AR-6 model results involving the three other factors (i.e., spawning habitat, fry/smolt habitat, and water temperature), are consistent with existing information. CDFW, in concert with fellow resource agencies, has previously submitted information that directly refutes the underlying assumptions presented in the W&AR-6 model. The following selection of excerpts from documents already filed with the Commission highlight the inconsistency of the W&AR-6 model results with existing information.

Spawning Habitat

The W&AR-6 model indicates redd superimposition is a key factor affecting Chinook salmon production; however, the analysis fails to acknowledge the uncertainty in measuring redd superimposition impacts or the limited scope of studies that have been conducted to date. As a consequence of this variability and small amount of empirical data, there is great uncertainty as to whether or not this ecological process (one or more fish spawning on top of a previously constructed redd) is having a significant limiting effect upon salmon populations in the lower Tuolumne River.

Data limitations include the potentially skewed arrival and timing of fish spawning during 2009 due to problems caused by a weir installed in the fall of that year. The impediment of fish passage resulted in fish stacking up downstream of the weir. The following excerpt from CDFW's 2009 carcass report (part of the 2010 Annual FERC report), details some of the problem and highlights the drawbacks of relying on limited sampling opportunities to develop key model relationships.

"An Alaskan weir began operation on the Tuolumne River on September 22, 2009 as a method for counting migrating salmonids.

> . . . By week 7 of the escapement survey, it was clearly obvious that a significant number of fish were unable to move upstream past the weir and as a result, were spawning in poor habitat that they would likely not otherwise choose. Live fish continued to be observed in close proximity to the weir, with some individuals choosing to spawn directly underneath the weir panels.
>
> . . . The Tuolumne weir appeared to have had a significant impact on migrating salmon in 2009. During the 15 weeks of the escapement survey, a total of 15 carcasses (tagged and skeleton) were found within 2 miles downstream of the weir, as compared to a total of 40 that were discovered for the entire 26.5 mile stretch upstream of the weir. The inability of fish to move upstream to desirable spawning grounds was unacceptable especially with the current trend of critically low annual escapement numbers."[2]

Unfortunately 2009, when unacceptable impacts to migrating salmon occurred, is one of four years of weir counts utilized in development of the sub-model's upmigration and spawning timing relationship.

Another data limitation involves the use of redd superimposition observations from the TID/MID 1992 Lower Tuolumne River Spawning Gravel Availability and Superimposition Report. The data presented in the report were collected in 1988 and 1989, and are of limited utility because only 5 riffles were physically studied.[3] The relevance of data collected in the late 1980s is questionable for the construction of model relationships designed to analyze Project impacts in 2013. The current ongoing study (W&AR-8) should add and update the dataset but will be limited to a single spawning season. As illustrated in the previous excerpt on weir passage impacts in 2009, inter-annual variation can be very significant when assessing aquatic resources in an ecosystem like the Tuolumne River watershed. The effect of inter-annual variability can only be addressed by repeated sampling over multiple years.

While CDFW concurs that the Project facility and operations degrade spawning habitat, CDFW does not concur with the high priority assigned to redd superimposition by the model. This ranking is not consistent with previous scientific findings and data collected to date. Previous analyses found redd superimposition to be a consequence of other, more proximate, factors (such as low flow and warm water temperatures). Of itself,

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[2] eLibrary 20110331-5199, pp. 119-120

[3] eLibrary 19920506-0242, p.216

redd superimposition was not found to be a high priority in-river factor. Both of these issues are addressed in the following excerpts from Mesick et al.'s 2008 Limiting Factors Analysis and Recommended Studies for Fall-Run Chinook Salmon and Rainbow Trout in the Tuolumne River.

First is the issue of identifying proximate versus indirect factors:

> "Another concern is that the distribution of early arriving adult spawners has been gradually shifting toward the upstream areas below La Grange Dam, particularly over the last 15 years. We suspect that low flows, unsuitably warm temperatures, and poor water quality in the lower reaches have caused the upstream shift in spawner distribution. As a result of the crowding, we suspect that redd superimposition rates are increasing which may result egg mortality for the early arriving fish."[4]

Second is the issue of relative significance:

> "Restoring spawning habitat through gravel augmentation and channel narrowing to increase sediment transport is unlikely to substantially increase adult recruitment, because the loss of eggs and fry from degraded habitats and red[d] superimposition has been inconsequential to the production of smolts in the Tuolumne River. This is because many more juveniles have been produced in spite of the degraded spawning habitat, than survived to a smolt-size under the [FERC Settlement Agreement] FSA flows schedules."[5]

Based upon review of existing information, CDFW does not find support for the W&AR-6 contention that redd superimposition is a significant factor affecting Chinook salmon populations in the lower Tuolumne River.

Fry/Juvenile Rearing Habitat

The W&AR-6 model conclusion, that there is no identified rearing habitat limitation for Chinook salmon fry and juveniles, contradicts previous studies. There are multiple sources of information demonstrating the need for floodplain rearing habitat in the lower Tuolumne River as well as the lack of rearing habitat under current Project operations. Rearing habitat quantity and quality on the Tuolumne River is inseparable from the

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[4] eLibrary 20091129-0301 p.29

[5] Ibid p.84

magnitude, timing, and duration of winter and spring time flows. Another excerpt from Mesick et al.'s study describes the likely mechanisms of this relationship:

> "**In-River Rearing**: *High flows between early-February and late-May are a primary determinant of the number of juvenile salmon that survive to smolt size in the Tuolumne River and contribute to adult recruitment.* It is assumed that when high flows begin in February and extend into late-May, a higher percentage of juveniles survive as a result of
>
> a. increased rearing habitat quantity and quality as floodplain habitat increases;
>
> b. increased food availability from inundated floodplains,
>
> c. improved water quality (including water temperature, contaminants, and dissolved oxygen) improves which reduces mortality from other stressors (e.g., disease, contaminates, and starvation), and
>
> d. reduced predation by Sacramento pikeminnow, black bass and striped bass."[6]

Mesick et al. conclude:

> "Flow management and restoration should focus on enhancing the quality and quantity of habitat for juveniles rearing in the Tuolumne River and for outmigrating smolts as the primary means of achieving adult salmon production targets."[7]

The high priority need for restoring floodplain and rearing habitat in Central Valley rivers is echoed in the Jeffres et al. 2008 article entitled "Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river":

> "When juvenile Chinook salmon leave fresh water at a larger size, as seen in fish reared on floodplains, overall survivorship to adulthood is increased (Unwin 1997; Galat and Zweimuller 2001). Restoration of river-floodplain connectivity should thus prove to be an effective part of any salmon conservation strategy. This study and that of Sommer et al. (2001) show that restoring floodplain

[6] Ibid p. 46

[7] Ibid pp. 84-85

> habitats in Central California should have major benefits to Chinook salmon populations."[8]

Contrary to the W&AR-6 findings, existing information establishes the importance of floodplain rearing habitat as a key limiting factor for Chinook salmon populations in the San Joaquin River basin.

Water Temperature

The W&AR-6 model asserts that there are no water temperature effects worth noting beyond changes in incubation and growth rates; however, water temperatures exceed the recommended criteria for juvenile and adult salmon when these life stages are present in the lower Tuolumne River, and this condition was the basis upon which the United States Environmental Protection Agency (USEPA) listed the lower Tuolumne River as impaired for temperature for fall-run Chinook salmon and steelhead rainbow trout in 2011. For reference, the transmittal in which the Director of the USEPA Region IX Water Division provides the final Section 303(d) list of impaired water bodies in California for 2008-2010 to the SWRCB is attached to this letter. Please refer to pages 12 through 28 for a detailed response from USEPA regarding the listing of the San Joaquin River and its tributaries as temperature impaired. This response includes multiple citations in support of the listing of the Tuolumne River below La Grange Dam as temperature impaired. Several of the USEPA citations documenting the water temperature impacts on Tuolumne River salmonids are already in the administrative record for this proceeding. The W&AR-6 model's lack of sensitivity to temperature effects is in direct contradiction to that record.

The following two excerpts from the Don Pedro Project Docket (P-2299) serve to illustrate the disconnect between the existing body of information and the W&AR-6 conclusion that water temperature is not affecting Chinook salmon production on the lower Tuolumne River.

From McBain and Trush's 2000 Habitat Restoration Plan for the Lower Tuolumne River Corridor, Report to the Tuolumne River Technical Advisory Committee (2000):

> "High water temperatures during rearing and smolt emigration are perhaps the most significant dam-related habitat alteration (apart from flow reduction and sediment blockage) in the Tuolumne River.

[8] eLibrary 20090914-5169, p. 125

> . . . Not only are the effects of high water temperature direct (e.g., thermal stress, mortality), but high temperatures may also contribute indirectly to other limiting factors such as bass predation, smolt survival during emigration, spawning distribution, and incubation success.
>
> . . . High water temperatures are also most likely responsible for limiting habitat of yearling chinook salmon. Low summer flows and resultant high water temperatures can be lethal to summer rearing."[9]

From Myrick and Cech's 2001 literature review of the effects of water temperature on Chinook salmon and steelhead, with particular emphasis on populations in the Central Valley of California:

> "*Water temperature is perhaps the physical factor with the greatest influence on Central Valley salmonids, short of a complete absence of water.* Temperature directly affects survival, growth rates, distribution, and developmental rates. Temperature also indirectly affects growth rates, disease incidence, predation, and long-term survival. The changes made to Central Valley rivers have had, and will continue to have far-reaching effects on chinook salmon and steelhead populations. All life-history stages of both chinook salmon and steelhead are affected by temperature; this report focuses primarily on the effects of temperature on the survival and physiology of eggs, alevins, juveniles, and smolts."[10] [emphasis added]

To summarize, CDFW considers the existing scientific literature on factors impacting Chinook salmon populations to support the significant role of both floodplain rearing habitat and water temperature, as well as the relatively minor role of redd superimposition. This existing information directly contradicts preliminary findings of the W&AR-6 model.

Lack of Peer Review and Next Steps

The paradigm shift(s) represented by the conclusions of the early W&AR-6 modeling runs reinforce CDFW's concern that the current modeling tool's underlying assumptions and structure have not been subject to adequate review. CDFW reiterates its recommendation that a formal peer review be conducted of the underlying model

[9] eLibrary 20110607-0545, p.96

[10] eLibrary 2020090914-5170, p. 316

assumptions and structure. Specifically, CDFW urges independent peer review of the following W&AR-6 assertions in regards to the lower Tuolumne River:

i) redd superimposition causes significant impact on Chinook populations;

ii) there are no Chinook juvenile rearing habitat limitations, and

iii) water temperature is not a significant factor when and where Chinook salmon are present in the river.

CDFW notes the San Joaquin River Group Authority (SJRGA), a coalition of water agencies whose members include both the Turlock and Modesto Irrigation Districts, has previously recommended peer-review of modeling tools as a way to establish scientific credibility and to avoid the appearance of self-serving advocacy. The SJRGA, in comments filed with the SWRCB, explicitly warned against reliance on science that had not been vetted for adequacy of data, analysis, or methodology (SJRGA 2010). The SJRGA comments suggest academic peer-review to ensure the adequacy of scientific data intended for regulatory purposes. Given these comments and the need to develop defensible license conditions for the Don Pedro Project, CDFW believes all relicensing participants would benefit from formal peer review of W&AR-6 as soon as possible. The peer review should be conducted and all reasonable recommendations responded to *prior* to the additional scenario testing and model training envisioned in the next steps portion of the draft Meeting Notes.

This concludes CDFW's comments on the Districts' W&AR-6 Workshop No. 2 and draft Meeting Notes. CDFW appreciates the opportunity to review and provide comments. If you have any questions regarding these comments, please contact Annie Manji, Senior Environmental Scientist (Specialist), at (530) 224-4924 or Annie.Manji@wildlife.ca.gov.

Sincerely,

Jeffrey R. Single, Ph.D.
Regional Manager, Central Region

Attachment

cc: See Page Nine

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US Department of the Interior (DOI). 2010. Comments regarding the California State Water Resources Control Board notice of public informational proceeding to develop Delta flow criteria for the Delta ecosystem necessary to protect public trust resources (Exhibit 1).

Attachment A

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IX

Water body-pollutant combinations added by EPA to California's 2008-2010 List of Water Quality Limited Segments Still Requiring Total Maximum Daily Loads Pursuant to Clean Water Act, sec. 303(d), and 40 CFR 130.7(d)(2)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105-3901

Tom Howard
Executive Director
State Water Resources Control Board
P.O. Box 100
Sacramento, California 95812

Dear Mr. Howard:

I am hereby transmitting to you the final list of water bodies that EPA is adding to California's 2008-2010 list of water quality limited segments still requiring total maximum daily loads pursuant to Clean Water Act, section 303(d), and 40 CFR 130.7(d)(2). Enclosure 1 identifies the water bodies added by EPA and the pollutants causing the impairment for which the water body was added.

On November 12, 2010, EPA took action on California's 2008-2010 Section 303(d) List, approving the State's inclusion of all waters and pollutants that the State identified as requiring a total maximum daily load (TMDL) and disapproving the State's omission of several water bodies and associated pollutants that met federal listing requirements.

EPA provided public notice and solicited public comment on its identification of additional water bodies and associated pollutants for inclusion on California's List. Enclosure 2 summarizes comments received and EPA's response. The final list of water bodies that EPA is adding to California's list of water quality limited segments still requiring a TMDL includes all the water bodies and associated pollutants identified in EPA's November 12, 2010 letter, with the exception of San Joaquin River (Mendota Pool to Bear Creek) for electrical conductivity.

If you have questions on any aspect of this final listing decision, please call me at (415) 972-3572, or refer staff to Dave Guiliano at (415) 947-4133 or Valentina Cabrera Stagno at (415) 972-3434.

Sincerely yours,

Alexis Strauss 11 October 2011
Alexis Strauss
Director, Water Division

Enclosures

Cc: SWRCB Members
Regional Board Executive Officers

Enclosure 1: Water body-pollutant combinations added by EPA to California's 2008-2010 List of Water Quality Limited Segments Still Requiring Total Maximum Daily Loads Pursuant to Clean Water Act, sec. 303(d), and 40 CFR 130.7(d)(2).

Description of Table Columns:

- "RB" column identifies the Regional Water Quality Control Board with jurisdiction over a listed water body.
- "Water body name" column identifies the listed water bodies.
- "Pollutant" column identifies the pollutant causing impairment.

Table 1: EPA's Additions to California's 2008-2010 List of Water Quality Limited Segments Still Requiring Total Maximum Daily Loads.

RB	Water body name	Pollutant
5	Merced River, Lower (McSwain Reservoir to San Joaquin River)	Temperature
5	Old River (San Joaquin River to Delta-Mendota Canal; in Delta Waterways, southern portion)	Electrical Conductivity
		Total Dissolved Solids
5	San Joaquin River (Bear Creek to Mud Slough)	Electrical Conductivity
5	San Joaquin River (Merced River to Tuolumne River)	Electrical Conductivity
		Temperature
5	San Joaquin River (Mud Slough to Merced River)	Electrical Conductivity
5	San Joaquin River (Stanislaus River to Delta Boundary)	Temperature
5	San Joaquin River (Tuolumne River to Stanislaus River)	Electrical Conductivity
		Temperature
5	Stanislaus River, Lower	Temperature
5	Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River)	Temperature
6	Carson River, East Fork	Total Dissolved Solids
6	Mammoth Creek (Headwaters to Twin Lakes outlet)	Total Dissolved Solids
8	Bolsa Chica Channel	Indicator Bacteria
8	Borrego Creek (from Irvine Blvd. to San Diego Creek Reach 2)	Indicator Bacteria
8	Cucamonga Creek Reach 1 (Valley Reach)	Lead
8	Goldenstar Creek	Indicator Bacteria
8	Morning Canyon Creek	Indicator Bacteria
8	Peters Canyon Channel	Indicator Bacteria
8	San Diego Creek Reach 2	Indicator Bacteria
8	Santa Ana Delhi Channel	Indicator Bacteria
8	Santa Ana River Reach 2	Indicator Bacteria
8	Santa Ana River Reach 3	Lead
8	Santa Ana River Reach 6	Copper
		Lead
8	Serrano Creek	Indicator Bacteria
8	Temescal Creek, Reach 6 (Elsinore Groundwater sub basin boundary to Lake Elsinore Outlet)	Indicator Bacteria

Enclosure 2: Responsiveness Summary

EPA Decision Concerning California's 2008-2010 Clean Water Act Section 303(d) List

Introduction

On November 12, 2010, EPA approved California's inclusion of all waters and pollutants that the State identified as requiring a total maximum daily load (TMDL) in California's 2010 Integrated Report. EPA also disapproved California's omission of several water bodies and associated pollutants that met Federal listing requirements. The water bodies and associated pollutants that EPA added to the States' 2008-2010 list of water quality limited segments requiring a TMDL are identified in Table 3 of the enclosure to EPA's November 12, 2010 letter.

EPA provided notice of availability of its decision and solicited public comment by Federal Register notice on November 23, 2010, and through its website. Written comments were received from the following parties concerning the issues shown in Table 2.

Table 2: Summary of Comments Received

Commenting Party	Issue
Eric Wesselman, Executive Director Tuolumne River Trust Doug Obegi, Staff Attorney, Western Water Project Natural Resources Defense Council Michael Martin, Ph.D., Conservation Director, Merced Fly Fishing Club Director, Merced River Conservation Committee Cindy Charles, Conservation Director, Golden West Women Flyfishers Northern California Council, Federation of Fly Fishers Kelly Catlett, Hydropower Reform Policy Advocate Friends of the River Curtis Knight, Program Manager California Trout John Buckley, Executive Director Central Sierra Environmental Resource Center Bill Jennings, Executive Director California Sportfishing Protection Alliance	Support listing of the San Joaquin River and tributaries for temperature.
156 letters from supporters of the Tuolumne River Trust	Support listing of the San Joaquin River and tributaries for temperature.

