Dry Season Survival of Juvenile Salmonids in an Intermittent Stream

Jason L. Hwan[1,2] and Stephanie M. Carlson[2]

[1]California Department of Fish and Wildlife

[2]University of California, Berkeley

Image Credit: http://bio.research.ucsc.edu/people/moore/images/Moore_juvenile_steelhead.jpg

Challenges for Stream Biota in Intermittent Streams

- Seasonal contraction and expansion
- Changes in water quantity and quality
- Minimizes movement of stream organisms
- Intensified community dynamics


Image Credit: http://www.arocha.org/int-en/work/species/954-DSY.html

Mass mortality

Heat Death of Fish in Shrinking Stream Pools

NEAL D. MUNDAHL

THE AMERICAN MIDLAND NATURALIST 1990 123(1)

Catastrophic Mortality of Stream Fishes Trapped in Shrinking Pools

ELLIOT J. TRAMER

THE AMERICAN MIDLAND NATURALIST 1977 97(2)

Transactions of the American Fisheries Society 136:1041–1062, 2007

Extirpation of Red Shiner in Direct Tributaries of Lake Texoma (Oklahoma–Texas): A Cautionary Case History from a Fragmented River–Reservoir System

WILLIAM J. MATTHEWS EDIE MARSH-MATTHEWS

Freshwater Biology (2011) **56**, 2070–2081

Severe drought drives novel community trajectories in desert stream pools

MICHAEL T. BOGAN AND DAVID A. LYTLE

Local Extinctions

Benefits for Stream Biota in Intermittent Streams

TRANSACTIONS OF THE AMERICAN FISHERIES SOCIETY
Vol. 105, No. 6, November 1976

The Quantitative Importance of an Intermittent Stream in the Spawning of Rainbow Trout

DON C. ERMAN

VERNON M. HAWTHORNE

Front Ecol Environ 2006; 4(10): 513–518

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

513

Coho salmon dependence on intermittent streams

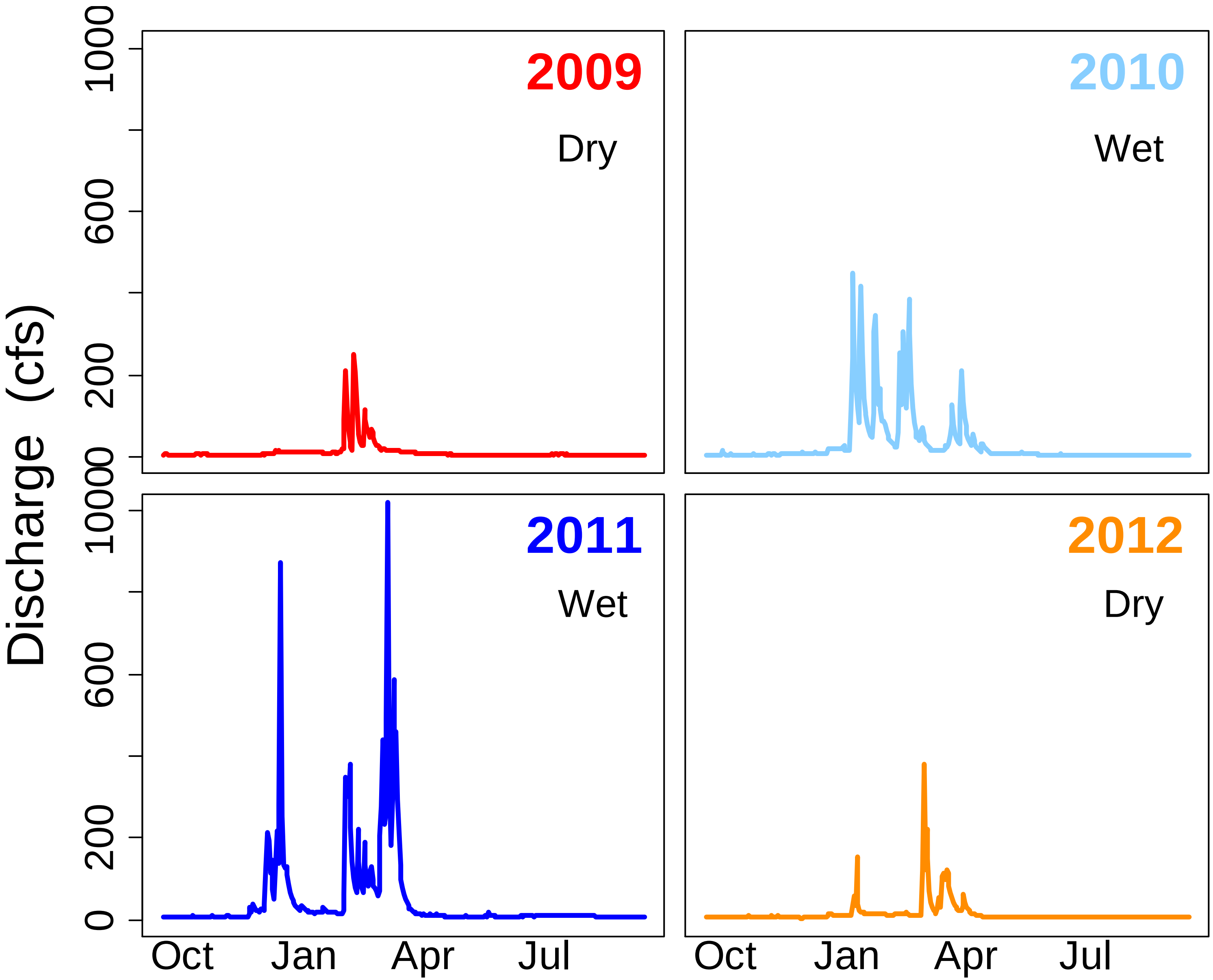
PJ Wigington Jr[1*], JL Ebersole[1], ME Colvin[2], SG Leibowitz[1], B Miller[3], B Hansen[4], HR Lavigne[5], D White[1], JP Baker[1,6], MR Church[1], JR Brooks[1], MA Cairns[1,7], and JE Compton[1]

Northwest Science. In press.

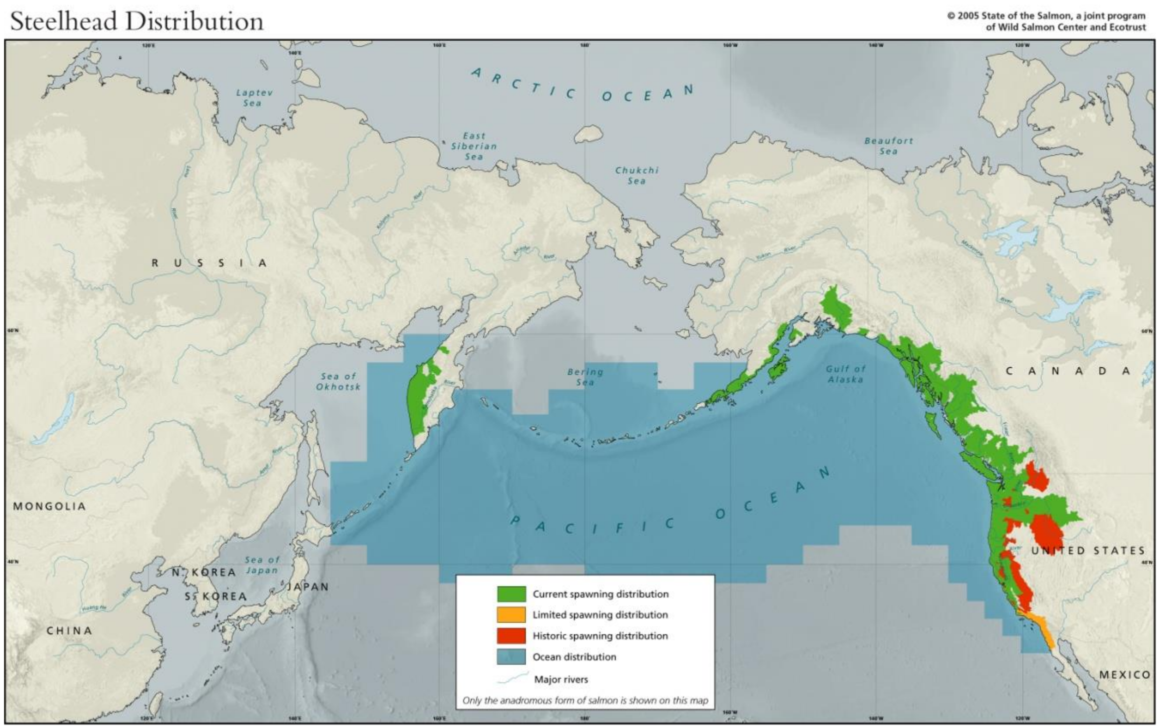
High aquatic biodiversity in an intermittent coastal headwater stream at Golden Gate National Recreation Area, California