Jeffrey R. Single, Ph. D., Regional Manager California Department of Fish and Game	Supports listing of the San Joaquin River and tributaries for temperature.
Maria Rea (two letters submitted) Sacramento Office Area Supervisor United States Department of Commerce National Oceanic and Atmospheric Administration National Marine Fisheries Services	Supports listing the San Joaquin River and tributaries for temperature and supports the listing of the San Joaquin River for electrical conductivity.
Kenneth Petruzzelli (two letters submitted) San Joaquin River Group	Opposes listing of the San Joaquin River and Old River for electrical conductivity and total dissolved solids. Opposes listing of the San Joaquin River and tributaries for temperature. Opposes listing Old River for Electrical Conductivity.
Michael R. Markus, P.E., General Manager Orange County Water District	Opposes listing of Santa Ana River Reach 2 for indicator bacteria.
Tim Moore, Risk Sciences (two letter submitted) On behalf of Santa Ana River Dischargers Association	Opposes various listings for indicator bacteria in the Santa Ana Region. Opposes various metals listings in the Santa Ana Region.
Kirsten James, Director of Water Quality Mark Gold, President Heal The Bay	Supports listing of 10 water bodies in Santa Ana Region for bacterial indicators including Morning Canyon Creek and Temescal Creek Reach 6.
Miyoko Sakashita Center For Biological Diversity	Requests ocean waters to be added to the 303(d) List for pH.
Linda Sheehan, Executive Director California Coastkeeper Alliance	Supports listing all waters in Table 3 of EPA's Partial Approval/Disapproval letter Opposes the approval of the omission of water bodies covered under a grazing waiver in the Lahontan Region from the 303(d) list.
Gary Niles, Business Manager Citizens Legal Enforcement and Restoration	Commenting on water quality of the Palo Verde Outfall Drain and Lagoon.
Chris Horgan, Executive Director Stewards of the Sequoia	Requests removal of Lake Isabella and Kern River from the 303(d) list.
Patricia Grantham, Forest Supervisor Klamath National Forest United States Forest Service	Requests removal of Klamath River HU, Middle HA and Lower HA, Scott River to Trinity River from the 303(d) List.

As indicated in Table 2, several commenters indicated support for one or more of EPA's listing determinations. Summaries of comments objecting to EPA's determination to add a water or pollutant to California's list, and summaries of other comments to which EPA is responding, and EPA's responses are as follows.

General Comments and Responses

A. San Joaquin River Group Authority Comments Addressing Electrical Conductivity and Total Dissolved Solids Impairments of Old River and Multiple Segments of the San Joaquin River

A1. Comment: "Do not list the Lower San Joaquin River for Electrical Conductivity/salinity" (cover letter, Dec. 15, 2010)

Response: EPA disagrees. The San Joaquin River segments that EPA added to California's 303(d) list are:

- San Joaquin River (Bear Creek to Mud Slough)
- San Joaquin River (Mud Slough to Merced River)
- San Joaquin River (Merced River to Tuolumne River)
- San Joaquin River (Tuolumne River to Stanislaus River)

These water bodies have data which indicate that the designated uses are impaired. This data from within the individual segments indicate that applicable water quality objectives for Electrical Conductivity have not been attained. EPA has carefully reviewed SWAMP data for this section of the river and continues to find significant impairment throughout the San Joaquin River from Bear Creek to the Stanislaus River.

A2. Comment: "The listing for Old River electrical conductivity should have been evaluated based on compliance with the Water Quality Objectives for Agricultural Beneficial Uses Southern Delta, contained in the *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary*, at the Old River at Middle River and at the Old River at Tracy Road Bridge compliance points" (cover letter, Dec. 15, 2010)

Response: Recent state court litigation concluded that agricultural (AGR) beneficial uses in the Delta should be evaluated only at the stated compliance points. See City of Tracy v. SWRCB, Case No. 34-34-2009-80000392 (May 10, 2011, Superior Ct, Sacramento County). EPA re-examined the data for the Old River compliance points; this assessment indicates impairment of Old River for Electrical Conductivity based on samples from 2000-2005 collected at the Tracy Boulevard Bridge, one of the compliance points shown for Old River in both the Basin Plan and Bay-Delta Plan. Accordingly, EPA is listing Old River as impaired for Electrical Conductivity based on exceedances of the AGR objective at the compliance point.

Table 3: Old River Electrical Conductivity and Total Dissolved Solids Data Summary

Water Body	Use	Objective	Data
Old River (San Joaquin River to Delta-Mendota Canal; in Delta Waterways, southern portion)	AGR	Max. 30-day running avg. Apr 1-Aug 31 0.7 µS/mm Sep 1-Mar 31 1.0 µS/mm	663 exceed of 1717
	MUN (EC)	900 µS/cm	20 exceed of 62
	MUN (TDS)	500 mG/L	7 exceed of 15

See also discussion of impairments to the municipal (MUN) beneficial use in the Delta, discussed below.

A3. Comment: "San Joaquin River between Turner Cut and Stockton should not [sic] longer be listed for dissolved oxygen" (cover letter, Dec. 15, 2010)

Response: EPA agrees. EPA has previously approved a TMDL which addresses this impairment of the water body segment. The San Joaquin River Dissolved Oxygen TMDL was approved by EPA on February 27, 2007. Thus, EPA has not added the segment to the 303(d) list for this impairment.

A4. Comment: "Listing Policy Section 6.1.5.3 (Temporal Representation) allows use of only recently collected data when implementation of a management practice results in a change to a water body segment." (page 20, Dec. 15, 2010)

Response: The commenter refers to a change in management practice which they say occurred in 1995. Without commenting on the validity of that assertion, EPA notes that the data indicates continued impairment for Electrical Conductivity on segments of the San Joaquin River. This data was collected between 1995 and 2007. Likewise, data from 2000 to 2005 showed impairment of Old River for Total Dissolved Solids and Electrical Conductivity. (U.S. Environmental Protection Agency, Enclosure, "Review of California's 2008-2010 Section 303(d) List", Table 3, page 16-17, November 12, 2010)

A5. Comment: "Currently, the salinity objective for Vernalis is the objective for the Lower San Joaquin River for the purposes of section 303(d) of the Clean Water Act. (San Joaquin River Exchange Contractors Water Authority et al. v. St. Water Resources Control Board (2010) 183 Cal. App. 4th 1110, 1119[15].) The objective at Vernalis has been met since its adoption 1995, without a single exceedance, through a dry period of two consecutive Critical years (2007 and 2008) and a third Below Normal (2009) year." (pages 21-22, Dec. 15, 2010)

Response: The objectives for the segments of the San Joaquin River apply throughout the segments, not only at Vernalis. EPA added the following San Joaquin River segments to the 303(d) list based on data indicating continued impairment on these segments:

- San Joaquin River (Bear Creek to Mud Slough)
- San Joaquin River (Mud Slough to Merced River)
- San Joaquin River (Merced River to Tuolumne River)
- San Joaquin River (Tuolumne River to Stanislaus River)

In each case, data indicates continued impairment by Electrical Conductivity. The data is from locations within the segments listed above. The designated uses and associated water quality objectives apply throughout the water bodies. Furthermore, Vernalis is not within the segments listed above.

The San Joaquin River listings for Electrical Conductivity were added to the 303(d) list by EPA based on data showing impairment within their respective segments. This data sufficiently indicates that the segments are impaired, regardless of whether Vernalis data shows the same impairment. See the discussion of the SJRECWA case, below. Additionally, data well after the date the commenter cites shows impairment, with exceedances found in 1995 and thereafter.

Table 4: San Joaquin River Electrical Conductivity Data Summary

Water Body	Use	Objective	Data
San Joaquin River (Bear Creek to Mud Slough)	AGR	Max. 30-day running avg. Apr 1-Aug 31 0.7 µS/mm Sep 1-Mar 31 1.0 µS/mm	5066 exceed of 7715
	MUN	900 µS/cm	691 exceed of 928
San Joaquin River (Mud Slough to Merced River)	AGR	Max. 30-day running avg. Apr 1-Aug 31 0.7 µS/mm Sep 1-Mar 31 1.0 µS/mm	5597 exceed of 7542
	MUN	900 µS/cm	632 exceed of 848
San Joaquin River (Merced River to Tuolumne River)	AGR	Max. 30-day running avg. Apr 1-Aug 31 0.7 µS/mm Sep 1-Mar 31 1.0 µS/mm	2345 exceed of 4059
	MUN	900 µS/cm	425 exceed of 565
San Joaquin River (Tuolumne River to Stanislaus River)	AGR	Max. 30-day running avg. Apr 1-Aug 31 0.7 µS/mm Sep 1-Mar 31 1.0 µS/mm	1102 exceed of 3745
	MUN	900 µS/cm	238 exceed of 537

A6. Comment: The following comment is pulled from footnotes 15 and 16 on page 22 of the commenter's letter. "[15] Although the court confirmed application of the Vernalis Salinity Objective as the objective for the LSJR for the purposes of section 303(d) of the Clean Water Act, because it was reasonable, it did not dispute that statute, case law, and water quality control plans and policies supported applicability of the Vernalis Salinity Objective as an applicable objective for the Delta, within the geographic boundaries of the Delta, as defined by California Water Code section 12220, and specifically protective of southern Delta agricultural beneficial uses. (San Joaquin River Exchange Contractors Water Authority et al., supra 183 Cal. App.4th at 1119.) No case law, statute, water quality control plan, or state policy supported applicability of the Vernalis Salinity Objective as an applicable objective for the LSJR. (Id.) In approving the Salt & Boron TMDL, the SWRCB approved a TMDL, but it did not approve any new or revised salinity objectives for the LSJR. Rather, the development of such objectives was deferred until later. When the Salt & Boron TMDL was submitted to EPA, the procedures for submitting TMDLs for approval were followed, but there is no evidence that the CVRWQCB and/or SWRCB followed any of the procedures for submitting a new or revised water quality objective for approval. (see 40 C.F.R. §131.6.) The Basin Plan continues to list the Vernalis Salinity Objective as an applicable objective for the Southern Delta, but not as an applicable objective for the LSJR. (Basin Plan, pp. III-6.01, Table III-5.)
[16] Had such evidence existed, D-1641's allocation of responsibility to the Bureau and the Department would have been illusory and would not have complied with the Board's obligation to implement its own water quality control plan. (St. Water Resources Control Bd. Cases, supra 136 Cal.App.4th at 734.)" (page 22, footnotes 15 and 16, Dec. 15, 2010)

Response: EPA's action includes the listing of four San Joaquin River water body segments for Electrical Conductivity. Much of the commenter's observations go beyond that action and involve interpreting the recent state appellate court decision for other purposes. EPA believes that the <u>San Joaquin River Exchange Contractors Water Authority et al. v. State Water Resources</u>

Control Board, 183 Cal. App. 4th 1110 (2010) (SJRECWA case) is both relevant to and illuminating of the issues in our listing decision. That case was a broader complaint about the SWRCB's salt and boron TMDL, but the court considered claims about the validity of the SWRCB's 303(d) listing decisions for salinity impairments on segments on the Lower San Joaquin[1]. In doing so, the state appellate court made two fundamental conclusions relevant to EPA's action. First, it noted that "the [plaintiff] asserts that the Vernalis Salinity [Water Quality Objective] applies only to the southern Delta and not in the Lower San Joaquin River. We disagree." (SJRECWA case, p. 1118.) Second, the court concluded that "there is sufficient evidence supporting the Lower San Joaquin River's section 303(d) listing for salinity." (SJRECWA case, p. 1122).

EPA is not literally bound to follow state court decisions when it makes its listing decisions under the federal Clean Water Act. Here, however, after reviewing the record submitted by the State and Regional Boards, we believe that the state court reached the right conclusion. In addition, we believe that the Court's rationale for applying the Vernalis Electrical Conductivity objective would also apply to the following segments: San Joaquin River (Bear Creek to Mud Slough); San Joaquin River (Mud Slough to Merced River); San Joaquin River (Merced River to Tuolumne River) and San Joaquin River (Tuolumne River to Stanislaus River) . Data indicates that the Vernalis Electrical Conductivity objective was not met on those segments. Accordingly, EPA is listing these segments as impaired for Electrical Conductivity.

The SWRECWA case does not discuss the question of impairments to the MUN beneficial use on the Lower San Joaquin River. MUN is listed as a "potential" beneficial use. See Table II-1, page II-8.00.[2] The MUN objectives for the Lower San Joaquin are the "minimum" objectives for

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[1] San Joaquin River (Mendota Pool to Bear Creek); San Joaquin River (Bear Creek to Mud Slough); San Joaquin River (Mud Slough to Merced River); San Joaquin River (Merced River to Tuolumne River) and San Joaquin River (Tuolumne River to Stanislaus River) and San Joaquin River (Stanislaus River to Delta Boundary).

[2] The addition of MUN beneficial uses to basin plans has a long history. SWRCB Resolution No. 88-63 (as revised by Resolution No. 2006-0008) mandates that "[w]here a body of water is not currently designated as MUN but, in the opinion of a Regional Board, is presently or potentially suitable for MUN, the Regional Board shall include MUN in the beneficial use designation." Further, "[t]he Regional Boards shall review and revise the Water Quality Control Plans to incorporate this policy." The Resolution also provided a list of exceptions, none of which clearly apply to the Lower San Joaquin.
EPA, in its approval letter of the Basin Plan on May 26, 2000, included an "understanding" at Attachment B., Page1:

> "It is EPA's understanding that: (1) Table II-1 notwithstanding, the MUN use is designated for all waters in the Sacramento and San Joaquin River Basins (including waters not identified by name in Table II-1), except those specifically excepted; (2) the Regional Board will only make exceptions to such designation in accordance with the provisions of SB Res. 88-63; (3) any such exceptions will be adopted into the Basin Plan through a public process in accordance with the requirements of 40 CFR 131.10…..Furthermore, it is EPA's understanding that waters may be considered, under SB Res. 88-63, to be "suitable" or "potentially suitable" for municipal or domestic water supply regardless of whether or not they are actually in use for these purposes; and that, for all waters that are considered "suitable" under SB Res. 88-63, MUN is designated as an "existing" use, as that term is defined in 40 CFR 131.3(e), and for all waters that are considered "potentially suitable" under SB Res. 88-63, MUN is designated as a "potential" use for water quality standards purposes…."

One California court recently found that Regional Boards can consider "potential beneficial uses" when establishing water quality objectives. City of Arcadia v. SWRCB, Case No. G041545 (4th App Dist., 12/14/10). This case found that "[t]he record reflects Regional Board's basin plan also took into considered (stet) "potential" beneficial uses of water in setting water quality objectives," and found that this was properly within the discretion of the Board.

Chemical Constituents at III-3.00. There are ranges specified for both Total Dissolved Solids and Electrical Conductivity. (California Code of Regulation, Title 22. Division 4. Environmental Health, Chapter 15. Domestic Water Quality and Monitoring Regulations, Article 16. Secondary Water Standards, Section 64449. Secondary Maximum Contaminant Levels and Compliance.) According to the data, there are exceedances in San Joaquin River (Bear Creek to Mud Slough); San Joaquin River (Mud Slough to Merced River); San Joaquin River (Merced River to Tuolumne River) and San Joaquin River (Tuolumne River to Stanislaus River) segments, and these should be listed as impaired.

A7. Comment: "For the Lower SJR, EPA uses the Specific Conductivity Secondary MCL. Under the Chemical Constituent Objective in the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basin*, water designated for use as domestic or municipal supply (MUN) shall not contain, at a minimum, concentrations of chemical constituents in excess of the maximum contaminant levels ("MCLs") specified in certain provisions of the California Code of Regulations, among them Title 22, §64449 Table 64449-B, which establishes "secondary MCLs" for several constituents, among them total dissolved solids. (CVRQCB, *Water Quality Control Plan for the Sacramento River and San Joaquin River Basin*, 4th ed. (1998), p. III-3.00.) MCL are established by the Department of Public Health ("DPH") and apply to drinking water provided to the public by community water systems. [17] (Cal. Code Regs., tit. 22, §64449(a).) Secondary MCLs apply to water "supplied to the public" that comes out of a tap. (Cal. Code Regs., tit. 22, §§64402.10, 64449(a).) It does not apply to water sources such as individual surface water intakes or to surface water generally." (page 23, Dec. 15, 2010)

Response: EPA disagrees. The Basin Plan is using the Maximum Contaminant Level (MCL) numbers as reference numbers defining the water quality objectives, not as MCLs. The referenced values (actually, in most cases, a range of values) are the water quality objectives for the surface water segments in question.

As discussed above, the segments in question are designated for MUN uses (Basin Plan, Central Valley Region, 2009, Table II-1, pp. II-7-8). The applicable objectives for the MUN use are defined by reference into the Sacramento and San Joaquin River Basin plan as chemical constituents that shall not exceed the MCLs specified in Title 22 of the California code of Regulations (Basin Plan, Central Valley Region, 2009, III-3). The secondary MCLs for Electrical Conductivity provide a range of values including a recommended level (900 uS/cm). EPA followed the reasonable approach of the Boards by assessing available data using the "Recommended" MCLs because they are protective of all drinking water uses. The review of the data for these four San Joaquin River segments for Electrical Conductivity shows that they are impaired for the MUN use because they do not meet the applicable water quality objectives. Thus, they were added to the 303(d) list by EPA.

A8. Comment: "Currently, MUN beneficial uses are protected by chloride objectives. (2006 Bay-Delta Plan, page 12; *see also* 1991 Salinity Plan, page 1-1.) When the Bay-Delta Plan was most recently reviewed, the secondary MCL for salinity was not even raised as a possible consideration. (2006 Bay-Delta Plan Appendix I, p. 43.)" (page 25, Dec. 15, 2010)

Response: The MUN beneficial use is designated as an "existing" use in the Basin Plan (Table II-1, page II-8.00). Questions about the validity of beneficial use designations or of the objectives adopted to protect those beneficial uses are beyond the scope of EPA's present action.

The MUN beneficial use in the Delta is protected by two sets of objectives. First, the incorporated Table III-5 from the WQCP has two specific chloride compliance stations for MUN in the Delta, neither of which is on Old River. So, under the view of the trial court in City of Tracy, there is no exceedance of those chloride objectives. Second, the Basin Plan includes "minimum" objectives to protect MUN in the "Chemical Constituents" section (page III-3.00). . The introductory language in the WQCP, at page 10, clarifies that both objectives apply: "This chapter establishes water quality objectives which, in conjunction with the water quality objectives for the Bay-Delta Estuary that are included in other State Water Board adopted water quality control plans and in water quality control plans for the Central Valley and San Francisco Bay Basins, when implemented, will: (1) provide for reasonable protection…." These Chemical Constituents objectives for MUN include both Total Dissolved Solids and Electrical Conductivity objectives. (California Code of Regulation, Title 22. Division 4. Environmental Health, Chapter 15. Domestic Water Quality and Monitoring Regulations, Article 16. Secondary Water Standards, Section 64449. Secondary Maximum Contaminant Levels and Compliance.) These objectives are stated as a "range" of values. The Boards used the most protective end of the range. EPA believes that is reasonable, given that the current task is identifying impairments of water bodies for all uses. The available data show that both the Total Dissolved Solids and Electrical Conductivity objectives are not met in Old River. Accordingly, the MUN beneficial use is impaired in this segment, and thus this segment is being included on the 303(d) list for Total Dissolved Solids and Electrical Conductivity.

A9. Comment: "Beneficial Uses for Old River were not specifically evaluated for Old River, as required by the Basin Plan. It cannot be determined what numeric criteria should apply if beneficial uses are not evaluated first. For Old River, beneficial uses must be specifically surveyed and evaluated." (page 26, Dec. 15, 2010)

Response: The commenter may be referring to footnote 8 in Table II-1 of the Basin Plan. We read the Basin Plan as fully adopting the beneficial uses as described in the table, subject to subsequent revision by the Board on a site-specific basis. This reading was confirmed by Board counsel [pers. Comm., State Board counsel Steven Blum]. Accordingly, absent some action by the Board, the beneficial uses for Delta waterways, including Old River, are those listed in Table II-1, as described above.

A10. Comment: "The correctly applied objective therefore should have been the Southern Delta salinity objectives for Old River at Middle River and Old River at Tracy Road Bridge, requiring 0.7 dS/m from April through August and 1.0 dS/m the rest of the year. While the Old River may nonetheless remain impaired, it is important that assessment occur based on the correct objective." (page 26, Dec. 15, 2010)

Response: EPA agrees as to the evaluation of Electrical Conductivity impairments for the AGR beneficial use. The assessment of Old River for Electrical Conductivity has now been evaluated using AGR (Agricultural Beneficial Uses) based on Water Quality Objectives for Electrical Conductivity. These are included in both the Basin Plan (Water Quality Control Plan for The Sacramento River and San Joaquin River Basins, September 2009, Table III-5*) and Bay-Delta Plan (Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, December 13, 2006, page 13). This assessment indicates impairment of Old River for Electrical Conductivity based on samples from 2000-2005 collected at the Tracy Boulevard

Bridge, one of the compliance points shown for Old River in both the Basin Plan and Bay-Delta Plan.

A11. Comment: "Since DO is continuously monitored at RRI and no averaging period is specified, impairment is assessed using a seven-day average of daily minimum measurements. (Listing Policy §3.2.) Since 2005, there are 293 7-day average samples and only 44 occurrences of noncompliance, sufficient to require de-listing under Section 4.2.[23]" (page 29, Dec. 15, 2010)

Response: EPA approved the San Joaquin River Dissolved Oxygen TMDL which addresses this impairment of the water body segment on February 27, 2007. Accordingly, EPA has not added the segment to the 303(d) list for this impairment.

A12. Comment: "In comments submitted in proceedings presently occurring at the SWRCB to review San Joaquin River flow and Southern Delta salinity objectives, the United States Department of the Interior ("Interior") has similarly noted that there are no intakes for community water systems in the Southern Delta area of Old River, stating –

> Salinity is regulated in the South Delta and the Lower San Joaquin River solely for protection of agricultural beneficial uses. Drinking water is protected as a beneficial use in the western Delta at Delta intakes, at a higher salinity than then [sic] most protective existing agricultural standards. There are no existing drinking water uses of the South Delta or the Lower San Joaquin River, which would require permission from the California Department of Public Health. (see attached, p. 32.)

Given that there are no existing municipal beneficial uses or other beneficial uses related to drinking water in the Southern Delta, the secondary MCL for specific conductivity was not an appropriate objective for use in decided [sic] whether Old River should be listed for Electrical Conductivity. Rather, the Southern Delta Water Quality Objectives for Agricultural Beneficial Uses are the applicable and appropriate objectives for Clean Water Act section 303(d) and for determining whether Old River should be listed for Electrical Conductivity. The correct applicable objective must be used, regardless of the final determination." (pages 1-2, Dec. 21, 2010)

Response: EPA, in this CWA 303(d) listing action, is evaluating whether the beneficial uses designated by the State are impaired. EPA is not re-evaluating whether those beneficial uses were properly adopted, EPA is evaluating impairments based on the approved Basin Plan. Both AG and MUN uses are designated "existing" uses in the Basin Plan (Table II-1, page II-8.00). The MUN beneficial use in the Delta is protected by two sets of objectives. First, Table III-5 from the WQCP has two specific chloride compliance stations for MUN in the Delta, neither of which is on Old River. So, under the view of the trial court in City of Tracy, there is no exceedance of those chloride objectives. Second, the Basin Plan includes "minimum" objectives to protect MUN in the "Chemical Constituents" section (page III-3.00). The introductory language in the WQCP, at page 10, clarifies that both objectives apply: "This chapter establishes water quality objectives which, in conjunction with the water quality objectives for the Bay-Delta Estuary that are included in other State Water Board adopted water quality control plans and in water quality control plans for the Central Valley and San Francisco Bay Basins, when implemented, will: (1) provide for reasonable protection…." Given these provisions in the approved Basin Plan, EPA disagrees with the commenter and believes that the data show impairments of the MUN beneficial use based on all applicable objectives.

B. San Joaquin River Group Authority Comments Addressing Temperature Impairment of the San Joaquin River and Tributaries

B1. Comment: The State Board's rejection of its staff's, Regional Board's or California Department of Fish and Game's (CDFG) recommendation was based on the following factors: the San Joaquin River, Stanislaus River, Tuolumne River, Merced River (collectively "Lower Tributaries") are naturally warm streams for which applying the recommended temperature criteria was not appropriate; and the State Board was not convinced that the EPA Region 10 temperature criteria that were the basis of CDFG's recommendation were appropriate criteria for Central Valley fall-run Chinook salmon in the Lower Tributaries. (page 1, Dec. 15, 2010)

Response: EPA has reviewed the State Board's action and the record of its hearing, and found no determination by the Board that the subject waters are naturally warm streams for which applying the recommended temperature criteria was inappropriate, or that the criteria recommended in the EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards, EPA 910-B-03-002 (2003) ("EPA Region 10 Guidance"), were inappropriate criteria for Central Valley fall-run Chinook salmon in those waters. See, State Water Resources Control Board Resolution No. 2010-0040, and recording of State Water Resources Control Board's hearing.

B2. Comment: "In its recommendation, the California Department of Fish and Game (DFG) never suggested that the Basin Plan temperature objective was not being met or that natural receiving water temperatures had changed to the detriment of salmon and steelhead." (page 1, Dec. 15, 2010)

Response: EPA disagrees. The letter dated February 28, 2007, from W. E. Loudermilk, Regional Manager, CDFG, to Joe Karkoski, Regional Water Quality Control Board, states in part:

> "The Department believes that one critical factor limiting anadromous salmon and steelhead population abundance is high water temperatures which exist during critical life-stages in the tributaries and the main-stem. This results largely from water diversions, hydroelectric power operations, water operations and other factors. Herein, we present water temperature results collected from the San Joaquin River (1971 through 2006), Stanislaus River (1999 through 2005), Tuolumne River (1998 through 2006), and Merced River (1997 through 2005), in support of our concern that elevated water temperatures are impairing San Joaquin Basin fishery beneficial uses and commonly exceeding the 'cool' water quality standards within the relevant Section 208 Water Quality Control Plans.
>
> Elevated water temperatures appear to be a factor in the continued decline in adult salmon escapement abundance in the San Joaquin, Stanislaus, Tuolumne, and Merced rivers, either by: i) inducing adult mortality as adults migrate into the San Joaquin River, and tributaries, to spawn (i.e., pre-spawn mortality); ii) reducing egg viability for eggs

deposited in stream gravels, iii) increasing stress levels and therefore reducing survival of juveniles within the tributary nursery habitats, and iv) reducing salmon smolt out-migration survival as smolts leave the nursery habitats within tributaries to migrate down the San Joaquin River to Vernalis and through the south Delta. For rainbow trout, potentially including anadromous steelhead, excessively warm water temperatures have the potential to limit trout population abundance by restricting juvenile and adult resident over-summer rearing habitat to very short stream reaches, due to downstream thermal regimes. As such, too few miles of suitable habitat may exist to sustain healthy population levels."

B3. Comment: "As DFG has previously explained, fall-run Chinook salmon spawned on the valley floor, downstream of the major dams, and was not significantly impacted by the construction of the rim dams. [Cite to Reynolds FL, Mill TJ, Benthin R, Low A, Restoring Central Valley Streams, A Plan for Action, California Department of Fish and Game, page IV-2 (1993).] This limited amount of spawning habitat was probably due to the deteriorating physical condition of the fish upon freshwater entry. [Cite to Yoshiyama R, Gerstung E, Fisher F, Moyle P, Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California, page 74 (2001).]" (page 1, Dec. 15, 2010)

Response: EPA believes that dams have significantly impacted fall-run Chinook salmon in the Lower San Joaquin, Stanislaus, Tuolumne and Merced rivers. EPA does not agree that the CDFG report referenced in the comment indicates that dams have had only an insignificant impact on fall-run Chinook salmon in those waters. The CDFG report is available at: http://www.dfg.ca.gov/fish/documents/Resources/RestoringCentralVallyStreams.pdf. The page of the report referenced in the comment states, in part:

> "Much of the area in which fall-run Chinook historically spawned was downstream from the major dam sites; therefore, this race was *not as severely affected* by early water project developments as were spring- and winter-run Chinook which historically spawned at higher elevations." Restoring Central Valley Streams, A Plan for Action, California Department of Fish and Game, page IV-2 (emphasis added).

The CDFG report compares the severity of the dams' effects on the three Chinook runs; however, EPA finds in the report no indication that the effect on any one of them was insignificant. To the contrary, see CDFG, Restoring Central Valley Streams, pp. I-2, I-3, I-6, III-1 thru -3, IV-6, VI-2, VII-84, VII-91, VII-99, and VII-107 (addressing dams' effects).

While Chinook salmon's distribution is unquestionably affected by their condition when entering freshwater, EPA does not interpret Yoshiyama, et al. (2001) as indicating that other factors, such as dams, have little effect. EPA notes the full statement in Yoshiyama, et al. (2001) to which the comment apparently refers does not support the commenter's assertion:

> "The fall run undoubtedly existed in all Central Valley streams that had adequate flows during the fall months, even if the streams were intermittent during other parts of the year. Generally, it appears that fall-run fish historically spawned in the valley floor and lower foothill reaches (Rutter 1904) — below 500 to 1,000 ft elevation, depending on location — and probably were limited in their upstream migration by their egg-laden and deteriorated physical condition." (page 74)

EPA also accepts many other findings in Yoshiyama, et al. (2001) related to the quality of salmon habitat formerly provided in the Lower San Joaquin, Stanislaus, Tuolumne and Merced rivers, and the current use impairments in those water bodies due to, among other things, high water temperature. See, e.g., Yoshiyama, et al. (2001), pp. 71 – 79, 85 – 107, 156, and 158.

B4. Comment: The commenter contends that it is impossible to interpret the Basin Plan's temperature-related water quality objectives without having data describing a water body's "natural receiving water temperature". The commenter provided text from the State Board's "Functional Equivalent Document, Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List" in support of its contention. (pages 1-2, Dec. 15, 2010)

Response: The State Board's "Functional Equivalent Document, Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List" (2004) is available at: http://www.swrcb.ca.gov/water_issues/programs/tmdl/docs/ffed_093004.pdf. It states, at page 133:

> "Without natural receiving water temperatures it is impossible to interpret the Basin Plan and Thermal Plan water quality objectives."

The quoted text is a part of the description of only the first of two alternative methods considered by the State for interpreting its temperature water quality objectives. However, EPA notes that the State's second alternative method clearly contemplates the interpretation and application of the temperature objectives "[w]hen 'historic' or 'natural' temperature data are not available." The State identifies the second alternative as its "recommended" alternative in those situations. The recommendation was made at least in part because that alternative "provides a mechanism for addressing potential temperature problems in the absence of often unavailable temperature background data. See, State Board, "Functional Equivalent Document, Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List", pp. 132 - 135 (2004). See also: id., at pp. 2, 39, 51, 78, 261 - 263 (addressing the purpose of providing recommendations as well as alternatives, and discussing relationship between flow modification, influences upon temperature, and use impairment). Accordingly, EPA believes it is possible to interpret and apply the State's water quality objectives related to temperature when 'historic' or 'natural' temperature data are unavailable, since the State Board's Functional Equivalent Document provides another alternative for temperature objective determinations.

B5. Comment: Unless EPA defines the term "natural receiving water temperature", it cannot conclude that the natural receiving water temperature has changed to the detriment of beneficial uses. (pages 4-5, Dec. 15, 2010)

Response: In its "Water Quality Control Plan for the Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California", the State Board defines the term "natural receiving water temperature" as "The temperature of the receiving water at locations, depths, and times which represent conditions unaffected by any elevated temperature waste discharge or irrigation return waters." Id., page 1. The State's plan is available at: http://www.waterboards.ca.gov/water_issues/programs/ocean/docs/wqplans/thermpln.pdf. In this action, EPA interprets the term as the State Board has defined it.

B6. Comment: "Although DFG generally identified diversions and dams as human activities responsible for altering stream temperatures to the detriment of beneficial uses, the assertion is unsupported by any data." (page 5, Dec. 15, 2010)

Response: The instream temperatures of the Lower San Joaquin River, Stanislaus River, Tuolumne River, and Merced River, have been altered by diversions and dams. Information supporting that conclusion is available in, e.g.:

> Lindley ST, Schick RS, Agrawal A, Goslin M, Pearson TE, Mora E, Anderson JJ, May B, Greene S, Hanson C, Low A, McEwan D, MacFarlane RB, Swanson C, Williams JG, Historical population structure of Central Valley steelhead and its alteration by dams, *San Francisco Estuary and Watershed Science* 4(1):article 3 (2006);
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> Brown LR, Bauer ML, Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: implications for fish populations, *River Research and Applications* 26(6):751-765 (2010);
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> Yoshiyama R, Gerstung E, Fisher F, Moyle P, Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California, Contributions to the Biology of Central Valley Salmonids, Fish Bulletin 179: Vol 1, p.71-176 (2001); and
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> McBain S, Trush W, Habitat Restoration Plan for the Lower Tuolumne River Corridor, Report to the Tuolumne River Technical Advisory Committee (2000), in particular pp. 12-38 (available at: http://www.fws.gov/stockton/afrp/documents/tuolplan2.pdf).

B7. Comment: "If current fishery returns in the Lower San Joaquin River, Stanislaus River, Tuolumne River, and Merced River are less than they once were, it is not due to water temperatures caused by human activities." (page 10, Dec. 15, 2010)

Response: EPA disagrees. First, the number of anadromous fish returning to the Lower San Joaquin River, Stanislaus River, Tuolumne River, and Merced River in recent years is substantially less than the number that returned to those rivers in prior periods. See:

> Marston, Dean, California Department of Fish and Game, San Joaquin River Fall-run Chinook Salmon and Steelhead Rainbow Trout Historical Population Trend Summary (2007) ("Substantial declines in fall-run Chinook salmon in the San Joaquin, Stanislaus, Tuolumne, and Merced Rivers has occurred since the 1940's and 1950's. Since the year 2000, when the most recent salmon escapement abundance high occurred, escapement has substantially declined in the Stanislaus, Tuolumne and Merced Rivers between the years 2000 and 2006.");
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> Clark, GH, Sacramento-San Joaquin Salmon (*Onchorhynchus tschawytscha*) Fishery of California. Fish Bulletin No. 17. Division of Fish and Game of California (1929) (available at http://content.cdlib.org/view?docId=kt8j49n9k8&brand=calisphere&doc.view=entire_text) (summarizing data on historical and contemporary salmon populations in the Sacramento-San Joaquin Rivers as of its publication in 1929);

Gustafson RG, Waples RS, Myers JM, Weitkamp LA, Bryant GJ, Johnson OW, Hard JJ, Pacific salmon extinctions: Quantifying lost and remaining diversity, *Conservation Biology* 21(4):1009-1020 (2007) (estimating that 57% of the historic populations of Pacific salmon in California's Central Valley are now extinct);

Lindley ST, Schick RS, Mora E, Adams PB, Anderson JJ, Greene S, Hanson C, May BP, McEwan DR, MacFarlane RB, Swanson C, Williams JG, Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento - San Joaquin Basin, *San Francisco Estuary and Watershed Science* 5(1): article 4 (2007) ("Perhaps 15 of the 18 or 19 historical populations of Central Valley spring-run Chinook salmon are extinct, with their entire historical spawning habitats behind various impassable dams (Figure 3 and Table 3).";

Lindley ST, Schick RS, Agrawal A, Goslin M, Pearson TE, Mora E, Anderson JJ, May B, Greene S, Hanson C, Low A, McEwan D, MacFarlane RB, Swanson C, Williams JG, Historical population structure of Central Valley steelhead and its alteration by dams, *San Francisco Estuary and Watershed Science* 4(1):article 3 (2006) ("Anadromous *O. mykiss* populations may have been extirpated from their entire historical range in the San Joaquin Valley and most of the larger basins of the Sacramento River."; "The extensive loss of habitat historically available to anadromous *O. mykiss* supports the status of *O. mykiss* as a species threatened with extinction.");

Mesick CA, The High Risk of Extinction for the Natural Fall-run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases. Prepared for California Sportfishing Protection Alliance, 30 November 2010 ("The decline in escapement is primarily due to inadequate minimum instream flow releases from Crocker-Huffman Dam during the spring when the daily maximum water temperatures in the lower river exceed the EPA (2003) threshold of 59°F for smoltification and to a lesser extent during late October when adult salmon are migrating upstream.");

Yoshiyama RM, Gerstung EP, Fisher FW, Moyle PB, Chinook salmon in the California Central Valley: an assessment, *Fisheries* 25(2):6-20 (2000), providing estimates for average spawning escapements of fall-run Chinook salmon during recent periods for the Mokelumne, Stanislaus, Tuolumne, and Merced rivers, and stating "Overall abundance of chinook salmon in the Central Valley system has decreased to less than 75% of their number in the 1950s. Fall-run chinook salmon in the Sacramento River basin compose by far the most abundant Central Valley stocks, but they substantially declined between 1953-1966 and 1967-1991.", and "… [T]he main arteries of the Central Valley - the Sacramento and San Joaquin rivers - are among the most disrupted rivers in the world, with hundreds of dams and diversions emplaced on the mainstems and tributaries. As the rivers were increasingly altered, chinook salmon and steelhead declined to the point where all runs of both species in the region currently are either listed as threatened or endangered under federal and state endangered species statutes or have been designated as candidates for listing (NMFS 1998a,b, 1999).";

Yoshiyama RM, Fisher FW, Moyle PB, Historical abundance and decline of Chinook salmon in the Central Valley region of California, *North American Journal of Fisheries Management* 18:487–521 (1998): "In the San Joaquin River drainage, total adult production (spawning runs plus ocean harvest) is said to have historically approached 300,000 fish (Reynolds et al. 1993)." "… [I]n the San Joaquin River drainage, estimated aggregate run sizes for the Stanislaus, Tuolumne, and Merced rivers dropped to about 600 natural spawners in 1990 and 500 spawners in 1991, and total estimated annual escapements (natural plus hatchery returns) during 1992–1994 were 1,250–4,570 fish (CDFG 1996, unpublished data)."; and

Yoshiyama et al (2001), referenced in Response B3.