Michael T. Bogan, Jason L. Hwan, and Stephanie M. Carlson

Strong Interannual Variation



Study System



- *Oncorhynchus mykiss*
- Native to N. America and Asia
- Anadromous
- Iteroparous
- Juveniles feed on insects
- In Californian streams, 15-18°C optimal temperature[1]

Corbis Images

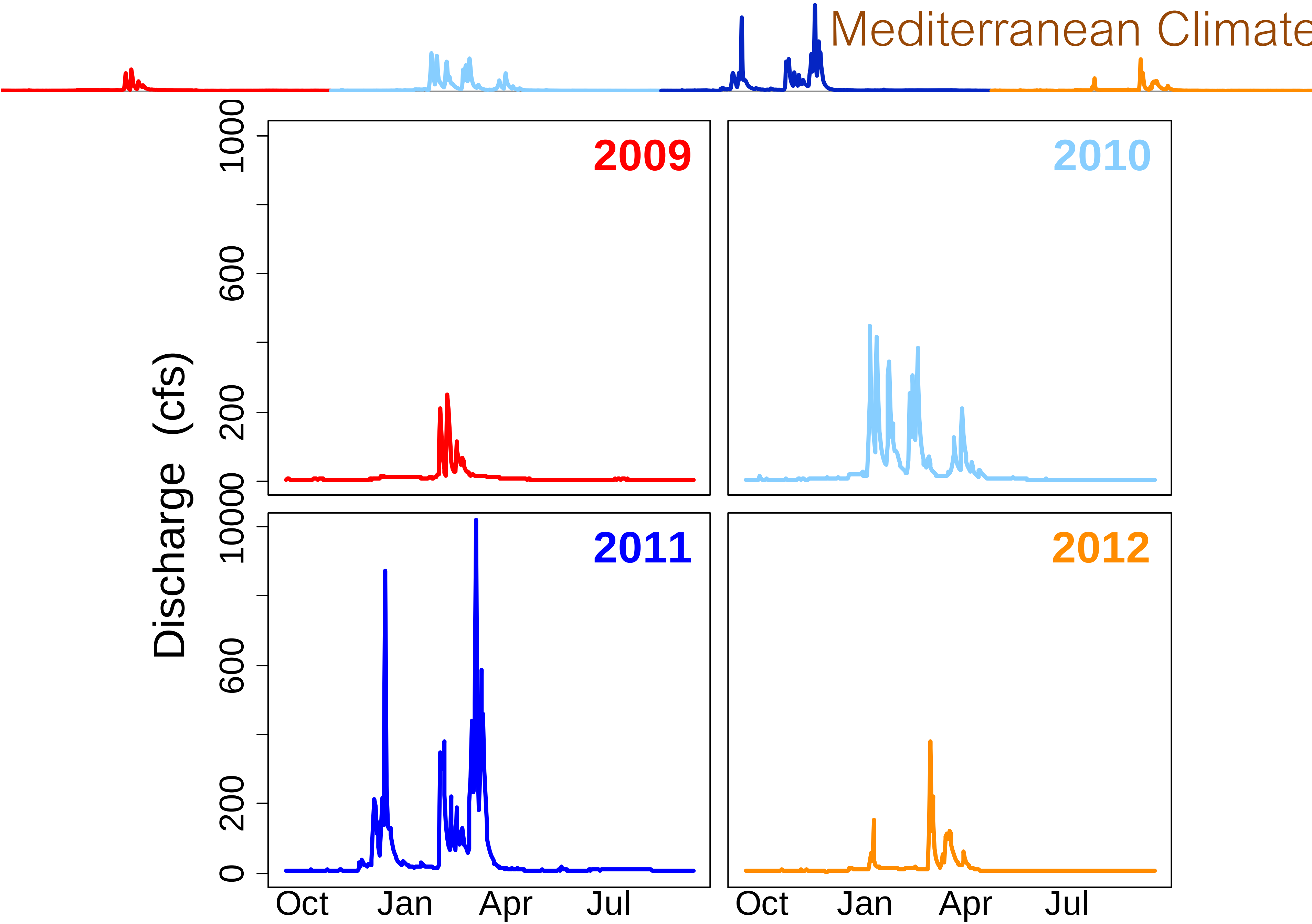
Image Credit: http://www.inforain.org/maparchive/maps_big/68642_distribution_steelhead_300dpi.jpg

[1]Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna. UC Davis, Davis.

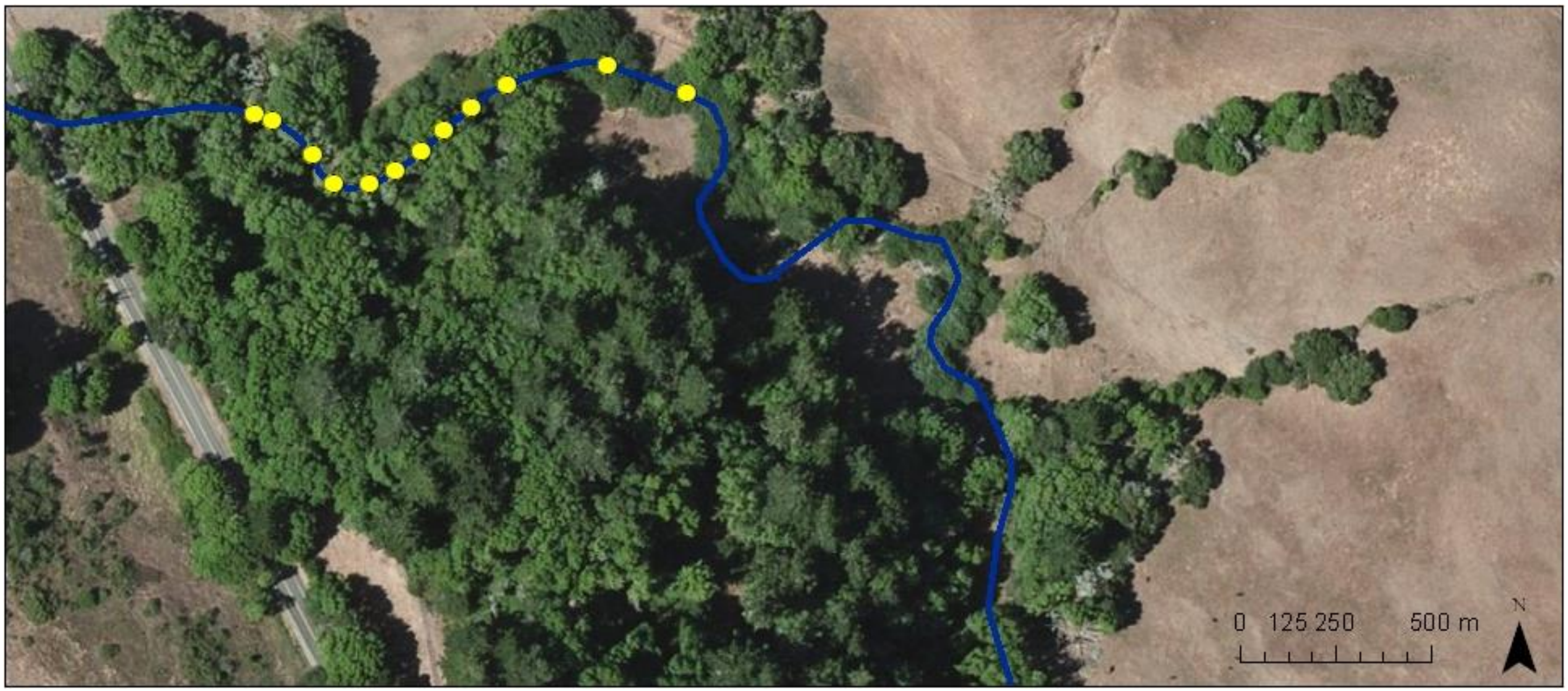
John West Fork

- Golden Gate National Recreation Area (Marin County, CA)
- 1.93 km^2
- Cattle grazing
- Coastal stream
- Unregulated
- Steelhead trout and coho salmon

Map Credit: Kristina Cervantes-Yoshida


Mediterranean Climate
2009
2010
2011
2012
Discharge (cfs)
0
200
600
1000
Oct
Jan
Apr
Jul

- 2009: focused on 12 pools



Study Reach

- 2009: focused on 12 pools
- 2010 - 2012: focused on 30 pools

Objectives

1. What are the patterns of stream fragmentation within and among years?
2. Does the contraction in pool habitat differ among years?
3. What are the consequences of habitat contraction on juvenile steelhead survival?