Second, the reduction in number of anadromous fish returning to the Lower San Joaquin River, Stanislaus River, Tuolumne River, and Merced River is due in part to alterations in water temperatures caused by human activities. See:

Lindley ST, Schick RS, Agrawal A, Goslin M, Pearson TE, Mora E, Anderson JJ, May B, Greene S, Hanson C, Low A, McEwan D, MacFarlane RB, Swanson C, Williams JG, Historical population structure of Central Valley steelhead and its alteration by dams, *San Francisco Estuary and Watershed Science* 4(1):article 3 (2006) ("Rivers and streams on the valley floor are largely rated as unsuitable for spawning and rearing because of high summer temperatures.");

Brown LR, Bauer ML, Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: implications for fish populations, *River Research and Applications* 26(6):751-765 (2010) ("While analyses of flow regimes are critical to developing our understanding of the effects of water management on biotic resources, other factors are also important. We know that temperature is important, especially for anadromous salmonids (Moyle, 2002)"; "In unaltered California rivers, flow and temperature covary seasonally, but the installation of temperature control devices that release water from selected depths in a reservoir or other infrastructure have disconnected temperature and flow."; and noting that, in the San Joaquin River drainage, "The low flows for much of the spring, summer and fall occur during a period of high air temperatures and likely promote warmer water temperatures, which would favour the alien species.");

U.S. Fish and Wildlife Service, Final Restoration Plan for the Anadromous Fish Restoration Program, A Plan to Increase Natural Production of Anadromous Fish in the Central Valley of California (2001) (available at: http://www.fws.gov/sacramento/camp/CAMP_documents/Final_Restoration_Plan_for_the_AFRP.pdf) ("Habitat quantity and quality have declined due to construction of barriers to migration and levees, modification of natural hydrologic regimes by dams and water diversions, elevated water temperatures, and water pollution.");

McBain S, Trush W, Habitat Restoration Plan for the Lower Tuolumne River Corridor, Report to the Tuolumne River Technical Advisory Committee (2000) (available at: http://www.fws.gov/stockton/afrp/documents/tuolplan2.pdf) ("High water temperatures during rearing and smolt emigration are perhaps the most significant dam-related habitat alteration (apart from flow reduction and sediment blockage) in the Tuolumne River."; "Not only are the effects of high water temperature direct (e.g., thermal stress, mortality), but high temperatures may also contribute indirectly to other limiting factors such as bass predation, smolt survival during emigration, spawning distribution, and incubation success. …. High water temperatures are also most likely responsible for limiting habitat of yearling chinook salmon. Low summer flows and resultant high water temperatures can be lethal to summer rearing.");

Newman KB, Rice J, Modeling the survival of Chinook salmon smolts out-migrating through the lower Sacramento River system, *Journal of the American Statistical Association* 97:983–993 (2002) ("…we found the most influential covariate to be the temperature of the water into which the fish were released, with increasing temperatures having a negative association with recoveries.");

Myrick CA, Cech JJ, Temperature effects on juvenile anadromous salmonids in California's central valley: what don't we know?, *Reviews in Fish Biology and Fisheries* 14(1):113-123 (2004) ("Populations of both species of anadromous salmonid [i.e., Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (rainbow trout, *O. mykiss*)] have experienced dramatic declines during the past 100 years, at least partly from water impoundments and diversions on most central valley rivers and their tributaries. These changes restricted the longitudinal distribution of these salmonids, often forcing the superimposition of steelhead populations and Chinook salmon populations in the same reaches. This superimposition is problematic in part because the alterations to the river systems have not only changed the historic flow regimes, but have also changed the thermal regimes, resulting in thermally-coupled changes in fish development, growth, health, distribution, and survival."); and

Rich, AA, Impacts of Water Temperature on Fall-run Chinook Salmon (*Oncorhynchus tshawytscha)* and Steelhead (*O. mykiss)* in the San Joaquin River System, (2007) ("In summary: (1) Higher than optimal water temperatures are resulting in the reduced long-term survival of both the fall-run Chinook salmon and the steelhead in the San Joaquin River System; (2) Stressful and lethal water temperatures have resulted in reduced egg viability, reduced growth rates, increased disease, higher predation rates, and direct mortality; (3) The substantial decline in Chinook salmon and steelhead populations in the San Joaquin River System are due, in large part, to increased water temperatures throughout their life cycles…").

B8. Comment: "When evaluating compliance with narrative water quality objectives such as the Basin Plan Temperature Objective, the CVRWQCB must adopt, in each circumstance, numeric limitations. [Cite to Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, page IV-17.00.]" (page 11, Dec. 15, 2010)

Response: Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region states:

In many instances, the Regional Water Board has not been able to adopt numerical water quality objectives for constituents or parameters, and instead has adopted narrative water

> quality objectives (e.g., for bacteria, chemical constituents, taste and odor, and toxicity). Where compliance with these narrative objectives is required (i.e., where the objectives are applicable to protect specified beneficial uses), the Regional Water Board will, on a case-by-case basis, adopt numerical limitations in orders which will implement the narrative objectives.
>
> To evaluate compliance with the narrative water quality objectives, the Regional Water Board considers, on a case-by-case basis, direct evidence of beneficial use impacts, all material and relevant information submitted by the discharger and other interested parties, and relevant numerical criteria and guidelines developed and/or published by other agencies and organizations (e.g., State Water Board, California Department of Health Services, California Office of Environmental Health Hazard Assessment, California Department of Toxic Substances Control, University of California Cooperative Extension, California Department of Fish and Game, USEPA, U.S. Food and Drug Administration, National Academy of Sciences, U.S. Fish and Wildlife Service, Food and Agricultural Organization of the United Nations). In considering such criteria, the Board evaluates whether the specific numerical criteria, which are available through these sources and through other information supplied to the Board, are relevant and appropriate to the situation at hand and, therefore, should be used in determining compliance with the narrative objective. For example, compliance with the narrative objective for taste and odor may be evaluated by comparing concentrations of pollutants in water with numerical taste and odor thresholds that have been published by other agencies. This technique provides relevant numerical limits for constituents and parameters which lack numerical water quality objectives. To assist dischargers and other interested parties, the Regional Water Board staff has compiled many of these numerical water quality criteria from other appropriate agencies and organizations in the Central Valley Regional Water Board's staff report, *A Compilation of Water Quality Goals*. This staff report is updated regularly to reflect changes in these numerical criteria. (Basin Plan, page IV-17.00.)

EPA does not interpret the Basin Plan to preclude a water body from being listed as impaired due to nonattainment of a narrative objective until the Regional Board has also adopted a numerical limitation for that objective. EPA notes that California has listed several water bodies in the Central Valley Region as impaired due to temperature. See, listings related to Feather River, Pit River, Willow Creek, and Yuba River, in 2010 California 303(d) List of Water Quality Limited Segments (available at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/category5_report.shtml).

B9. Comment: EPA claimed that the Region 10 temperature criteria was developed based on a full range of salmon in California. (page 14, Dec. 15, 2010)

Response: In its "Review of California's 2008-2010 Section 303(d) List", EPA stated, in relevant part:

> "EPA believes that the Region 10 guidance [Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (2003)] and its associated Technical Issue Papers provide the most comprehensive compilation of research related to salmonid temperature requirements available. The studies compiled in the guidance and associated

papers address the full geographic extent of salmonid populations including California." Review of California's 2008-2010 Section 303(d) List, page 9, enclosure to letter dated Nov. 12, 2010, from Alexis Strauss to Tom Howard.

The studies compiled in the EPA Region 10 Guidance and its associated Technical Issue Papers were not limited to studies solely addressing salmonid populations in EPA Region 10. The studies compiled in the Guidance and its associated Technical Issue Papers include studies addressing salmonid populations throughout California as well as other areas. See, in particular, Issue Paper 5, Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids, pp. 24 – 31, 45, 60, 62 – 64, and 80, and the cited references at pp. 95 – 114 and Issue Paper 1, Salmonid Behavior and Water Temperature, pp. 4, 24 and the cited references at pp. 27-36 (available at: www.epa.gov/r10earth/temperature.htm).

B10. Comment: "DFG, in its Section 303(d) temperature listing recommendation, does not evaluate the studies cited by Region 10. Nor does it evaluate any other studies." (page 14, Dec. 15, 2010)

Response: The letter dated February 28, 2007 (and attachments), from W. E. Loudermilk, Regional Manager, CDFG, to Joe Karkoski, Regional Water Quality Control Board, make plain that CDFG reached its position regarding the effects of temperature and protection of anadromous fish beneficial uses in the San Joaquin, Merced, Stanislaus and Tuolumne rivers after evaluating various studies, including the EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards.

B11. Comment: "The DFG data only includes maximum daily temperature and 7DADM." (page 15, Dec. 15, 2010)

Response: EPA disagrees. The temperature data that CDFG provided is not limited to maximum daily temperatures and the 7DADMs (7 Day Average of the Daily Maxima) calculated from them. See, administrative record for "Final California 2010 Integrated Report (303(d) List/305(b) Report)", material identified as reference number 2965, "California Department of Fish and Game. 2008. Access and DSS database files of water temperature data, one each for the San Joaquin, Merced, Stanislaus, and Tuolumne rivers", available at http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/r5_ref_index.shtml .

B12. Comment: **"**The Lower San Joaquin River, Stanislaus River, Tuolumne River, Merced River should not be listed for temperature." (cover letter, Dec. 15, 2010)

Response: EPA disagrees. The San Joaquin River (Stanislaus River to Delta Boundary), San Joaquin River (Tuolumne River to Stanislaus River), San Joaquin River (Merced River to Tuolumne River), Merced River, Lower (McSwain Reservoir to San Joaquin River), Stanislaus River, Lower, and Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River), are water quality-limited segments still requiring TMDLs for temperature pursuant to CWA, sec. 303(d) and 40 CFR 130.7(b).

Applicable water quality standards for these water bodies are established in the Basin Plan for the Sacramento and San Joaquin River Basins ("Basin Plan"), available at http://www.swrcb.ca.gov/centralvalley/water_issues/basin_plans/index.shtml.

The San Joaquin River (Stanislaus River to Delta Boundary), San Joaquin River (Tuolumne River to Stanislaus River), San Joaquin River (Merced River to Tuolumne River), Merced River, Lower (McSwain Reservoir to San Joaquin River), Stanislaus River, Lower, and Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River) have the Migration of Aquatic Organisms (MIGR) designated use for Cold Freshwater Habitat (COLD) with a footnote indicating "salmon and steelhead". See, Basin Plan, Table II-1. The Merced River, Lower (McSwain Reservoir to San Joaquin River), Stanislaus River, Lower, and Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River) also have: the Cold Freshwater Habitat (COLD) designated use; and the Spawning, Reproduction, and/or Early Development (SPWN) designated use for COLD with a footnote indicating "salmon and steelhead". See, Basin Plan, Table II-1, p II-8.

A water body's designated uses are themselves components of the water quality standards applicable to the water body. See, Clean Water Act, sec. 303(c)(2)(A), and 40 CFR 130.2(d), 130.3, 130.7(b), 131.2, and 131.3.

As stated in *PUD No. 1 of Jefferson County v. Washington Dept. of Ecology*, 114 S. Ct. 1900, 1910 (1994):

> "Under the statute, a water quality standard must 'consist of the designated uses of the navigable waters involved *and* the water quality criteria for such waters based upon such uses.' 33 U.S.C. § 1313(c)(2)(A) [emphasis added by Court]. The text makes it plain that water quality standards contain two components. We think the language of § 303 is most naturally read to require that a project be consistent with both components, namely, the designated use and the water quality criteria. Accordingly, under the literal terms of the statute, a project that does not comply with a designated use of the water does not comply with the applicable water quality standards."

See also, *Northwest Environmental Advocates v. City of Portland*, 56 F.3d 979, 987-990 (9th Cir. 1995) (addressing role of non-numeric components of water quality standards, and stating "In *Jefferson County*, the Supreme Court recognized that the numerical criteria components of state water quality standards cannot reasonably be expected to address all the water quality issues arising from every activity which can affect the State's hundreds' of individual water bodies.").

California's Water Resources Control Board has also addressed the role of designated uses. See, *In the Matter of the Petitions of County Sanitation District No. 2 of Los Angeles and Bill Robinson*, State Water Resources Control Board, Order No. WQO 2003-0009, 2003 WL 25914831 (2003):

> "Standards consist of beneficial use designations *and* criteria, or water quality objectives under state law, to protect the uses. Hence, the Regional Board was required to include any effluent limits in the District's permit necessary to protect the GWR use. …. The fact that there are no criteria or objectives specific to the GWR use did not deprive the Regional Board of the ability to protect the use. *The Clean Water Act contemplates*

enforcement of both beneficial uses as well as criteria in state water quality standards." Page 2 (footnotes omitted; emphasis added).

See also:

> Flynn R, New Life for Impaired Waters: Realizing the Goal to "Restore" the Nation's Waters Under the Clean Water Act, 10 *Wyoming Law Review* 35, 42 (2010) ("Section 303 mandates three specific components of a state's water quality program. First, a state establishes the 'designated uses' of its waters. Second, a state promulgates 'water quality criteria,' both numeric and narrative, specifying the water quality conditions, such as maximum pollutant levels, that are necessary to protect the designated uses. Third, a state adopts and implements an 'antidegradation' policy to prevent any further degradation of water quality. *These three components of a state water quality program are independent and separately enforceable requirements of federal law.*") (footnotes omitted; emphasis added);
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> Adler RW, 27 *Vermont Law Review* 249, 281-286 (2010) ("…the real-world goal of the statute is to ensure not only that the nominal goal of meeting numeric criteria is met, but also to ensure that water bodies are suitable for, and actually achieve, the uses to be protected, such as propagation and support of fish and aquatic life."); and
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> Bell N, TMDLs at a Crossroads: Driven by Litigation, Derailed by Controversy?, 22 *Public Land & Resources Law Review* 61, 70 (2001) ("The beneficial use and narrative criteria are essential as gap fillers. In other words, they fill the gaps in the level of technical knowledge that we have today when we develop the numeric criteria in our water quality standards.").

To determine whether the subject reaches of the San Joaquin, Merced, Stanislaus and Tuolumne rivers are water quality-limited segments still requiring TMDLs, EPA considered their designated uses pursuant to 40 CFR 130.7(b)(3).

In order to evaluate whether the "Cold Freshwater Habitat (COLD)", "Migration of Aquatic Organisms (MIGR)" and "Spawning, Reproduction, and/or Early Development (SPWN)" uses associated with salmon and steelhead are being implemented, EPA looked at two lines of evidence. First, EPA utilized the EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards, EPA 910-B-03-002 (2003) ("EPA Region 10 Guidance"), and its supporting Technical Issue Papers to evaluate temperature data against appropriate benchmarks. The EPA Region 10 Guidance, its supporting Technical Issue Papers and related material, is available at www.epa.gov/r10earth/temperature.htm. Second, EPA evaluated the available information on historic Chinook salmon and Steelhead trout populations and the recent population declines in fall-run Chinook salmon. The subject reaches of the San Joaquin, Merced, Stanislaus and Tuolumne rivers historically sustained vast salmon and trout populations, of which three runs are now extirpated and the remaining populations show negative population trends. See response to comments B6 and B7 above.

The EPA Region 10 Guidance includes tables summarizing the recommended uses and criteria for salmonids during different periods of their lives and times of year. The criteria relevant to the species in the subject water bodies include those for: salmon/trout "core" juvenile rearing;

salmon/trout migration plus non-core juvenile rearing; salmon/trout migration; salmon/trout spawning, egg incubation, and fry emergence and steelhead smoltification. See, EPA Region 10 Guidance, Tables 3 & 4 and pp. 25 – 32. The recommended criteria were developed after a meticulous literature review documented in the technical issue papers prepared in support of the guidance. See Issue Papers 1-5.

The EPA Region 10 Guidance recommends using "the maximum 7 day average of the daily maxima (7DADM)" metric for the criteria in Tables 3 and 4. This metric is "recommended because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day." *Id.*, page 19.

In this action, EPA evaluated whether the "Cold Freshwater Habitat (COLD)," "Migration of Aquatic Organisms (MIGR)" and "Spawning, Reproduction, and/or Early Development (SPWN)" uses are being implemented in the respective reaches of the San Joaquin, Merced, Stanislaus and Tuolumne rivers. To do so, EPA determined whether those uses are supported for Chinook salmon and Steelhead trout. The evaluation included analyses related to two periods of the Chinook salmon lifecycle in the mainstem segments of the San Joaquin River: smolt downstream migration; and adult upstream migration. The evaluation also included analyses related to three periods of the Chinook salmon lifecycle in the tributary segments: spawning; smoltification and juvenile rearing; and adult migration. Further, the evaluation included analyses related to Steelhead trout during their juvenile rearing period. As part of its evaluation, EPA calculated 7DADM values using temperature data for various sites in each of the subject reaches for multiple years. EPA calculated the 7DADM values by adding the daily maximum temperatures recorded at a site on seven consecutive days and dividing by seven. EPA then identified the maximum 7DADM during each of the relevant periods in each year. The maximum 7DADM values were then compared to benchmarks consistent with the EPA Region 10 Guidance's recommended criteria. The benchmarks EPA used were:

a. for the mainstem segments of the San Joaquin River (i.e., San Joaquin River (Stanislaus River to Delta Boundary), San Joaquin River (Tuolumne River to Stanislaus River), and San Joaquin River (Merced River to Tuolumne River)):

i. during the Chinook salmon smolt out migration period (Julian weeks 11 - 24, Mar. 15 – June 15), a 7DADM equal to or greater than the salmon/trout migration criteria of 20° C; and

ii. during the Chinook salmon adult migration period (Julian weeks 36 – 43, Sept. 1 – Oct. 31), a 7DADM equal to or greater than the salmon/trout migration criteria of 20° C; and

b. for the tributary segments (i.e., Merced River, Lower (McSwain Reservoir to San Joaquin River); Stanislaus River, Lower; and Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River)):

i. during the Chinook salmon smoltification and juvenile rearing period (Julian weeks 11 – 24, Mar. 15 – June 15), a 7DADM equal to or greater than the salmon/trout "core" juvenile rearing criteria of 16° C;

ii. during the Steelhead trout summer rearing life stage (Julian weeks 24 – 37, June 15 – Sept. 15), a 7DADM equal to or greater than salmon/trout migration plus noncore juvenile rearing criteria of 18° C;

iii. during the Chinook salmon adult migration life stage (Julian weeks 36 – 43, Sept. 1 – Oct. 31), a 7DADM equal to or greater than the salmon/trout migration plus noncore juvenile rearing criteria of 18° C; and

iv. during the Chinook salmon spawning life stage (Julian weeks 40 – 50, Oct. 1 – Dec. 15), a 7DADM equal to or greater than the salmon/trout spawning, egg incubation and fry emergence criteria of 13° C.

The benchmarks used are consistent with the recommendations of the EPA Region 10 Guidance, and EPA finds that the use of those benchmarks is appropriate in this action.

For example, EPA believes that the frequency of exceedances of the 20° C 7DADM benchmark in the mainstem segments of the San Joaquin River provides an indication of the increased risk of disease, migration blockage and delay, and overall reduction in salmonid migration fitness, due to high temperature, during juvenile and adult migration in those segments. See: Temperature Guidance, Table 1; and Issue Paper 1, pp. 15 – 16; Issue Paper 4, pp. 12 – 23; Issue Paper 5, pp. 8 – 10, 13, 17, 65 – 74, and 83 – 87, and references cited therein. Similarly, EPA believes that the frequency of exceedances of the 7DADM benchmarks used for the Merced, Stanislaus and Tuolumne river segments provide indications of the temperature-related risks and impairments occurring during the respective salmonid life stages in those segments. See, Temperature Guidance, Table 1, the referenced issue papers, and cites therein.

Additionally, EPA believes that EPA's Temperature Guidance values are appropriate for use in the Central Valley. The criteria have been used by California in their 303(d) list recommendations as well as selected as targets in Total Maximum Daily Loads (TMDLs) in the North Coast Region of California (Carter 2008). They have also been used by National Marine Fisheries Service ("NMFS") to analyze the effects of the long term operations of the Central Valley Project and State Water Project, and to develop the reasonable and prudent alternative actions to address temperature-related issues in the Stanislaus River (NMFS 2009a). Reviews of appropriate temperature criteria for use in the Stanislaus have yielded findings consistent with the EPA Temperature Guidance values (Deas (2004) and Marston (2003)).

EPA also notes that a letter dated November 15, 2010 (pp 5-6) from Maria Rea, NMFS, to Alexis Strauss also supports the use of the Temperature Guidance values:

> "The use of the US EPA 2003 criteria for listing water temperature impaired water bodies in the San Joaquin River basin is scientifically justified. It has been recognized that salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. There is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards (US EPA 2001). Based upon reviewing a large volume of thermal tolerance literature, McCullough (1999) concluded that there appears to be little justification for assuming large genetic adaptation on a regional basis to temperature regimes. Prior to adoption of the revised water temperature standards for Oregon streams in 1996, there

> were separate water temperature standards assigned to salmon habitat in the western vs. the eastern portions of the state. Salmon-bearing streams in the western Cascades and Coast Range were assigned a standard of 14.4°C, but salmon-bearing streams in northeastern Oregon had a standard of 20.0°C, largely on the assumption that they would be adapted to the warmer air temperature regimes of the region. The large (5.6°C) difference in adaptation that would be required, however, is not supportable by any known literature (McCullough 1999).
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> Varying climatic conditions could potentially have led to evolutionary adaptations, resulting in development of subspecies differences in thermal tolerance. However, the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (US EPA 2001).
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> Although many of the published studies on the responses of Chinook salmon and steelhead to water temperature have been conducted on fish from stocks in Oregon, Washington, and British Columbia, a number of studies were reported for the Central Valley salmonids. Myrick and Cech (2001, 2004) performed a literature review on the temperature effects on Chinook salmon and steelhead, with a focus on Central Valley populations…
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> It is evident that the difference in thermal response is minimal in terms of egg incubation, growth, and upper thermal limit. Healey (1979 as cited in Myrick and Cech 2004) concluded that Sacramento River fall-run Chinook salmon eggs did not appear to be any more tolerant of elevated water temperature than eggs from more northern races. Myrick and Cech (2001) concluded that it appears unlikely that there is much variation among races with regard to egg thermal tolerance because data from studies on northern Chinook salmon races generally agree with those from California. They further concluded that fall-run Central Valley and northern Chinook growth rates are similarly affected by water temperature."

EPA finds that at least one of the identified benchmarks was exceeded, frequently, in each of the respective segments, summarized as follows:

San Joaquin River (Stanislaus River to Delta Boundary)

In this segment, the Chinook salmon adult migration period occurs from river mile 71 (Durham Ferry) to river mile 74.5 (above Two Rivers) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles: 71, 73.5, 74 and 74.5 from 2001 to 2005. Thirteen of 13 yearly maximum 7DADM values exceeded the 20^{o}C benchmark.

The Chinook salmon smolt out migration period occurs from river mile 71 (Durham Ferry) to river mile 74 (above Two Rivers) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles: 71, 73.5, and 74 from 2002 to 2005. Five of 7 yearly maximum 7DADM values exceeded the 20^{o}C benchmark.

San Joaquin River (Tuolumne River to Stanislaus River)

In this segment, the Chinook salmon adult migration period occurs from river mile 80 (Gardner Cove) to river mile 84 (above West Side Lift Canal) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles 80, 81, 83, and 84 from 1996 to 2006. Thirteen of 13 yearly maximum 7DADM values exceeded the 20°C benchmark.

The Chinook salmon smolt out migration period occurs from river mile 80 (Gardner Cove) to river mile 84 (above West Side Lift Canal) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles 80, 81, 83 and 84 from 1997 to 2007. Nine of 12 yearly maximum 7DADM values exceeded the 20°C benchmark.

San Joaquin River (Merced River to Tuolumne River)

In this segment, the Chinook salmon adult migration period occurs from river mile 86.2 (Dos Rios) to river mile 118 (Hills Ferry) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles: 86.2, 89, 91, 93, 117, and 118 from 1996 to 2006. Eighteen of 18 yearly maximum 7DADM values exceeded the 20°C benchmark.

The Chinook salmon smolt out migration period occurs from river mile 86.2 (Dos Rios) to river mile 118 (Hills Ferry) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles: 86.2, 89, 91, 93, 117, and 118 from 1997 to 2007. Eighteen of 20 yearly maximum 7DADM values exceeded the 20°C benchmark.

Merced River, Lower (McSwain Reservoir to San Joaquin River)

In this segment the Chinook salmon adult migration period occurs from river mile 0 (confluence with the San Joaquin River) to 52 (Merced River Hatchery) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles: 0, 1, 4, 12, 13, 21, 22, 28, 30.5, 31, 39, 40, 41, 42, 43, 44, 46, 47 and 52 from 1992 to 2007. One hundred and five of 128 yearly maximum 7DADM values during the adult migration period exceeded the 18°C benchmark.

The Chinook salmon smoltification and juvenile rearing period occurs from river mile 0 (confluence with San Joaquin River) to river mile 52 (Merced River Hatchery) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles: 0, 1, 4, 12, 13, 21, 22, 28, 30.5, 31, 39, 40, 41, 42, 43, 44, 46, 47 and 52 from 1992 to 2007. One hundred and one of 124 yearly maximum 7DADM values exceeded the 16°C benchmark.

The Chinook salmon spawning period occurs from river mile 28 (near Santa Fe Bridge) to river mile 52 (Merced River Hatchery) and Oct1-Dec15 (Julian weeks 40-50). Stream temperatures were monitored at river miles: 28, 30.5, 31, 39, 40, 41, 42, 43, 44, 46, 47 and 52 from 1991 to 2007. Ninety-five of 96 yearly maximum 7DADM values exceeded the 13°C benchmark.

The Steelhead trout summer rearing period occurs from river mile 42 (Hwy 59 Bridge) to river mile 52 (Merced River Hatchery) and Jun15-Sep15 (Julian weeks 24-37). Stream temperatures were monitored at river miles: 42, 43, 44, 46, 47, and 52 from 1992 to 2007. Thirty-one of 47 yearly maximum 7DADM values exceeded the 18°C benchmark.

Stanislaus River, Lower

In this segment, the Chinook salmon adult migration period occurs from river mile 0 (confluence with the San Joaquin River) to river mile 58 (Goodwin Dam) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles: 0, 15, 16, 19, 29, 31, 33, 34, 38, 40, 46, 54, and 58 from 1999-2007. Thirty-eight of 76 yearly maximum 7DADM values exceeded the 18°C benchmark.

The Chinook salmon spawning period occurs from river mile 33 (Jacob Meyers Park) to river mile 58 (Goodwin Dam) and Oct1-Dec15 (Julian weeks 40-50). Stream temperatures were monitored at river miles 33, 34, 38, 40, 46, 54, and 58 from 1999 to 2007. Thirty-eight of 49 yearly maximum 7DADM exceeded the 13°C benchmark.

The Chinook salmon smoltification and juvenile rearing period occurs from river mile 0 (confluence with the San Joaquin River) to 58 (Goodwin Dam) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles: 0, 15, 19, 29, 31, 33, 34, 38, 40, 46, 54, and 58 from 1999-2007. Thirty-six of 73 yearly maximum 7DADM values exceeded the 16°C benchmark

The Steelhead trout summer rearing period occurs from river mile 45 to 58 (Goodwin Dam) and Jun15-Sep15 (Julian weeks 24-37). Stream temperatures were monitored at river miles 58, 54 and 46 from 1999 to 2007. Seven of 27 yearly maximum 7DADM values exceeded the 18°C benchmark.

Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River)

In this segment, the Chinook salmon adult migration period occurs from river mile 3.4 (Shiloh Bridge) to river mile 52 (LaGrange Powerhouse) and Sep1-Oct31 (Julian weeks 36-43). Stream temperatures were monitored at river miles: 3.4, 12, 16, 16.3, 19, 21, 23.6, 26, 31, 32, 33, 35, 36.5, 36.7, 38, 39.5, 42.6, 42.9, 43.2, 43.4, 45, 45.5, 45.7, 47.5, 48.8, 49, 49.7, 50.5, 50.8, 51.6 and 52 from 1991 to 2007. Eighty three of 145 yearly maximum 7DADM values exceeded the 18°C benchmark.

The Chinook salmon spawning period occurs from river mile 26 (Fox Grove) to river mile 52 (LaGrange Powerhouse) and Oct1-Dec15 (Julian weeks 40-50). Stream temperatures were monitored at river miles: 26, 31, 32, 33, 35, 36.5, 36.7, 38, 39.5, 42.6, 42.9, 43.2, 43.4, 45, 45.5, 45.7, 47.5, 48.8, 49, 49.7, 50.5, 50.8, 51.6 and 52 from 1996 to 2007. One hundred and two of 118 yearly maximum 7DADM values exceeded the 13°C benchmark.

The Chinook salmon smoltification and juvenile rearing period occurs from river mile 3 (Grayson Rotary Screw Trap) to river mile 52 (LaGrange Powerhouse) and Mar15-Jun15 (Julian weeks 11-24). Stream temperatures were monitored at river miles: 3, 3.4, 12, 16, 16.3, 19, 21, 23.6, 26, 31, 32, 33, 35, 36.5, 36.7, 38, 39.5, 42.6, 42.9, 43.2, 43.4, 45, 45.5, 45.7, 47.5, 48.8, 49, 49.7, 50.5, 50.8, 51.6 and 52 from 1997 to 2008. Seventy-five of 137 yearly maximum 7DADM values exceeded the 16°C benchmark.

The Steelhead trout summer rearing period occurs from river mile 42.6 (Riffle K1) to river mile 52 (LaGrange Powerhouse) and Jun15-Sep15 (Julian weeks 24-37). Stream temperatures were monitored at river miles: 42.6, 42.9, 43.2, 43.4, 45, 45.5, 45.7, 47.5, 48.8, 49, 49.7, 50.5, 50.8, 51.6 and 52 from 1998 to 2007. Twenty-six of 78 yearly maximum 7DADM values exceeded the 18°C benchmark.[3]

C. Santa Ana River Dischargers' Association Comments Addressing EPA's Additions in the Santa Ana Region

C1. Comment: Santa Ana River Dischargers' Association indicated that it opposes EPA's proposal to add twelve water body-pollutant combinations, including Buck Gully Creek, San Diego Creek Reach 1, and Santa Ana River Reach 2. EPA understands the commenter to contend that EPA erroneously applied a criteria for *E. coli* to determine if the water bodies were impaired, and failed to use the applicable fecal coliform criteria established in the Water Quality Control Plan, Santa Ana River Basin. Additionally, Orange County Water District urged EPA to reconsider its decision to add the Santa Ana River Reach 2 to the list of water quality limited segments for indicator bacteria. The commenter indicates that the collaborative effort currently being undertaken by the Stormwater Quality Standards Task Force has nearly completed the preparation of a Basin Plan amendment to update bacteria water quality standards; and the commenter contends that EPA's decision to list the Santa Ana River Reach 2 as impaired for bacteria is not warranted at this time.

Response: EPA's action on November 12, 2010, added various water bodies to California's list of water quality limited segments still requiring total maximum daily loads; it did not propose to do so. EPA's action on November 12, 2010, did not add Buck Gully Creek or San Diego Creek Reach to California's list, or otherwise revise California's list with respect to those waters. EPA determined that Santa Ana River Reach 2 and the remaining water bodies referenced by the comments met the Federal requirements for listing. EPA did so after assessing: the frequency of exceedances of the fecal coliform criteria applicable to them under the Basin Plan; and the degree to which a designated use ("Water Contact Recreation (REC1)") applicable to each of them pursuant to the Basin Plan was not being attained. With respect to exceedances of the fecal coliform criteria, as EPA indicated in its November 12, 2010, determination, *E. coli* is one species within the broader category of fecal coliform, and *E.* coli monitoring data can be used to

[3] EPA notes that, even if substantially less protective benchmarks were used to evaluate the use impairments in the segments, frequent exceedances would still occur in each of the segments. For example, as noted above, the Region 10 Guidance includes a table summarizing the important water temperature considerations, and associated temperature values, for three life stages of salmon and trout. Region 10 Guidance, Table 1. For the adult migration life stage "21-22°C (constant)" is identified with the "Lethal Temp. (1 Week Exposure)" temperature consideration. *Id.* Using a benchmark 2 °C hotter than the top end of this range, to account for the difference between a constant and a 7DADM temperature, during the migration period (Julian weeks 36-43, Sep1-Oct31) in the respective reaches would still result in the following exceedances : in the San Joaquin River (Stanislaus River to Delta Boundary) the benchmark would still be exceeded by 5 of 13 yearly maximum 7DADM values; in the San Joaquin River (Tuolumne River to Stanislaus River) the benchmark would still be exceeded by 4 of 13 yearly maximum 7DADM values; in the San Joaquin River (Merced River to Tuolumne River) the benchmark would still be exceeded by 9 of 18 yearly maximum 7DADM values; in the Merced River, Lower (McSwain Reservoir to San Joaquin River) the benchmark would still be exceeded by 28 of 128 yearly maximum 7DADM values; in the Stanislaus River, Lower the benchmark would still be exceeded by 2 of 76 yearly maximum 7DADM values; and in the Tuolumne River, Lower (Don Pedro Reservoir to San Joaquin River) the benchmark would still be exceeded by 13 of 83 yearly maximum 7DADM values.

evaluate whether the fecal coliform criteria is being met. In particular, if monitoring data indicates that *E. coli* in the water body is, alone, sufficient to exceed the fecal coliform criteria, the fecal coliform criteria has not been met. With respect to nonattainment of the REC1 designated use applicable to the EPA-added water bodies, see response to comment B12, (addressing whether designated uses are themselves water quality standards to be applied when determining if a water body is impaired). EPA finds that the *E. coli* monitoring data referenced in its November 12, 2010, determination is relevant, that relying upon that data is warranted in this case, and that the data support the conclusion that the REC1 designated use for the EPA-added waters is not being attained. In addition to an analysis assessing the fecal coliform criteria, EPA assessed the data against the EPA recommended *E. coli* criteria for the protection of recreational uses. This assessment serves as additional confirmation that the recreational use is being impaired. Additionally, EPA does not agree that its determination to add Santa Ana River Reach 2 to the list of water quality limited segments should be deferred until new water quality standards are developed by the State. See, Clean Water Act, sec. 303(d)(2) and 40 CFR 130.7(d)(2), addressing the schedule for EPA's determinations. Once updated water quality standards are approved by EPA, the State can reevaluate the data during the next 303(d) listing cycle.