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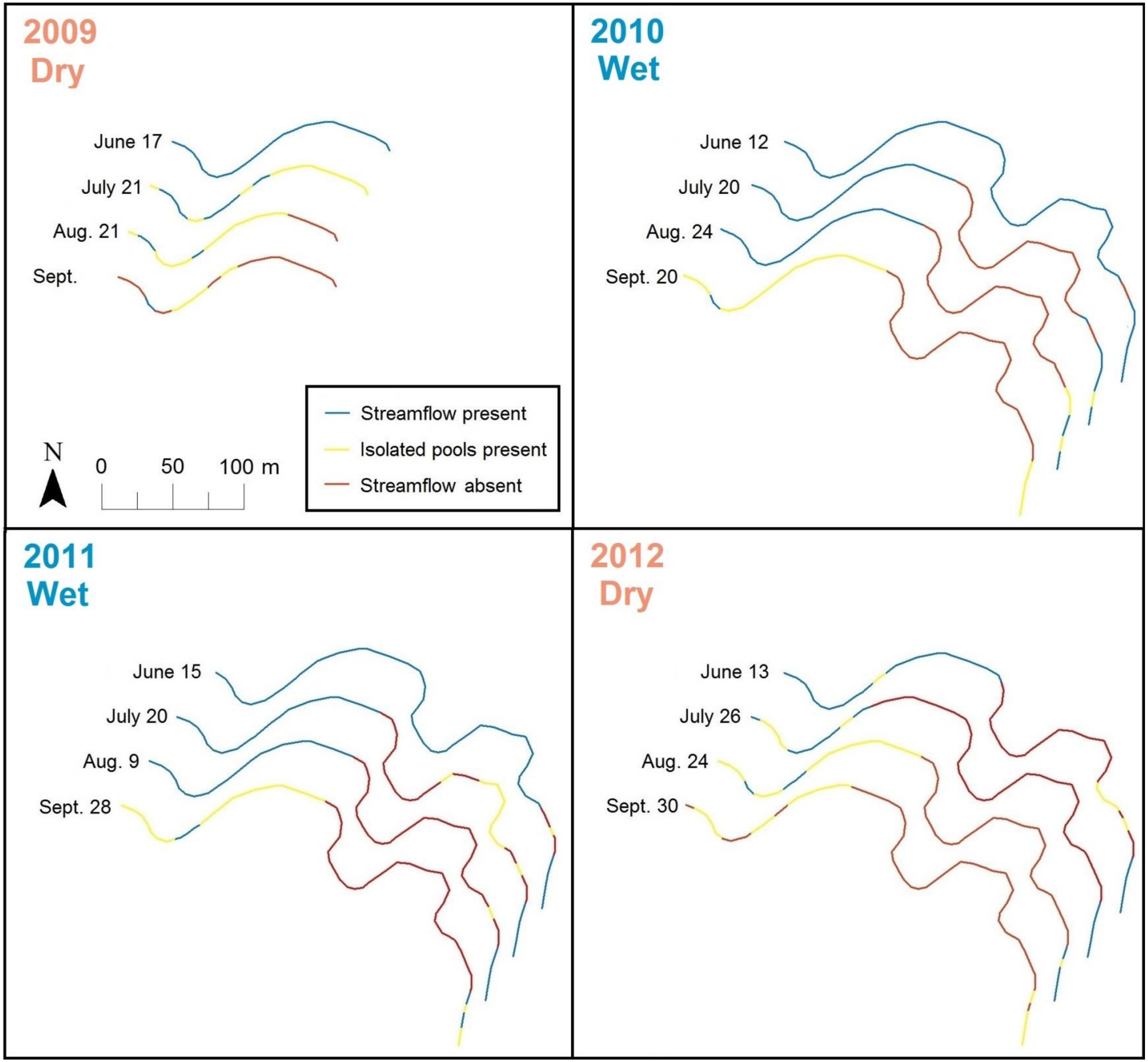
Wet-dry Mapping

6/2/2010

7/8/2010



2009
Dry
June 17
July 21
Aug. 21
Sept.
Streamflow present
Isolated pools present
Streamflow absent
N
0
50
100 m
2010
Wet
June 12
July 20
Aug. 24
Sept. 20
2011
Wet
June 15
July 20
Aug. 9
Sept. 28
2012
Dry
June 13
July 26
Aug. 24
Sept. 30

Objectives

1. What are the patterns of stream fragmentation within and among years?

2. **Does the contraction in pool habitat differ among years?**

3. What are the consequences of habitat contraction on juvenile steelhead survival?

Estimating Pool Volume

- Mapped streambed and water surface using total station
  - Estimated volume in ARCMap
- Meter sticks to estimate stage
  - Tracked changes in volume

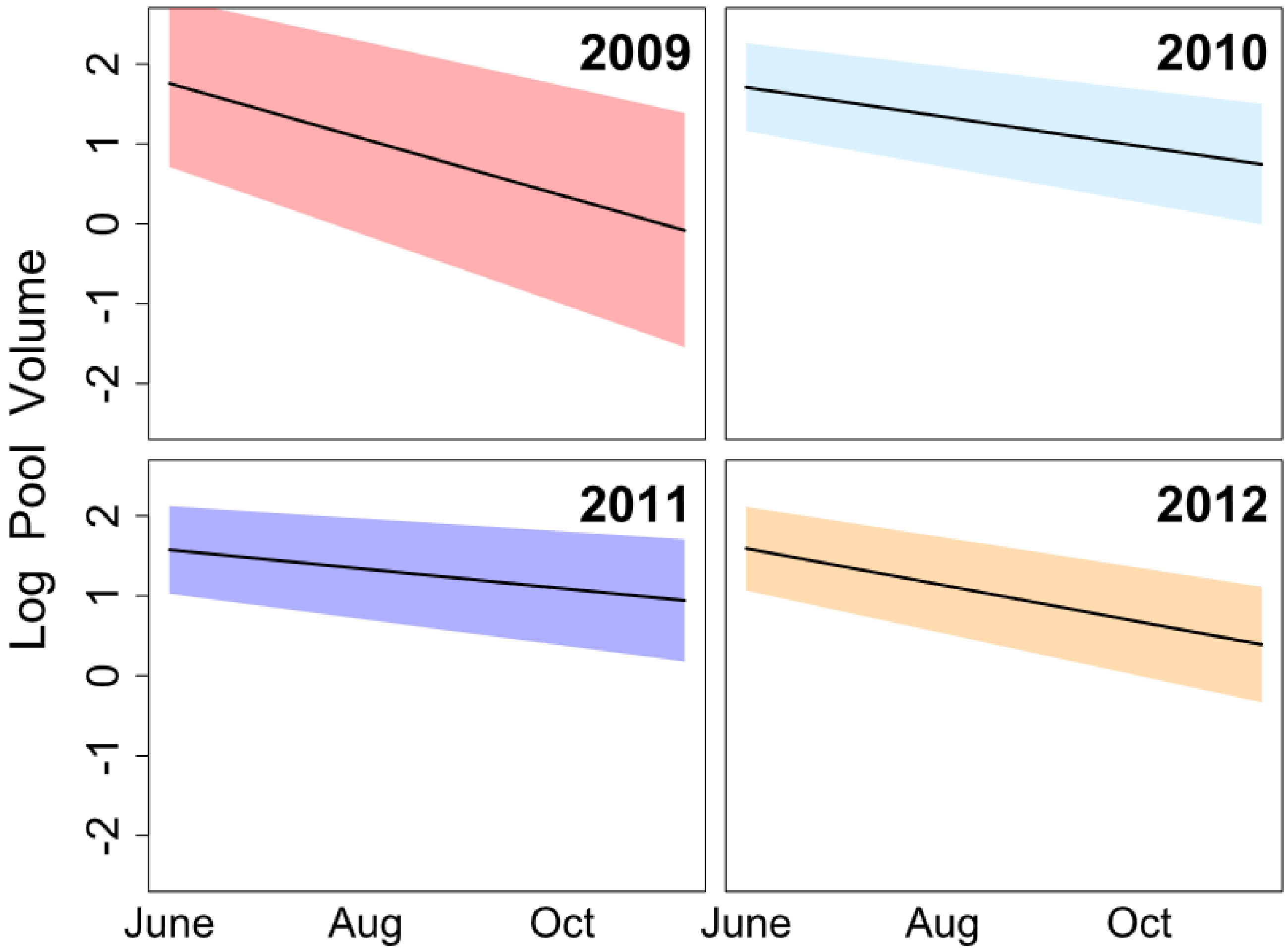
Hwan and Carlson. 2015 River Research and Applications.