C2. Comment: Santa Ana River Dischargers' Association indicated that it opposes EPA's proposal to add the following water body-pollutant combinations to California's 303(d) list:

1) **Cucamonga Creek Reach 1 for copper and lead**
2) **Santa Ana River Reach 2 for cadmium copper and lead**
3) **Santa Ana River Reach 3 for cadmium and lead**
4) **Santa Ana River Reach 6 for copper and lead**

In summary, EPA understands the commenter to contend that: EPA incorrectly determined that the numeric criteria for cadmium, copper and lead in 40 CFR 131.38 were exceeded in those waters; EPA erred because it failed to apply a translator that could have been applied under Section 1.4.1 of the State Board's Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays and Estuaries of California; it is inappropriate to use "default California Toxic Rule (CTR) Translators" when assessing the subject waters; because "dissolved data" is absent, there is insufficient information to make a listing determination; and EPA's use of and extrapolations from, the available water quality data were erroneous because the data were not representative of normal conditions.

Response: On November 12, 2010, EPA added various water bodies to California's list of water quality limited segments still requiring total maximum daily loads. Additionally, EPA's action on November 12, 2010, did not add all the water body pollutant combinations noted by the commenter. EPA added lead as a pollutant causing an impairment of Cucamonga Creek Reach and Santa Ana River Reach 3, and copper and lead as a pollutant causing an impairment of Santa Ana River Reach 6.

EPA has established numeric criteria for priority toxic pollutants in California. 40 CFR 131.38. The criteria include numeric criteria for copper and lead, and those criteria are applicable to Cucamonga Creek Reach 1 (Valley Reach), Santa Ana River Reach 3, and Santa Ana River Reach 6. 40 CFR 131.38(a, b, and c). As indicated in the regulation, California has adopted and

EPA has approved criteria for some toxic pollutants in specified waters that apply instead of the criteria in 40 CFR 131.38. See, 40 CFR 131.38(b)(1), footnotes b, p through t, and x. However, the numeric criteria in 40 CFR 131.38 are applicable to Cucamonga Creek Reach 1 (Valley Reach), Santa Ana River Reach 3, and Santa Ana River Reach 6.

Section 1.4.1 of the 2000 State Board policy document to which the comment refers was amended in 2005. The section addresses procedures for calculating permit effluent limitations. Neither version of the section rendered the numeric criteria in 40 CFR 131.38 inapplicable to Cucamonga Creek Reach 1 (Valley Reach), Santa Ana River Reach 3, and Santa Ana River Reach 6. Neither version revised those criteria, or specified a method that EPA must use when it determines whether the EPA-established criteria have been met.

The EPA-established criteria applicable to those waters "are expressed in terms of the dissolved fraction of the metal in the water column." See, 40 CFR 131.38(b)(1), footnote m.

Although the criteria are expressed in terms of the dissolved fraction of the metal in the water column, monitoring data quantifying the total recoverable fraction of the metal in the water column can be used to assess whether the criteria are being met. EPA has done so here using a conversion factor for each of the metals. The conversion factors that EPA used are those identified in 40 CFR 131.38(b).

Using the 40 CFR 131.38(b) conversion factors for copper and lead is appropriate in this action. The numeric criteria in 40 CFR 131.38 applicable to those metals are themselves products of the conversion factors. Before developing the criteria that EPA is now assessing, the agency established, pursuant to Clean Water Act section 304, Guidance Values for copper and lead expressed in the total recoverable fraction. Using those "total recoverable" Guidance Values, EPA then calculated the current "dissolved" criteria for those metals by applying the conversion factors in 40 CFR 131.38(b). See, 40 CFR 131.38(b)(1), footnote m. EPA concludes that the same factors that EPA used to convert "total recoverable" to "dissolved" values can be appropriately used to convert the current "total recoverable" data to a "dissolved" equivalent.

After considering the monitoring data quantifying the total recoverable fraction of copper and lead in the water column of Cucamonga Creek Reach 1 (Valley Reach), Santa Ana River Reach 3, and Santa Ana River Reach 6, and applying the conversion factors in 40 CFR 131.38, EPA calculated the frequency with those water bodies exceeded the applicable numeric criteria. See, Table 3, Enclosure to EPA's November 12, 2010, letter. As there indicated, the data included sampling results from both wet and dry periods. EPA notes that the subject criteria apply regardless of season, and EPA concludes that the sampling data are sufficiently representative. The high frequency of exceedances of the lead criteria in all three water bodies, and the high frequency of exceedances of copper in Santa Ana River Reach 6, amply support the conclusion that those water are impaired.

D. The Center for Biological Diversity suggests that EPA must designate California's marine waters as threatened or impaired by ocean acidification.

Response: The commenter notes the growing body of evidence supporting the relationship between increased levels of atmospheric carbon dioxide and ocean acidification. However, the studies the commenter provided to EPA and to California during their public comment periods, except for three studies, do not include ambient water quality data collected in California. One study (Feely et al. 2008) estimated marine pH in California waters from dissolved inorganic carbon and total alkalinity samples, but these estimates showed attainment of California's water quality objective for pH. Another study (Hauri et al. 2009) simulated pre-industrial (1750), current (2000), and seasonal surface marine pH using models and springtime data from Feely et al. (2008). While the results from this Hauri study show a declining trend, direct comparisons cannot be made with the 2007 data from Feely et al. (2008) because monthly values were not reported for the pre-industrial year. Therefore, it is unclear whether pH values exceed 0.2 units from natural condition. The third study (Barry et al 2005) was a carbon dioxide enrichment experiment and is therefore not appropriate for assessing ambient conditions.

In the absence of specific data showing exceedance of the existing marine pH criteria, data showing impairment of California biota due to altered pH, or data demonstrating declining water quality due to acidification, EPA finds CA's omission of ocean acidification from its 303(d) list to be appropriate.

As discussed in EPA's recent 2012 Listing Guidance related to Ocean Acidification (at http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/oa_memo_nov2010.cfm) EPA recommends that for future lists, States with marine waters (such as CA) include as part of their routine integrated report data request, a provision that solicits existing and readily available water quality-related data and information, including modeling and other non-site-specific data, for marine pH and natural background conditions. Also, as stated in the guidance, currently, EPA believes that not enough information is available to develop ocean acidification-related carbon TMDLs, and is deferring development of TMDL guidance related to ocean acidification listings until more information becomes available.

E. California Coastkeeper Alliance disagreed with California's decision not to list some water bodies in the Lahontan Regional Board for pathogens.

Response: EPA solicited comment on the water bodies and associated pollutants that EPA added to the States' 2008-2010 list of water quality limited segments requiring a TMDL. The waters and associated pollutants cited by the commenters were omitted by the State from the list approved by EPA it its November 12, 2010 action. Because the State had already provided opportunities for public review and comment on its listing and delisting decisions, we did not solicit public comment on these waters and associated pollutants. Additionally, EPA believes that the Grazing Waiver is adequate justification for not identifying these water body pollutant combinations as requiring a TMDL at this time. The State and EPA will reevaluate these water body pollutant combinations in the next 303(d) list which will occur under a renewed version of the Waiver.

F. National Marine Fisheries Service commented in support of San Joaquin River from Mendota Pool to Stanislaus River for Electrical Conductivity and Old River for Total Dissolved Solids and Electrical Conductivity.

Response: EPA acknowledges the comment. With respect to electrical conductivity, EPA concludes that data show impairment for electrical conductivity in four segments of the San Joaquin River: San Joaquin River:

- San Joaquin River (Bear Creek to Mud Slough)
- San Joaquin River (Mud Slough to Merced River)
- San Joaquin River (Merced River to Tuolumne River)
- San Joaquin River (Tuolumne River to Stanislaus River)

However, further data review of San Joaquin River (Mendota Pool to Bear Creek) did not confirm clear impairment of the applicable water quality standards, so this water body segment is not included on the 303(d) list for electrical conductivity.

G. The Citizens Legal Enforcement And Restoration requested that Palo Verde Lagoon, including the bypassed lagoon, be included on the 303(d) list for bacteria.

Response: California has identified Palo Verde Outfall Drain and Lagoon as impaired by pathogens on its 2008-2010 list of water quality limited segments requiring a TMDL. EPA approved the list on November 12, 2010. (See 2010 Integrated Report (Clean Water Act Section 303(d) List / 305(b) Report) website: http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/01496.shtml#6842

Consequently EPA believes this listing satisfies the commenter's request.

H. Stewards of the Sequoia and US Forest Service requested that EPA remove several water bodies from the list of water bodies that California identified as impaired.

Response: EPA solicited comment on the water bodies and associated pollutants that EPA added to the States' 2008-2010 list of water quality limited segments requiring a TMDL. The waters and associated pollutants cited by the commenters were listed by the State and approved by EPA in its November 12, 2010 action. As the State had already provided opportunities for public review and comment on its listing and delisting decisions, we did not solicit public comment on these waters and associated pollutants. Moreover, EPA believes that it is appropriate to defer to the State's decision that the subject waters are water quality- limited segments for which TMDLs are still required. The State has discretion when evaluating the information that it assembled to develop its impaired waters list. To the extent that California's policy allows for, or even encourages, an approach for identification of impaired waters that results in a broader or more inclusive list because of how the State evaluates data or interprets its standards, such an approach would not be inconsistent with the requirements of the CWA and EPA's regulations. Furthermore, the CWA specifies that nothing in the Act precludes or denies the right of any State to adopt or enforce any requirement respecting the control and abatement of water pollution. 33 U.S.C. § 1270(1)(B); see also *S.D. Warren Co. v. Maine Board of Environmental Protection*, 547 U.S. 370 (2006) (acknowledging a state's legitimate interests in determining its desired levels of water quality and the CWA's respect for state concerns in protecting waters beyond federal standards).

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Attachment C
California State Water Resources Control Board Comments on the W&AR-6 Chinook Salmon Population Model Study Report and Workshop No.2 Draft Meeting Notes

CALIFORNIA
Water Boards

State Water Resources Control Board

SEP 2 3 2013

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, D.C. 20426

DON PEDRO HYDROELECTRIC PROJECT, FEDERAL ENERGY REGULATORY COMMISSION PROJECT NO. 2299, W&AR-6 CHINOOK SALMON POPULATION MODEL STUDY REPORT AND WORKSHOP NO. 2 DRAFT MEETING NOTES

Dear Secretary Bose:

The State Water Resources Control Board (State Water Board) has reviewed the draft Chinook Salmon Population Model Study Report (Study Report) and Draft Meeting Notes from the August 6, 2013 W&AR-6 Workshop No. 2 distributed by Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) to all relicensing parties on August 21, 2013. It is State Water Board staffs' understanding that this Study Report was developed in an effort to satisfy the Initial Study Report requirements of the Federal Energy Regulatory Commission (Commission) Integrated Licensing Process (ILP). As active participants in the ILP, State Water Board staff submits the following comments on the Study Report and Draft Meeting Notes.

Temperature Criteria

On October 11, 2011, the United States Environmental Protection Agency (USEPA) issued its final list of water bodies to be added to California's 2008-2010 list of water quality limited segments pursuant to Clean Water Act (CWA), section 303(d), and 40 CFR 130.7(d)(2). The Tuolumne River, from Don Pedro Reservoir to its confluence with the San Joaquin River, was included on this list as impaired for temperature, among other pollutants. The approval for listing was based upon the recommendation of the Central Valley Regional Water Quality Control Board (CVRWQCB) that increased temperatures in the Tuolumne River were impairing the beneficial use, as identified in the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Basin Plan), of cold freshwater habitat. In their recommendation for listing, the CVRWQCB cited six lines of evidence from the administrative record which includes temperature data on five life stages for anadromous fish as well as information on the historical and current state of the fishery. In their review of the available data, the CVRWQCB found that a large number of the historical seven-day averages of maximum (7DADM) daily temperatures exceeded the anadromous fish life stage temperature criteria put forth for the salmonids in the *USEPA Region 10 Guidance for the Pacific Northwest State and Tribal Temperature Water Quality Standards* (USEPA 2003). Additional information regarding the lines of evidence submitted by the CVRWQCB in order to support their recommendation for listing can be found on their website at:
http://www.swrcb.ca.gov/rwqcb5/water_issues/tmdl/impaired_waters_list/final_2008_303d/01263.shtml#15207.

In previous comments regarding water temperature, State Water Board staff has indicated that they generally rely upon the temperature standards for salmonids recommended by the USEPA in order to inform water quality certification conditions as these standards seem to be most protective of the designated beneficial uses of the Tuolumne River.

It is clear that water temperature is an important input into any Chinook Salmon Population Model, as it affects the species in all life stages. In the Study Report, the Districts have identified water temperature thresholds for various Chinook salmon life stages. These thresholds are based upon a literature review and are representative of what the Districts believe to be *maximum* temperature limits and are not consistent with the optimal temperature criteria put forth by the USEPA.

Since the Districts have relied upon maximum temperature thresholds, their modeling efforts indicated that water temperature has little effect on Chinook salmon life stages aside from changes in egg incubation rates and juvenile growth rates, which are affected by lower temperatures. The results indicate that there is no sensitivity to maximum spawning temperature, egg mortality threshold, and juvenile mortality thresholds. This leads the Districts to conclude that there is "little sensitivity to temperature during the times of year the fish are present" (pg. 5 of Draft Meeting Notes). The preliminary findings presented in the Study Report directly contradict the information relied upon in the listing of the Tuolumne River as temperature impaired pursuant to CWA, section 303(d). While the model may show little sensitivity to *maximum* temperature thresholds, it does not take into consideration the effects of non-optimal temperature conditions on the various life stages of Chinook salmon during which productivity would be impaired.

Model Validation

The Chinook Salmon Population Model has been developed through the ILP process, as directed by the Commission in the Chinook Salmon Population Model Study Plan. As a result, the model has not gone through independent peer-review. Submission of the Chinook Salmon Population Model to a third party for peer-review may help identify some of its strengths and weaknesses and lead to improvements. Additionally, a third party peer-review may increase the confidence of relicensing participants in the results that the models produce, making it a more useful tool in the relicensing process.

If the Districts agree to a peer-review of the Chinook Salmon Population Model, it is State Water Board staff's recommendation that they work with relicensing participants to identify an appropriate person or group for submission.

In addition to these comments, State Water Board staff acknowledges and supports the comments submitted on the behalf of the participating fishery agencies, specifically the California Department of Fish and Wildlife and the United States Fish and Wildlife Service. These agencies have specialized expertise in the evaluation of impacts to both aquatic and terrestrial biological resources which are integral components of the beneficial uses designated in the Basin Plan.

State Water Board staff appreciates the opportunity to review and provide comments on the Study Report and Draft Meeting Notes and looks forward to continued participation in the relicensing of the Don Pedro Hydroelectric Project. If you have any questions regarding this letter, please contact me at (916) 445-9989 or by email at Peter.Barnes@waterboards.ca.gov. Written correspondence should be addressed as follows:

State Water Resources Control Board
Division of Water Rights – Water Quality Certification Program
Attn: Peter Barnes
P.O. Box 2000
Sacramento, CA 95812

Sincerely,

Peter Barnes
Engineering Geologist

cc: Mr. Jim Hastreiter
Office of Energy Projects
805 SW Broadway
Fox Tower – Suite 550
Portland, OR 97205

Mr. Steven Boyd
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Mr. John Devine
HDR Engineering, Inc.
970 Baxter Boulevard, Suite 301
Portland, ME 04103

Barnes, Peter@Waterboards

From:	Staples, Rose <Rose.Staples@hdrinc.com>
Sent:	Friday, September 20, 2013 1:36 PM
To:	Barnes, Peter@Waterboards
Cc:	Devine, John
Subject:	RE: Time Extension to Submit Comments on W&AR 6

Peter, I have checked with the Districts and with John Devine, and I have their approval to extend the deadline for your comments on the W&AR-06 Workshop No. 2 draft notes until close of business on Monday, September 23rd.

From: Barnes, Peter@Waterboards [mailto:Peter.Barnes@waterboards.ca.gov]
Sent: Friday, September 20, 2013 1:25 PM
To: Staples, Rose
Cc: Devine, John
Subject: Time Extension to Submit Comments on W&AR 6

Rose,

I am requesting an extension until the close of business, Monday, September 23, 2013 to submit my comments on the W&AR 6 Meeting notes and Study Report. Due to other project commitments I have not been able to give these notes the time needed for adequate review. Please let me know if you, and the Districts, are agreeable to this request. Thank you.

Sincerely,

Peter Barnes
Engineering Geologist
Water Quality Certification Program
Division of Water Rights
State Water Resources Control Board
Phone: (916) 445-9989
Email: Peter.Barnes@waterboards.ca.gov

Attachment D
U.S. Fish and Wildlife Service Comments on
W&AR-6, Chinook Salmon Population Model Study Draft Report and
Workshop No.2 Draft Meeting Notes
for the Don Pedro Hydroelectric Project, Federal Energy Regulatory
Commission Project No. P-2299 on the Tuolumne River;
Tuolumne and Stanislaus Counties, California

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, California 95825-1846

In Reply Refer To:

SEP 20 2013

Ms. Kimberly Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Subject: U.S. Fish and Wildlife Service Comments on W&AR- 6, Chinook Salmon Population Model Study Draft Report and Workshop No. 2 Draft Meeting Notes for the Don Pedro Hydroelectric Project, Federal Energy Regulatory Commission Project No. P-2299 on the Tuolumne River; Tuolumne and Stanislaus Counties, California

Dear Ms. Bose:

Pursuant to 18 CFR § 5.15, the U.S. Fish and Wildlife Service (USFWS) files for Federal Energy Regulatory Commission (Commission or FERC) consideration its comments on the W&AR- 6 Chinook Salmon Population Model Study Draft Report and Workshop No. 2 Draft Meeting Notes that were distributed for 30 day review and comment by the Turlock Irrigation District and the Modesto Irrigation District (Applicants or Districts) for the Don Pedro Hydroelectric Project (Project), FERC No. 2299, on August 21, 2013. On August 6, 2013, the Districts held Workshop No. 2 to (1) update Relicensing Participants (RPs) on study progress; (2) demonstrate model functionality through Calibration/Validation and Base Case simulations; (3) provide updated assessment of important factors affecting Chinook salmon; and (4) solicit input on potential scenarios for evaluation. The USFWS submits the following comments and recommendations under the Central Valley Project Improvement Act (CVPIA) (Title 34, Public Law 102-575), Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. § 661 *et seq.*), and the Federal Power Act (FPA) (16 U.S.C. § 791a, *et seq.*).