Statistical Analysis

- Pool Volume vs Time
- Mixed effects log-linear model
  - Compared pairwise intercepts (initial water volume) and slopes (rate of drying)
  - Individual pools were random effects
  - Time and year were fixed effects
- Bayesian Approach
- Package R2jags in R

Hwan and Carlson. 2015 River Research and Applications.

Pool Drying



Initial volume

- No difference between any two years

Rate of drying

- Two wettest years (2010 and 2011) dried at a slower rate than driest year (2009)
- No other differences observed

Hwan and Carlson. 2015 River Research and Applications.

Objectives

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Mark-Recapture

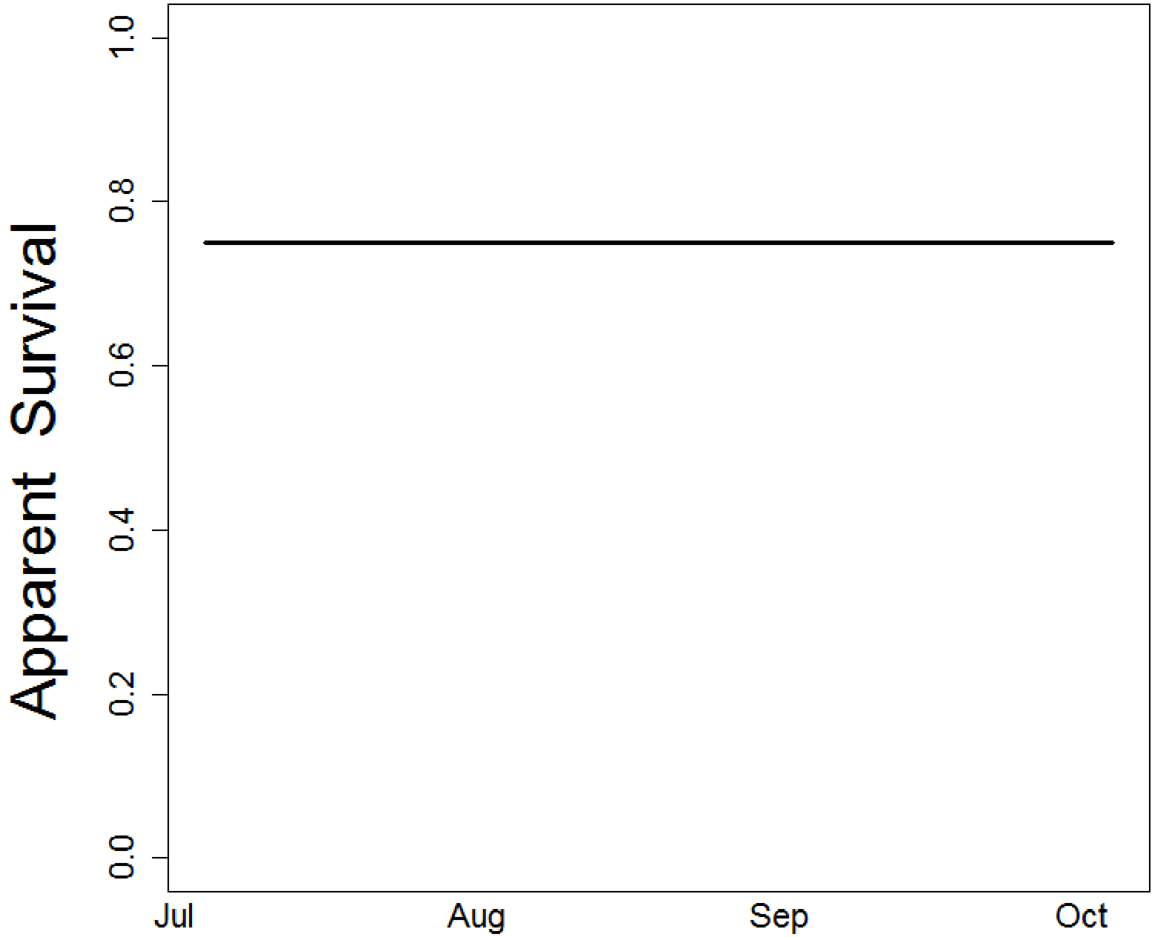
- Electrofish
  - 3-pass depletion
- Sampled each pool
- Implanted fish >60mm with PIT tags
  - Unique ID

Survival

- Tracked fish once per week
- Portable PIT tag antenna
  - Allowed weekly re-sight information
- Program MARK
  - Cormack-Jolly-Seber Model
  - Logit Link Function
  - Estimates of re-sight probability and apparent survival

Within Year

- Constant survival
- Fully time-dependent
- Resistance



Within Year

- Constant survival
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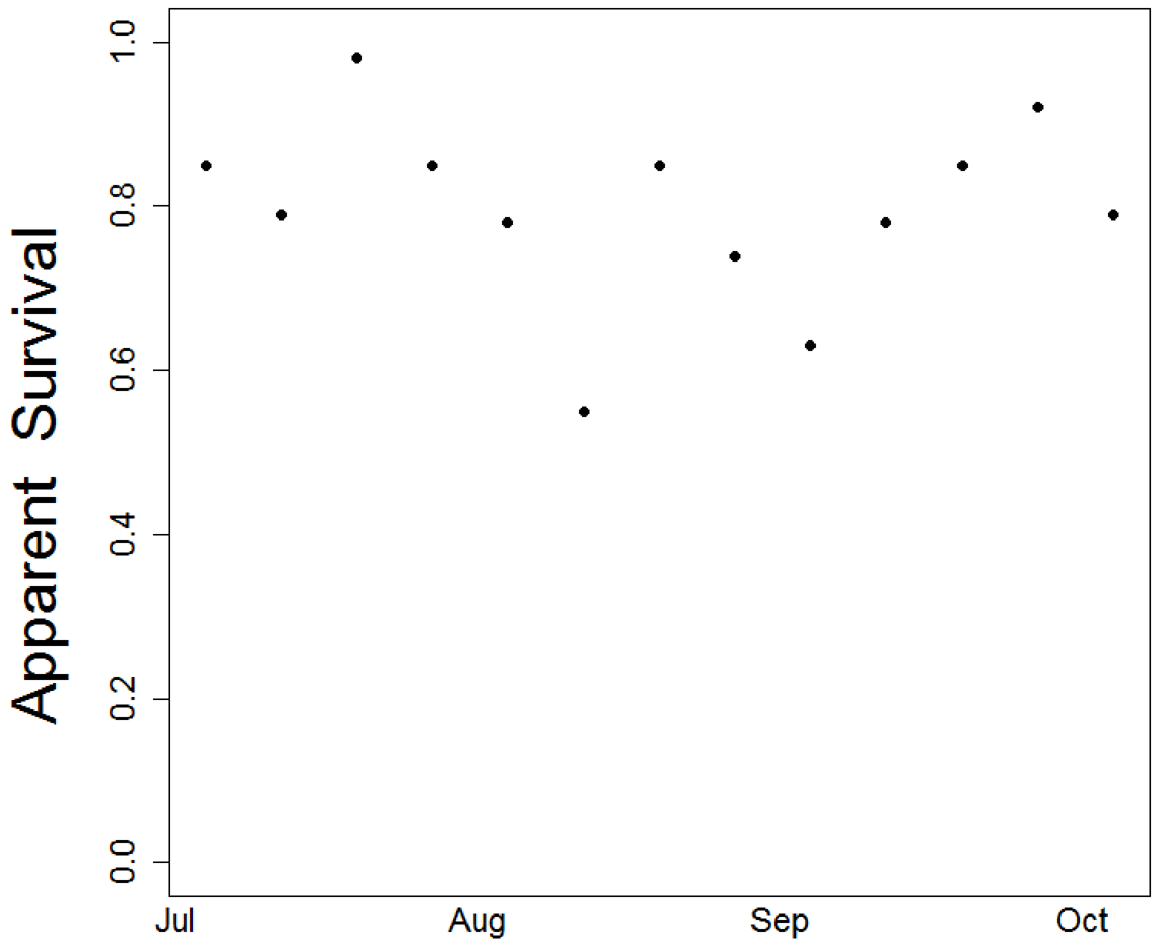

Within Year

- Constant survival
- Fully time-dependent
- Resistance

Freshwater Biology

Freshwater Biology (2013) doi:10.1111/fwb.12280

Invertebrate assemblages of pools in arid-land streams have high functional redundancy and are resistant to severe drying

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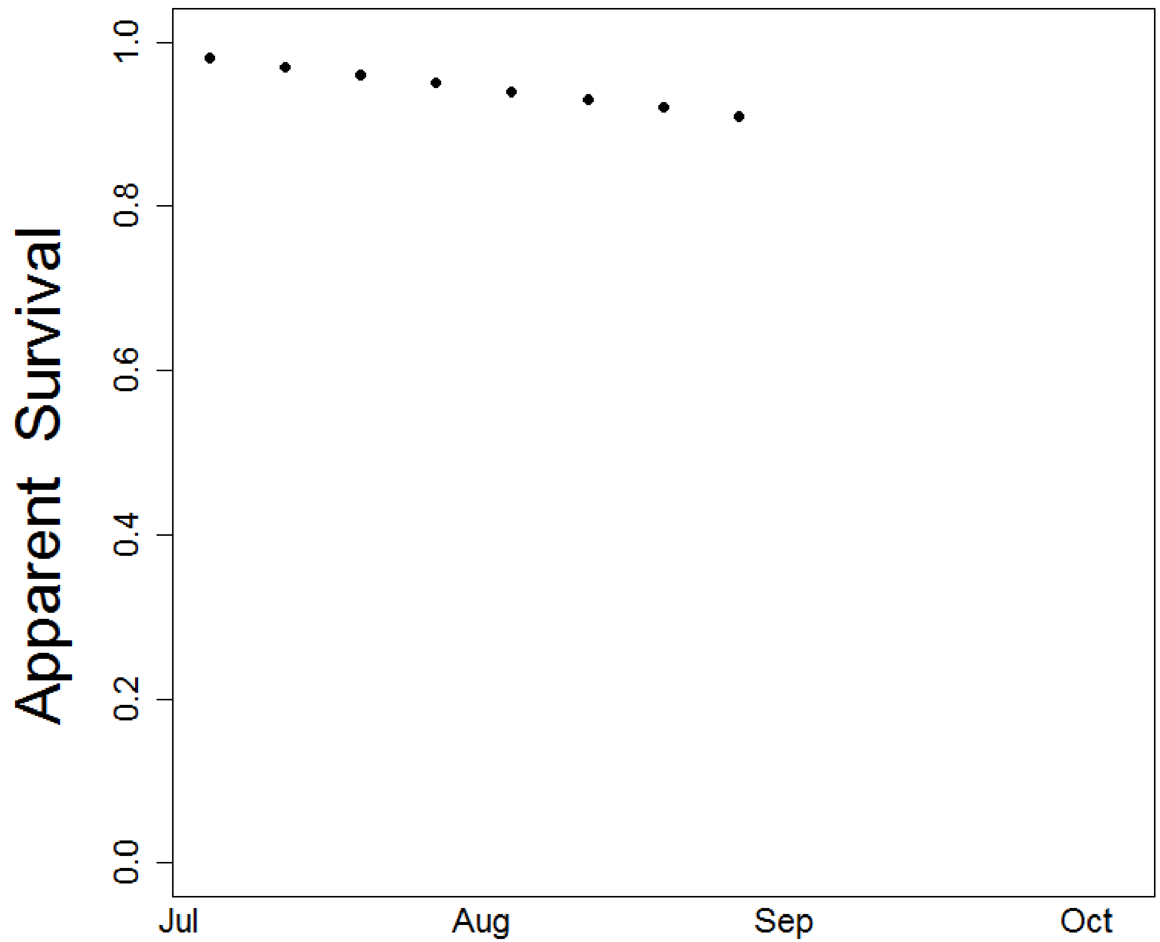
*Department of Zoology, Oregon State University, Corvallis, OR U.S.A.

†Department of Environmental Science, Policy & Management, University of California, Berkeley, CA, U.S.A.

Within Year

- Constant survival
- Fully time-dependent
- Resistance



Within Year

- Constant survival
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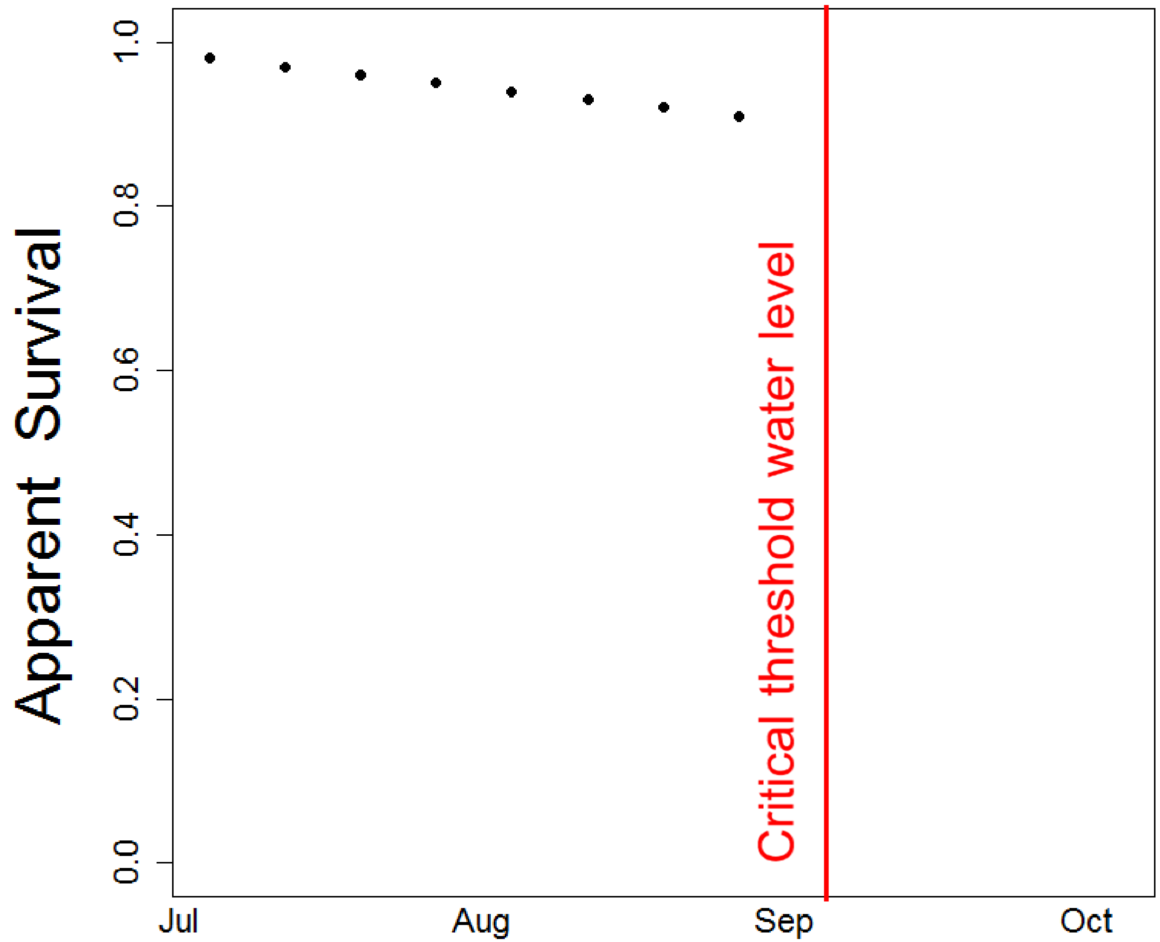