The information requested herein is pursuant to the Commission's regulations under 18 CFR § 5.15. The information requested will inform the USFWS and the Commission in determining the effects of the Project on habitat availability and production of in-river life stages of Chinook salmon (*Oncorhynchus tshawytscha*) in the lower Tuolumne River, because Project operations directly affect the amount and quality of spawning habitat, floodplain rearing habitat including riparian vegetation and large woody material available to salmonids, adult and juvenile fish migration, water temperatures, and growth and survival of juvenile salmonids. The USFWS will use information from existing and new studies to inform decisions on our FPA Section 10(a) and 10(j) authorities and Section 18 Mandatory Fish Passage Prescriptions.

USFWS Goals and Objectives

The USFWS identified goals and objectives in our June 10, 2011, comment letter on the Preliminary Application Document (PAD) and Scoping Document 1, which is in the Commission record for this proceeding. The USFWS seeks to: (1) determine how various factors influence life-stage specific production of Chinook salmon in the Tuolumne River; (2) identify critical life-stages and limiting factors; and (3) develop alternative operational scenarios and conservation measures with measureable objectives. This information is critical so that the Commission can determine, as required under Section 10(a)(2)(A) of the FPA, whether the Project is consistent with the Final Restoration Plan[1] for the Anadromous Fish Restoration Program (AFRP) and its goal to double the natural production of anadromous fish under the CVPIA. This information is essential for determining the level of Project effects on native anadromous fish contributing to the AFRP goal and for determining whether the Water Quality Control Basin Plan beneficial uses of the Tuolumne River are being protected (CVRWQCB 1998). The study results will inform the development of license requirements such as water operation modifications to provide instream flow downstream of La Grange Dam to support and protect the native anadromous fish resources in the Tuolumne River.

Comments

Section 1.2
In the Relicensing Process section in the last paragraph, the Recreation Facility Condition and Public Accessibility Assessment and Recreation Use Assessment Study (RR-01) is incorrectly referenced, rather than the Chinook Salmon Population Model Study (W&AR-6).

Section 4.1
The USFWS is concerned that the information underlying the modeling to support this study did not include essential stressors and limiting factors that must be addressed in order to sustain populations. For example, reduced quantity and quality of juvenile rearing habitat is a well-known stressor on salmonid populations (Jeffres 2006, Sommer *et al.* 2001, USFWS 1995). In addition, the energetics of prey availability is an essential population driver (Brett 1995). Not including these stressors and drivers, and only looking at predation as a primary stressor, will likely bias modeling results and decision-making. Focusing on predation as a stressor but not addressing the factors that lead to predation, may misrepresent or obscure the underlying predator-prey relationships and the true sources of mortality affecting juvenile Chinook salmon. Attributes of quality rearing habitat include appropriate temperatures, cover, access to productive floodplain habitat, food availability, and appropriate depths and velocities. In the absence of quality rearing habitat, juveniles are likely to become stressed and weakened, have reduced growth rates, and become more susceptible to disease and predation.

The EPA (2003) criteria should be used to model the temperature effects on adult migration timing (Section 4.1.1.1), spawning habitat use (Section 4.1.1.2), egg incubation (Section 4.1.2.1 and 4.1.2.2), fry mortality (Section 4.1.3.4), juvenile mortality (Section 4.1.4.4), and smolt mortality (Section 4.1.5.2), because the criteria were developed to address potential chronic and

1 The Final Restoration Plan for AFRP has been filed with the Commission as a comprehensive plan.

sub-lethal effects that are likely to occur to Chinook salmon exposed to maximum weekly average temperatures. These chronic and sub-lethal effects have population-level consequences (McCullough 1999, McCullough *et al.* 2001, Wilson 2003) including reduced juvenile growth, increased incidence of disease (Holt *et al.* 1975, Holt *et al.* 1993, Nichols *et al.* 2012, Ordal and Pacha 1963), reduced viability of gametes in adults prior to spawning (McCullough 1999, McCullough *et al.* 2001), increased susceptibility to predation and competition (Mesa 1994), and suppressed or reversed smoltification (Clarke *et al.* 1981, Clarke and Shelbourn 1985, McCormick *et al.* 1999, Rowe 1990). Specific thermal requirements and water temperature criteria for salmonids can be found in Table 1 of the EPA (2003) criteria[2].

The Districts used an initial mortality threshold of 25° C average daily water temperature for Chinook salmon fry (Section 4.1.3.4), juveniles (Section 4.1.4.4), and smolts (Section 4.1.5.2) which is not consistent with daily water temperature dynamics, Chinook salmon biology, or the EPA (2003) criteria. Daily averages do not account for the maximum temperatures that fish are actually exposed to, nor do they account for sub-lethal effects. For instance, the most significant health issues that have been observed in the San Joaquin tributaries are *Renibacterium salmoninarum* (the causative agent of Bacterial Kidney Disease) and *Tetracapsuloides bryosalmonae* (causative agent of Proliferative Kidney Disease) infection in the out-migrant Chinook salmon during April and May. Advanced signs of kidney inflammation were observed by histopathology in 50 percent of out-migrant smolts captured in May 2012 from the Merced River and may be prevalent in the Tuolumne River in certain years. This disease can compromise fish performance in many areas (swimming, salt water entry, disease resistance) and decreases the potential for juvenile fish to survive during out-migration (Nichols *et al.* 2012).

The Districts did not represent in the model a parameter that incorporates adult fish mortality during upmigration and spawning due to elevated water temperature (Section 4.1.1.3). Susceptibility of adult Chinook salmon to diseases such as columnaris (*Flavobacterium columnare*) in water temperatures >15° C has been well established (Holt *et al.* 1975; Holt *et al.* 1993). Water temperatures of 20°C resulted in nearly 100 percent mortality of Chinook salmon during columnaris outbreaks (Ordal and Pacha 1963). Fatal infection rates caused by *C. columnaris* are high at temperatures greater than or equal to 17.8°C (EPA 2001). In addition, while it is correct that no specific studies have been conducted to assess the response of Chinook salmon to instream temperatures during the upstream migration, CDFW has found that female Chinook returning to the Merced Hatchery experience substantial reductions in egg viability following migration through warmer waters (CDFW unpublished information). Chinook salmon embryos from adults held at 17.5°C to 19°C had greater numbers of pre-hatch mortalities and developmental abnormalities than embryos from adults held at 14°C to 15.5°C (Berman 1990). The Districts also used a water temperature threshold of 16°C for spawning to adjust their spawning area estimates but these should also be consistent with the EPA (2003) criteria for spawning (Section 4.1.1.2).

The fry growth methodology section needs additional detail (Section 4.1.3.3). It is unclear how ration levels were developed for the two in-channel reaches characterized [river mile (RM) 52.2

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2 EPA (2003) water temperature criteria can be accessed at:
http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

to RM 17.2 and RM 17.2 to RM 0] or how these are used to develop fry growth estimates. Further, the report states that higher growth rates have been observed in published floodplain rearing studies, but does not seem to incorporate a higher overbank habitat ration level into the model.

It is unclear how the linear regression of log-weight and log-length of Tuolumne River Chinook salmon was incorporated into the model. The USFWS recommends that the model incorporates empirical growth or length–weight relationship data from the Tuolumne River. A comparison with length-weight relationship data from other Central Valley rivers may be useful in further refining growth estimates for the model (*e.g.,* Castleberry *et al.* 1991, Castleberry *et al.* 1993) or for use in the sensitivity testing for the ration and size at smoltification parameters (Table 4-6).

Off-channel habitats (overbank and floodplain) in California have been shown to be very important ecological drivers, because they increase both the growth and survival of juvenile salmonids (*e.g.*, Sommer *et al.* 2001, Jeffres 2006). The contribution of off-channel habitat function to salmonids in the lower Tuolumne River has not been studied, although preliminary evaluations have shown significant differences on fish size and survival across different water year types (USFWS, unpublished data) with different floodplain inundation amounts.

The USFWS requests that the amount of fry rearing habitat available as a function of river discharge be shown more clearly. Figures 4-5 and 4-6 illustrate these relationships separately, but the habitat-discharge relationship would be clearer if the data were combined in one graphic showing total usable area for each reach at river discharges ranging from 0 to 8,400 cfs. Benefits to fish populations specifically from seasonal floodplain inundation are thought to be linked to reduced predation rates, increased habitat availability, and increased food supply (Bennett and Moyle 1996). Floodplain activation flows that trigger these conditions typically occur in the spring, are relatively frequent, and are of long duration (Philip Williams & Associates, Ltd. and Opperman 2006). Therefore, additional information is needed to not only evaluate the amount but also the frequency and duration of floodplain inundation of off-channel habitats at various flows. The USFWS requests that the floodplain inundation analysis from the W&AR 21 Floodplain Inundation Study be used to update the estimate of suitable habitat availability for fry and juvenile rearing at higher flows, including (a) observed La Grange Flows, (b) Unimpaired Flows, (c) percent of unimpaired flows that were evaluated in the Substitute Environmental Document (ICF International 2012), and (d) USFWS (2005) Chinook doubling flow recommendations.

Section 4.2

The current iteration of the model lacks the energetic input of nutrients as a population driver. The relationship between large woody material (LWM) and large woody debris (LWD) with nutrients, prey availability, and cover has been overlooked in the model or it was unclear how such factors may have been indirectly incorporated. The importance of LWM and LWD to salmonid rearing and to the energetics of the riparian ecosystem are well understood (Cederholm *et al.* 1997, Montgomery and Piégay 2003), as is the importance of marine-derived nutrients and salmon carcass contribution to the riparian ecosystem (Cederholm *et al.* 1999, Gende *et al.* 2003, Quinn *et al.* 2009, Schindeler *et al.* 2003, Wilzbach *et al.* 2005).

Section 4.2.1
The demographics of populations include age structure as a mechanism for considering population growth, stability, and viability. The USFWS recommends that age structure be a component of the model or be modeled separately and used as a model input for Upmigration and Spawning (Section 4.2.1). The Districts state that the model must be provided with a "spawning run" that may include the age or size of each spawner and from such values we assume that fecundity estimates are derived. We support this approach but would need further clarification on how this is incorporated into the model.

Section 4.2.3, 4.2.4
The Districts state that the stock production model uses a maximum fry rearing density value of 1.496 ft^{-2} (Table 4-3) and a maximum juvenile rearing density of 0.465 ft^{-2} (Table 4-4). Estimating fry carrying capacity based upon maximum attainable densities from the seine surveys (Attachment B) or from snorkel surveys overestimates carrying capacity, because not all fry rearing habitat in the Tuolumne River is optimum. The USFWS recommends estimation of fry rearing habitat carrying capacity based upon average densities for discrete habitat suitability categories. The Districts do not present any rationale on how the rearing density parameter ranges (*i.e.*, Min, Max) that were tested in the sensitivity analyses were determined (Table 4-6). The USFWS recommends that values from observed ranges in Central Valley streams be used for the sensitivity testing.

Section 4.5 Evaluation of Juvenile Chinook Salmon Production under Current and Potential Future Project Operations Scenarios
The Districts estimated juvenile Chinook salmon production at three levels of spawning escapement: 200 female spawners (Low), 2,000 female spawners (Medium), and 10,000 female spawners (High). The USFWS recommends that the High level use 19,000 female spawners in order to evaluate the factors limiting achievement of the AFRP doubling goal target in the Tuolumne River (USFWS 2001). The USFWS would like to determine from the model how much spawning and rearing habitat, discharge, and temperatures are needed to meet the CVPIA and Water Quality Control Basin Plan doubling goal production targets (CVRWQCB 1998). Additionally, the USFWS requests that the Districts evaluate juvenile Chinook salmon production under the following Project operations scenarios: (a) observed La Grange Flows (*i.e.*, base case), (b) Unimpaired Flows, (c) percent of unimpaired flows that were evaluated in the Substitute Environmental Document (ICF International 2012), and (d) USFWS (2005) Chinook doubling flow recommendations.

Conclusion

The USFWS appreciates the opportunity to comment on the W&AR- 6 Chinook Salmon Population Model Study Draft Report. The USFWS may submit additional comments once we receive a copy of the stock production models and have adequate time to review the large amount of information, model parameters, site specific data, and references that were presented in the Draft Report. With some clarification, revision, and the additional requested analysis, the information presented in the draft study report has the potential to provide valuable results that will inform the development of Project license conditions. The USFWS commends the Districts for their willingness to incorporate our comments and suggestions in a collaborative effort and all the insightful information that was presented at the workshop. We look forward to our continued participation in the development of the quantitative salmon production model for the Tuolumne River. If you have any questions regarding this response, please contact Alison Willy of my staff at (916) 414-6600.

Sincerely,

Daniel Welsh
Acting Field Supervisor

Enclosures

cc:
Rose Staples, HDR Engineering, Portland Maine
FERC #2299 Service List, Don Pedro Hydroelectric Project

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BEFORE THE
UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

CERTIFICATE OF SERVICE

I hereby certify that U.S. Fish and Wildlife Service Comments on W&AR-6, Chinook Salmon Population Model Study Draft Report and Workshop No. 2 Draft Meeting Notes for the Don Pedro Hydroelectric Project, Federal Energy Regulatory Commission Project No. P-2299 on the Tuolumne River; Tuolumne and Stanislaus Counties, California has this day been electronically filed with the Federal Energy Regulatory Commission and electronically served on Parties indicating a willingness to receive electronic service and served, via deposit in U.S. mail, first-class postage paid, upon each other person designated on the service list for Project No. 2299 compiled by the Commission Secretary.

Dated at Sacramento, California, this 20th September, 2013.

Name:
Heeja Seto
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Attachment E
Tuolumne River Trust and California Sportfishing Protection Alliance Comments on W&AR-6 Chinook Salmon Population Model Workshop No. 2 Draft Meeting Notes

Tuolumne River Trust

September 20, 2013

Steve Boyd
Turlock Irrigation District
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Greg Dias
Modesto Irrigation District
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Modesto, CA 95352

RE: Don Pedro Project (FERC Project P-2299) Comments on W&AR-6 Chinook Salmon Population Model Workshop No. 2-Draft Meeting Notes.

Dear Messrs. Boyd and Dias:

Tuolumne River Trust (TRT) and California Sportfishing Protection Alliance (CSPA) submit these comments on the W&AR-6 Chinook Salmon Population Model Workshop No. 2-Draft Meeting Notes.

<u>Background</u>
On August 6, 2013, the Turlock Irrigation District and Modesto Irrigation District (collectively the Districts) conducted the second workshop for the Chinook Salmon Population Model. The workshop was conducted in accordance with the study plans prepared for this study and approved by the Federal Energy Regulatory Commission (FERC) in its December 22, 2011 Study Plan Determination (SPD).

The purpose of this workshop was to (1) update Relicensing Participants (RPs) on study progress; (2) demonstrate model functionality through Calibration/Validation and Base Case simulations; (3) provide updated assessment of important factors affecting Chinook salmon; and (4) solicit input on potential scenarios for evaluation.

<u>Comments</u>
The Tuolumne River Chinook Salmon Population Model Study (Tuolumne Model) is intended to *"…address the association between flows, water temperature, changing habitat conditions, predation, and the population response for specific in-river life-stages including smolts for existing conditions and for potential future conditions*." (Draft Report, p. 1-5). The goal of this study is "…*to provide a quantitative salmon production model to investigate the influences of various factors on the life- stage specific production of Chinook salmon in the Tuolumne River, identify critical life-stages that may represent a life-history "bottleneck," and compare relative changes in population size between potential alternative management scenarios.*" (Draft Report 2-1). We note several issues and or inaccuracies in the model that I believe would make it inadequate to its intended purposes.

I. The model has not been successfully validated and is specific to historical relationships with reservoir operations; thus, its use as a forecasting tool is not recommended.

II. The model does not account for impacts to Tuolumne River salmonids of flow conditions in the San Joaquin River below the confluence of these two rivers; thus it is only a first step in a piecemeal approach to evaluating the impact of Tuolumne River flows on Tuolumne River salmonids.

III. The model assumes environmental tolerances for fall run Chinook salmon that exceed those documented in the available literature. In addition, though the model was not intended to address population response of federally threatened steelhead to environmental conditions on the Tuolumne, FERC staff and others should be aware that *O. mykiss* have very different ecological requirements than Chinook salmon; thus, operating Don Pedro Reservoir towards the environmental conditions identified (inaccurately) in this report as suitable for Chinook salmon may produce adverse effects for other fishes in the Tuolumne River, including steelhead and spring-run Chinook salmon, whose migration to the Tuolumne is anticipated.

I. The model has not been validated and thus its use as a forecasting tool is not recommended

In general, models are sets of hypotheses about the nature of real-world relationships. Model outputs are thus predictions that can be used to test the validity of the suite of hypotheses the model embodies; hence the saying “all models are wrong; but some models are useful”. Models based on historical data relationships are subject to the assumption (among many) that historical relationships will be maintained in the future – this is a risky supposition when relationships that are key to the model are subject to change (in this case, relationships that are determined by reservoir operations which may be re-conditioned during the licensing process). In general, it is not advisable to rely on model outputs as predictions of the future until a model has demonstrated its ability to predict future events with accuracy. The Tuolumne Model is particularly suspect in this regard because

- key attributes of the model are based on very small data sets,
- it substitutes deterministic relationships (e.g. size-fecundity of adult spawners, temperature-mortality relationships at different life stages) that are well-known to be much more subtle, and
- the model validation runs (section 5.2 of the Study Report) are distinctly unimpressive

Some aspects of the model rely on extremely short time series. For example, the model’s empirically-based estimate of spawner arrival relies on only 4 years of data (2009-2012). In those 4 years, the onset of spawner passage differs by ~ 3 weeks and the completion of spawner passage differs by up to ~1.5 months among years studied (see Study Report; Figure 4.1). Even when a longer data set (1992-2010) is used to estimate spawner arrival timing, major differences among years are evident (*see* Study Report; Figure 4.2). This high degree of variance probably reflects actual behavioral differences among returning spawners within and among years, however, it lends little support to the model’s estimation of “average” run-timing/egg deposition for this population and, since, flows and temperatures are dependent on the season when they are measured, the error that results from averaging widely divergent estimates could produce very different modeled outcomes. Similarly, inputs to the model regarding Chinook salmon environmental requirements (nest size) and life history attributes (fecundity-size relationships, egg weight, etc.) are based on data from just one or two years. Although some of these measurements are averages of large numbers of individuals, the fact that the measurements were all taken during one or two years reveals that the numbers used reflect conditions *only* in those years – inter-annual variance (as seen in just about every aspect of Chinook salmon life history) is completely ignored.