Within Year

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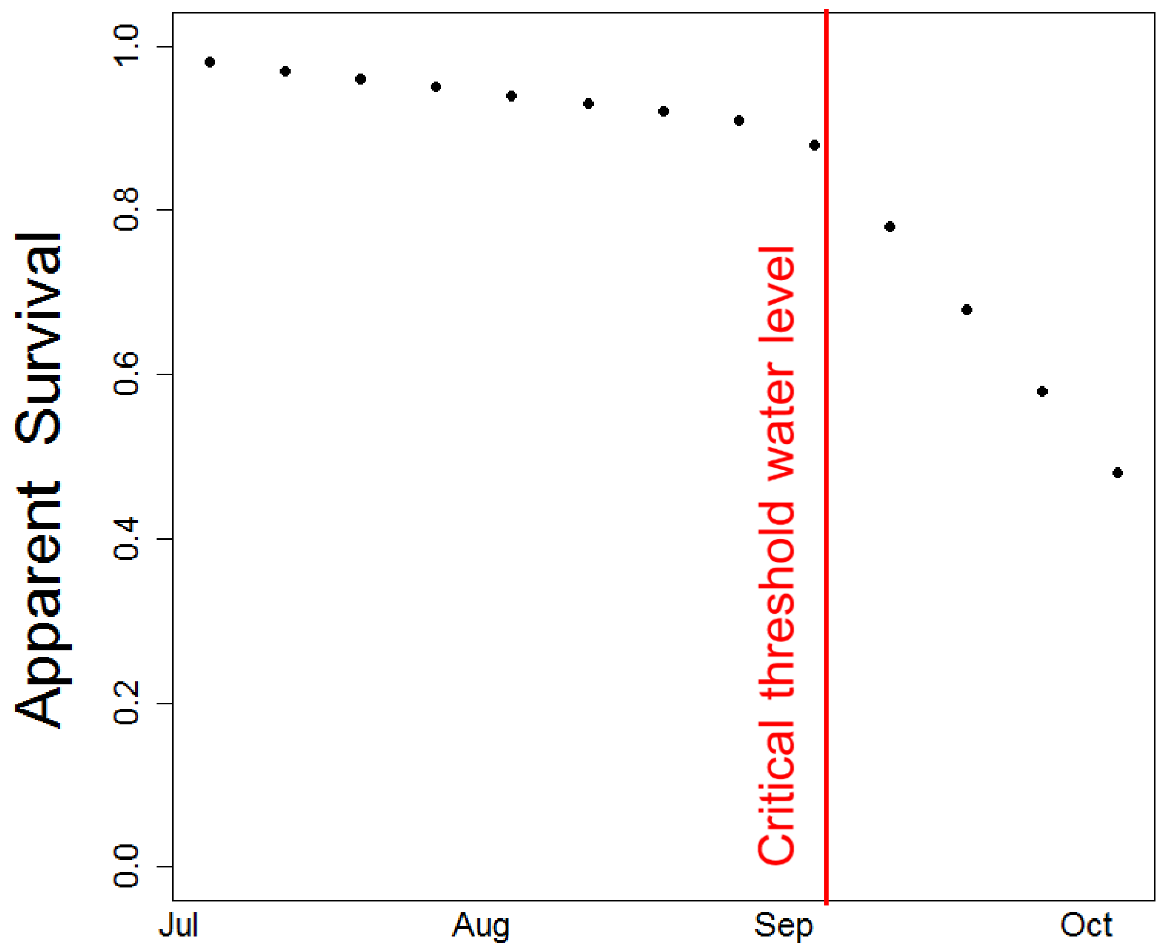