Also, the Tuolumne model is, for all its detail, a very simple representation of Chinook salmon life history and ecology. All the relationships are highly deterministic when, in fact, Chinook salmon exhibit an amazing plasticity in their response to environmental changes below lethal thresholds (Healy 1991; Moyle 2002; Quinn 2005). Also, the relationships built into the model are subject to large amounts of error due to natural (and well documented) individual and inter-annual variation. For example, the predictive power of body size for estimating female fecundity is notoriously low for Pacific salmon and Chinook salmon, in particular; typically, female body size explains less than 50% of the variation in fecundity (Healy 1991; Quinn 2005). Reliance on such a relationship (particularly one derived from very few cohorts of returning salmon) will generate outputs that are subject to high variance. As a result, model outputs that are based on these estimated "average" inputs are highly suspect. Similarly, the model treats temperature as either "lethal" or "non-lethal" when, in fact, temperatures below lethal have a wide range of effects on everything from salmon growth, to life history (migration timing, age at first reproduction), and anti-predator success (Healy 1991; Quinn 2005; Myrick and Cech 2004, 2005; Marine and Cech 2005).

In addition, the validation runs presented in the Study Report do not instill confidence in the model's output. Basically, the model is somewhat successful at predicting field results from the year 2010-2011; however, in the small number of other years available for validation[1], model outputs appear to differ from field data by a factor of ~2x. This suggests that the model is more accurate under the generally positive conditions of high flow years like 2010-2011 than it is under low-flow years that form the rest of the study period.

Finally, as described below, the model is not designed to evaluate impacts to Tuolumne River salmon that occur beyond the confluence, despite the fact that these impacts are partly determined by the quantity and quality of water emerging from the Tuolumne into the San Joaquin. Because it is blind to the fates of salmon beyond the mouth of the Tuolumne, sequential predictions (i.e. using outputs of one modeled year as inputs to a subsequent year to establish a time series for the population) that would be necessary to understand the cumulative effects over generations of operational changes to river flows, are not possible with this model.

II. **The model does not account for impacts to Tuolumne River salmonids of flow conditions in the San Joaquin River below the confluence of these two rivers.**

Based on review of scientific information presented to the State Water Resources Control Board in 2010, the Board concluded that flows entering the Delta from the San Joaquin River would need to increase dramatically in order to protect public trust fish and wildlife resources including, in particular, San Joaquin River Chinook salmon. In particular, the State Board found:

> *Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide*

[1] It is still not clear whether the authors "validated" the model with data they used to construct the model; such a scenario would be problematic.

conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow, though the time periods are somewhat different (AFRP is for February through May and DFG is for March 15 through June 15). Available information also indicates that flows of 3,000 to 3,600 cfs for 10 to 14 days are needed during mid to late October to reduce straying, improve olfactory homing fidelity, and improve gamete viability for San Joaquin basin returning adult Chinook salmon. [SWRCB 2010: 119]

It is difficult to imagine that San Joaquin River inflows to the Delta approaching those the Board found to be necessary could be attained if the Tuolumne River were only providing flows found to be sufficient by the TID/MID salmon production model for the Tuolumne.

Model inputs reflect only conditions on the Tuolumne River; but freshwater flow rates in the Tuolumne have direct and indirect impacts on conditions that Tuolumne River salmon will experience in the San Joaquin River, below the confluence of these two rivers. Isolating the effect of Don Pedro reservoir operations on Chinook salmon only during their residence in the Tuolumne River is arbitrary – the fish and the water released from the reservoir experience the Tuolumne, San Joaquin, and freshwater Delta as a river continuum. Stopping the analysis of Tuolumne River reservoir operational impacts on Tuolumne River Chinook salmon at the confluence with the San Joaquin denies the physical reality of this continuum and may result in management that "solves" problems in the Tuolumne while exacerbating actual population bottlenecks that result from Tuolumne River operations and manifest downstream.

The Tuolumne is a major tributary of the San Joaquin River. Flow conditions on the lower San Joaquin River are heavily influenced by reservoir operations at Don Pedro. The table below reveals the relative contributions of the Tuolumne River to flows in the San Joaquin where it enters the Delta (i.e. Vernalis). Without Central Valley dams and diversions ("unimpaired"), the Tuolumne would account for approximately 1/3 (range: 27-37%) of San Joaquin Valley flows into the Delta (not counting the Mokelumne system, which joins the San Joaquin in the Delta). Because of differential diversions from the Tuolumne relative to other San Joaquin Basin waterways, the Tuolumne actually delivers only one-quarter of the San Joaquin's flow into the Delta. In other words, freshwater in the Tuolumne River is more heavily developed than other contributors to San Joaquin Valley flow into the Delta.

Percentage of Vernalis Flows (Mar-Jun) Delivered by the Tuolumne River; 1985-2010

	Unimpaired	**Actual**
Maximum Year	37%	47%
Minimum Year	27%	11%
Median Year	33%	25%
Mean	32%	27%

"Unimpaired" represents flows at the Tuolumne Rim Station (Below LaGrange). Actual refers to actual flows measured near Modesto, CA.

In addition to flow volumes, temperatures on the Tuolumne influence temperatures on the San Joaquin River below the confluence. Water temperatures on the Tuolumne River are, in turn, influenced by seasonal and ambient temperatures, release rates from Don Pedro Reservoir, and storage at the reservoir. Thus, considering the impact of Tuolumne River releases only within the geographical limits of the Tuolumne River misses the true impact of flow schedules on the Tuolumne as these influence flow and temperature conditions on the San Joaquin directly and indirectly (through their impact on carryover storage).

All anadromous fish spawned on the Tuolumne must migrate through the mainstem San Joaquin on their way to and from the San Francisco Estuary and Pacific Ocean. Flow and flow-related conditions (temperature, dissolved oxygen, habitat availability) in the lower San Joaquin are inextricably linked to flow levels on the Tuolumne and specifically, reservoir releases from Don Pedro Dam/Reservoir. Thus, reservoir operations on the Tuolumne affect salmon growth and survival to reproduction on both their downstream journey (as juveniles/smolts) and upon their return from the ocean. The model's myopic focus on salmon survival/growth in the Tuolumne River proper ignores the crucial role of Tuolumne River flow rates throughout the freshwater life stages of Chinook salmon from this drainage.

For example, temperature conditions in the lower San Joaquin River affect Chinook salmon survival and growth in the lower San Joaquin River just as they do in the Tuolumne River. Maintenance of acceptable spring temperatures for Chinook salmon juveniles in the lower San Joaquin River requires greater rates of flow from the San Joaquin's tributaries than would be required to maintain temperatures on the tributaries themselves because water gains heat as it flows towards the Delta and the rate of heat gain is inversely proportional to the flow rate. Cain et al (2003) determined empirically that flow ≥5,000cfs in late May corresponded to temperatures tolerated by juvenile Chinook salmon, but that temperatures exceeded Chinook salmon tolerances when flows were <5,000 cfs at Vernalis in the late spring. The effect of Tuolumne River flow rates on survival of juvenile Chinook salmon cannot be evaluated without also incorporating the effect of Tuolumne River flow rates on water temperature in the lower San Joaquin River Valley.

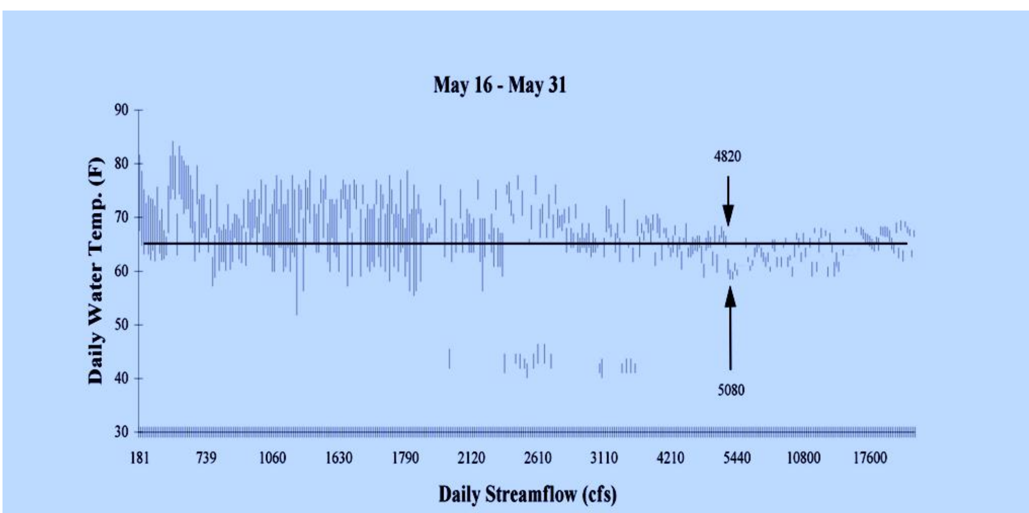

Figure from Cain et al. 2003 showing relationship of San Joaquin River flow and temperature at Vernalis during the late-May migration period for juvenile Chinook salmon. The horizontal line represents an important temperature threshold for emigrating salmon. Note that temperatures are reliably less than this threshold when flows exceed ~5000cfs.

The California Department of Fish and Wildlife has demonstrated a strong statistical connection between flow rates in the lower San Joaquin River Valley (e.g. at Vernalis) during late spring when Chinook salmon are emigrating from the river and subsequent return of adult Chinook salmon to the Tuolumne River and other tributaries (CDFW 2013). Based on that relationship (and the likely mechanistic relationship between river flow and salmon success), the Department developed flow recommendations for the lower San Joaquin River that are believed to be necessary to maintain and restore fall run Chinook salmon to the San Joaquin's tributaries, including the Tuolumne. These flow recommendations assumed a proportionate contribution to lower San Joaquin River flows from the San Joaquin's main tributaries (i.e. allocation of all flows necessary to achieve these targets to one or two tributaries would not be expected to result in the intended conservation and recovery of Chinook salmon).

Table 6: Delta (Vernalis) Flows Needed to Double Smolt Production at Chipps Island (by Water Year Type)

	Water Year Type				
Flow Type	Critical	Dry	Below Normal	Above Normal	Wet
Base (cfs)	1,500	2,125	2,258	4,339	6,315
Pulse (cfs)	5,500	4,875	6,242	5,661	8,685
Pulse Duration (days)	31	40	50	60	70
Total Flow (cfs)	7,000	7,000	8,500	10,000	15,000
Acre-Feet Total	614,885	778,772	1,035,573	1,474,111	2,370,768

[CDFW Flow Objectives for the lower San Joaquin River necessary to protect and restore fall run Chinook salmon in the San Joaquin Basin. Table 6 from CDFW (2010)].

Furthermore, the success of Tuolumne River Chinook salmon adults migrating upstream to spawn is influenced by flow rates on the lower San Joaquin River, which in turn are heavily influenced by flow rates in the Tuolumne River. This contradict the Study Report's implication that Chinook salmon adult migrations are unaffected by Tuolumne River flows (e.g. at page 4-1).
For example, Marsten et al (2012) found:

> [San Joaquin River] *salmon stray rates were negatively correlated (P = 0.05) with the average magnitude of pulse flows (e.g., 10 d) in mid- to late-October and positively correlated (P = 0.10) with mean Delta export rates*[2]*. It was not possible to differentiate between the effects of pulse flows in October and mean flows in October and November on stray rates because of the co-linearity between these two variables. Whether SJR-reduced pulse flow or elevated exports causes increased stray rates is unclear. Statistically speaking the results indicate that flow is the primary factor. However empirical data indicates that little if any pulse flow leaves the Delta when south Delta exports are elevated, so exports in combination with pulse flows may explain the elevated stray rates.* [Marsten et al. 2012: Abstract]

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[2] San Joaquin River salmon refers to salmon spawning in the river's three main tributaries (Stanislaus, Tuolumne, Merced) as salmon have not spawned in the mainstem San Joaquin River for several decades.

Also, the lower San Joaquin River frequently experiences periods of low dissolved oxygen (in violation of Clean Water Act standards) that have the potential to block upstream migration of adult Chinook salmon (Hallock et al. 1970) and other native fishes (CVRWQCB and CBDA 2006); downstream migrations may also be affected as low DO events have been recorded in every month of the year. Dissolved oxygen levels in the Stockton Deepwater Ship Channel are positively related to flow rates in that area (Van Niewenhuyse 2002; Jassby and Van Niewenhuyse 2005) specifically, when flows are <~1,000cfs in the ship channel (corresponding to flows of ~2,000cfs at Vernalis, before water is distributed among Old and Middle River channels) low DO events are much more common than when flows exceed that level. Again, flows from the Tuolumne River are major determinants of flow rates in the lower San Joaquin River.

III. The model assumes environmental tolerances for fall run Chinook salmon that exceed those documented in the available literature. In addition, though the model was not intended to address population response of federally threatened steelhead to environmental conditions on the Tuolumne, FERC and others should be aware that *O. mykiss* have very different ecological requirements than Chinook salmon; operating Don Pedro Reservoir towards the environmental conditions identified (inaccurately) in this report as suitable for Chinook salmon may produce adverse effects for other fishes in the Tuolumne River, including steelhead.

The Model Study indicates temperature thresholds that were applied to different Chinook salmon life stages. Below is a table that reveals where temperatures used in the Tuolumne Model differ from generally accepted levels. In many cases, these temperatures are not in line with generally accepted temperature standards or those found in studies specific to Central Valley populations of Chinook salmon. Furthermore, there is little recognition of the numerous ways in which temperature affects fish ecology including metabolic rates and requirements for food, predator activity and success, growth rates, migration rates, condition, etc. The relationships between river water temperature, reservoir release rates, and carryover storage have the potential to change model outputs significantly if assumptions about temperature thresholds (including sub-lethal effects) are altered. In particular, The Tuolumne Model appears to allow for substantially higher temperatures to persist during egg, juvenile, and smolt life stages than most scientists and trustee agencies would allow – this would likely reduce projected demand for coldwater storage behind the reservoir and/or coldwater releases during the critical Mar-Jun period.

Estimated temperature thresholds for various Chinook salmon life stages input into the Tuolumne Salmon Model vs. those reported in the literature (^{o}C)

Life Stage	Central Valley specific estimate[A]	EPA 2003	Richter & Kolmes 2005	Tuolumne Model
Egg Incubation	<13.3 (6-12 Optimal)	<13.0	<11-12 (adjusted 7-day average of the daily maximum temperatures; 7-DAM) <13.5-14.5 (individual daily maximum temperature limits; 1-DM)	14.4

Juvenile Rearing	<24-25 (UILT; Upper Incipient Lethal Temp.) <22-24[2] (UILT; Upper Incipient Lethal Temp.) >20[1] (Negative sublethal effects) <17[1] (Optimal)	18	12-17 (Optimal)	25
Smolt **(incl. inhibition of metapmorphosis)**	20[1] (smoltification inhibited)		>17 (smoltification inhibited)	25
Returning Adult		20	<20-21	16
	[A]Central Valley specific estimates, except where otherwise indicated, source: Myrick and Cech (2004) [1]Marine and Cech (2004) [2]Baker et al. 1995			

The model also does not account for negative effects that occur below lethal limits. For example, all temperature limits are specified as those where "mortality increases from 0% to 100%". It is biologically unrealistic to consider a particular temperature to be 100% lethal and all conditions with temperatures below this threshold temperature to be 100% non-lethal. Also, "sub-lethal effects" (those that may increase susceptibility to other mortality mechanisms or reduce fecundity/fertility) are well-documented in the literature on Chinook salmon. Negative sub-lethal effects begin to occur at temperatures lower than lethal thresholds. In the laboratory, when fish have access to full rations, growth of juvenile salmonids increases with temperature up to fishes' physiological limits; however, when food supply is limited (as it often is under normal conditions in the field) optimal growth occurs at lower temperatures. Among juvenile fall run Chinook salmon from California's Central Valley population, Marine and Cech (2004) found decreased growth, smoltification success, and ability to avoid predation at temperatures above 20^{o}C. They also reported that fish reared at temperatures 17-20^{o}C experienced increased predation relative to fish raised at 13-16^{o}C, although they found no difference in growth rate among fish reared in these two temperature ranges. The finding of decreased performance at temperatures above 17^{o}C is consistent with several studies that suggest optimal growth and survival among Chinook salmon occurs at temperatures somewhat lower than 17^{o}C. Richter and Kolmes (2005) cite optimal temperatures in the range of 12-17^{o}C.

The Tuolumne Model does not document differences in temperature sensitivity for steelhead, though imperiled steelhead do spawn and rear in the Tuolumne River. Optimal incubation temperatures for steelhead eggs occur in a narrower range than those for Chinook salmon. Indeed, Myrick and Cech (2004) warned against managing water temperatures for the upper end of the Chinook salmon thermal tolerance range in waterways and during periods when steelhead are also incubating because incubating steelhead cannot tolerate such high temperatures. Richter and Kolmes (2005) concluded that egg mortality increased as incubation temperatures exceeded 10°C. Based on experience at hatcheries in the Central Valley, optimal incubation temperatures appear to be in the 7-10°C range (Myrick and Cech 2004). California's steelhead management plan (CDFG 1996) suggests a slightly higher temperature range (from 9-11°C).

Optimal temperatures for steelhead juvenile growth occur between 15-19°C (e.g., Moyle 2002; Richter and Kolmes 2005). Steelhead juveniles are much more sensitive than Chinook salmon to elevated temperatures during the smoltification process (US EPA 1999). Richter and Kolmes (2005) and US EPA (1999) cited studies that present a range of temperatures, between 11-14°C that may inhibit steelhead smoltification. Myrick and Cech (2005) cautioned that smolting steelhead must experience temperatures <11°C to successfully complete this metamorphosis.

This concludes our comments on the W&AR-6 Workshop No. 2 Draft Meeting Notes. We request that the Districts respond to these specific requests in their filing with FERC on revised meeting notes.

TRT and CSPA appreciate the Districts' consideration of our comments. If there are any questions, they can be directed to Patrick Koepele, Tuolumne River Trust, 209-588-8636 or patrick@tuolumne.org.

Sincerely,

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CALIFORNIA SPORTFISHING PROTECTION ALLIANCE
CSPA
* Since 1983 *

Cc: FERC Project #2299 Service List, Don Pedro Project

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