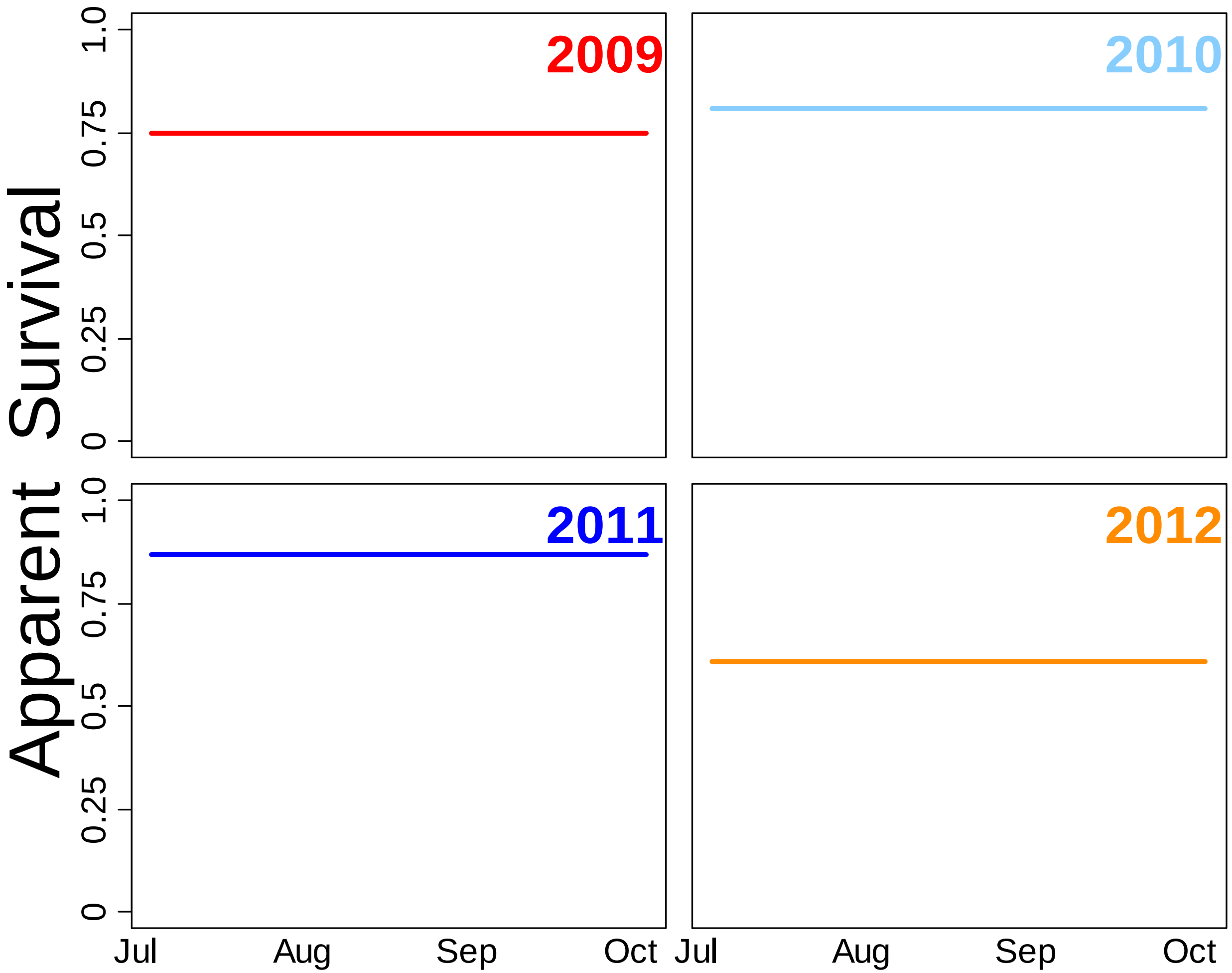
Survival Models

Within Year

- Constant survival
- Fully time-dependent
- Resistance

Among Year

- Year
- Precipitation Regime



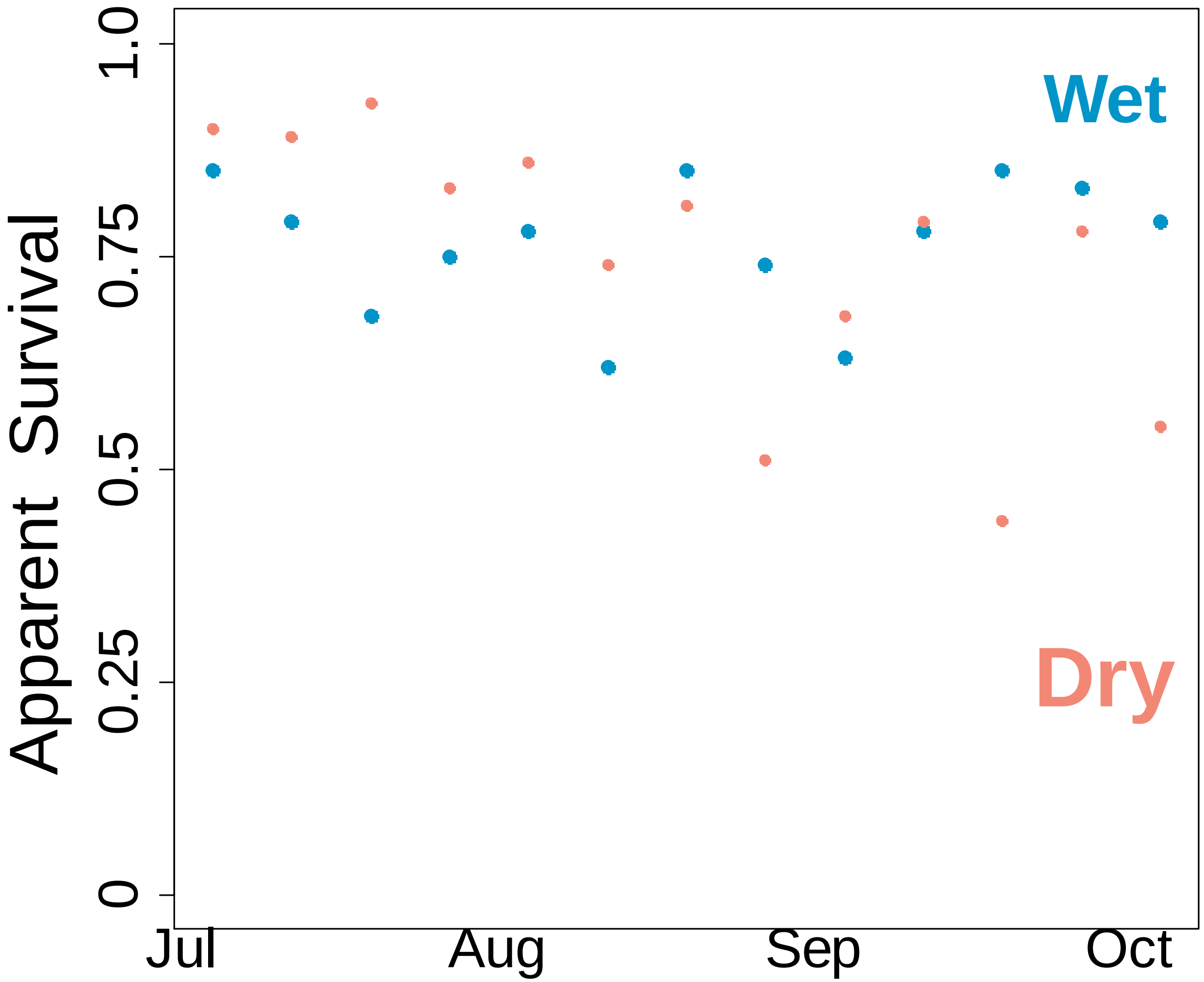
Survival Models

Within Year

- Constant survival
- Fully time-dependent
- Resistance

Among Year

- Year
- Precipitation Regime

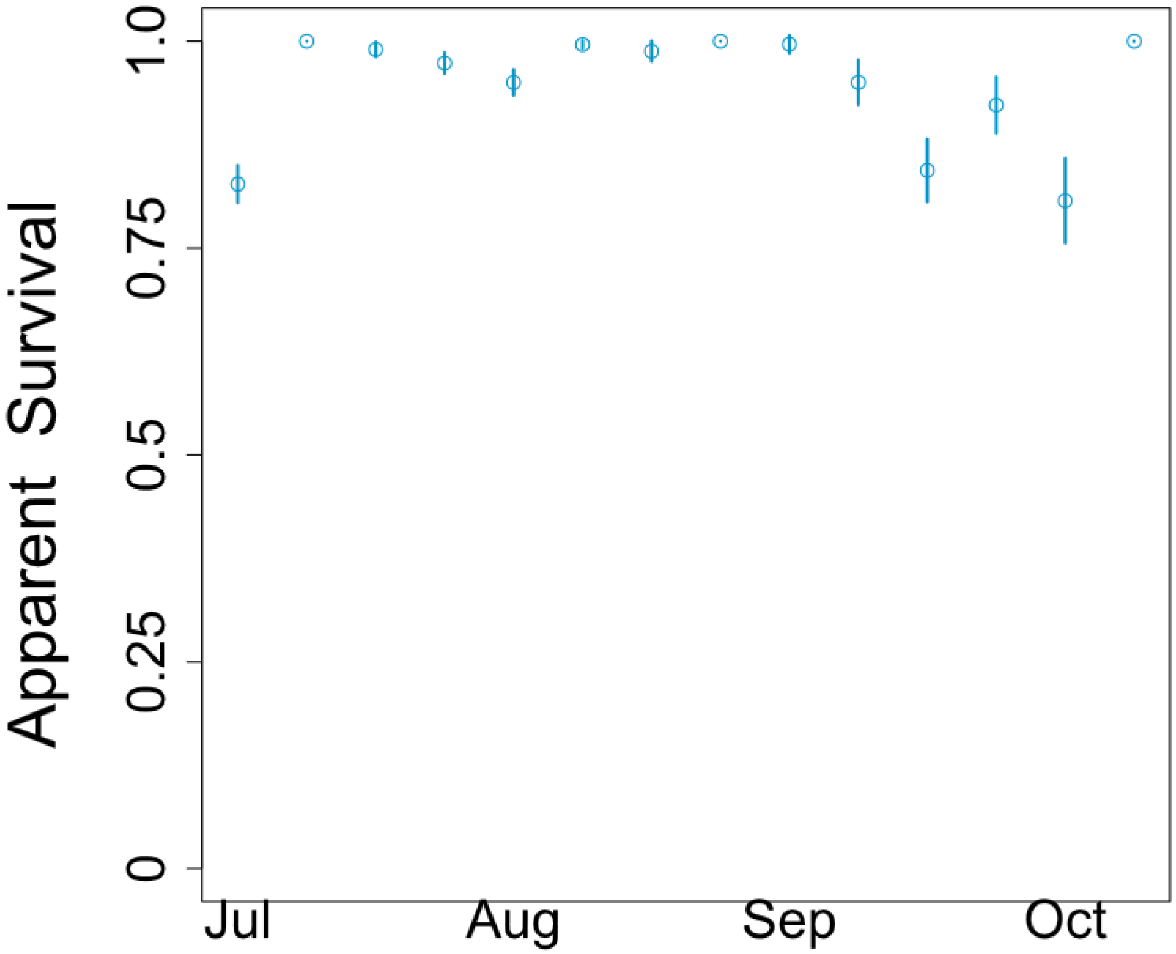


Best Model

Model Name	AIC_c	ΔAIC_c	K	Deviance
Precipitation regime * resistance (dry years)-time-dependent (wet years)	3831.72	0	52	3725.9
Precipitation regime * time-dependent	3837.95	6.23	60	3715.93
Year * time-dependent	3844.94	13.22	73	3695.34
Week	3946.29	114.57	50	3844.61
Precipitation regime * Constant	4010.17	178.45	41	3927.03
Year * Constant	4013.52	181.8	43	3926.28
Constant	4036.42	204.7	41	3953.29

- Evidence of precipitation regime effect
  - Full time-dependence wet years
  - Resistance pattern in dry years

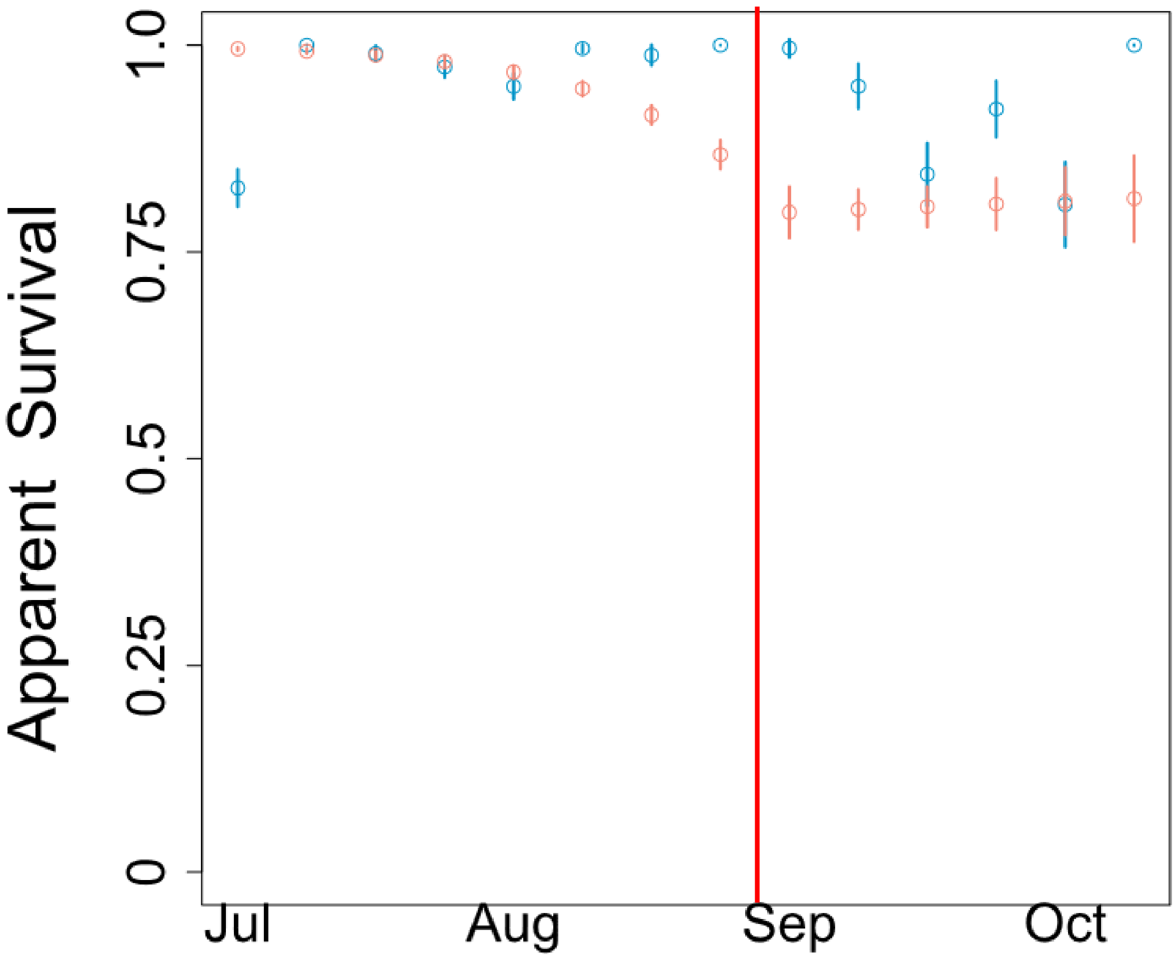
Best Model



Wet Years

- Full time-dependence

Best Model



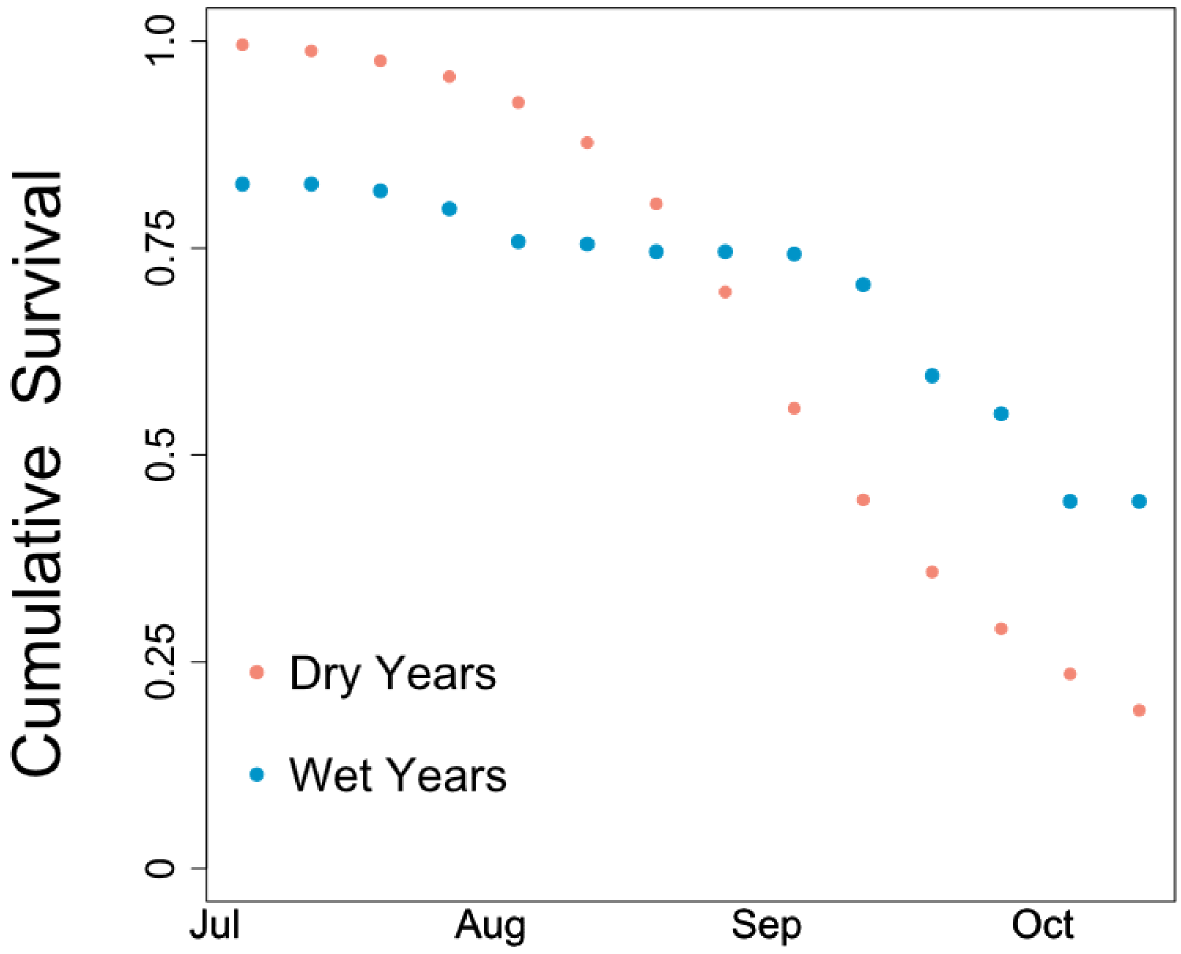
Wet Years

- Full time-dependence

Dry Years

- Resistance

Cumulative Survival

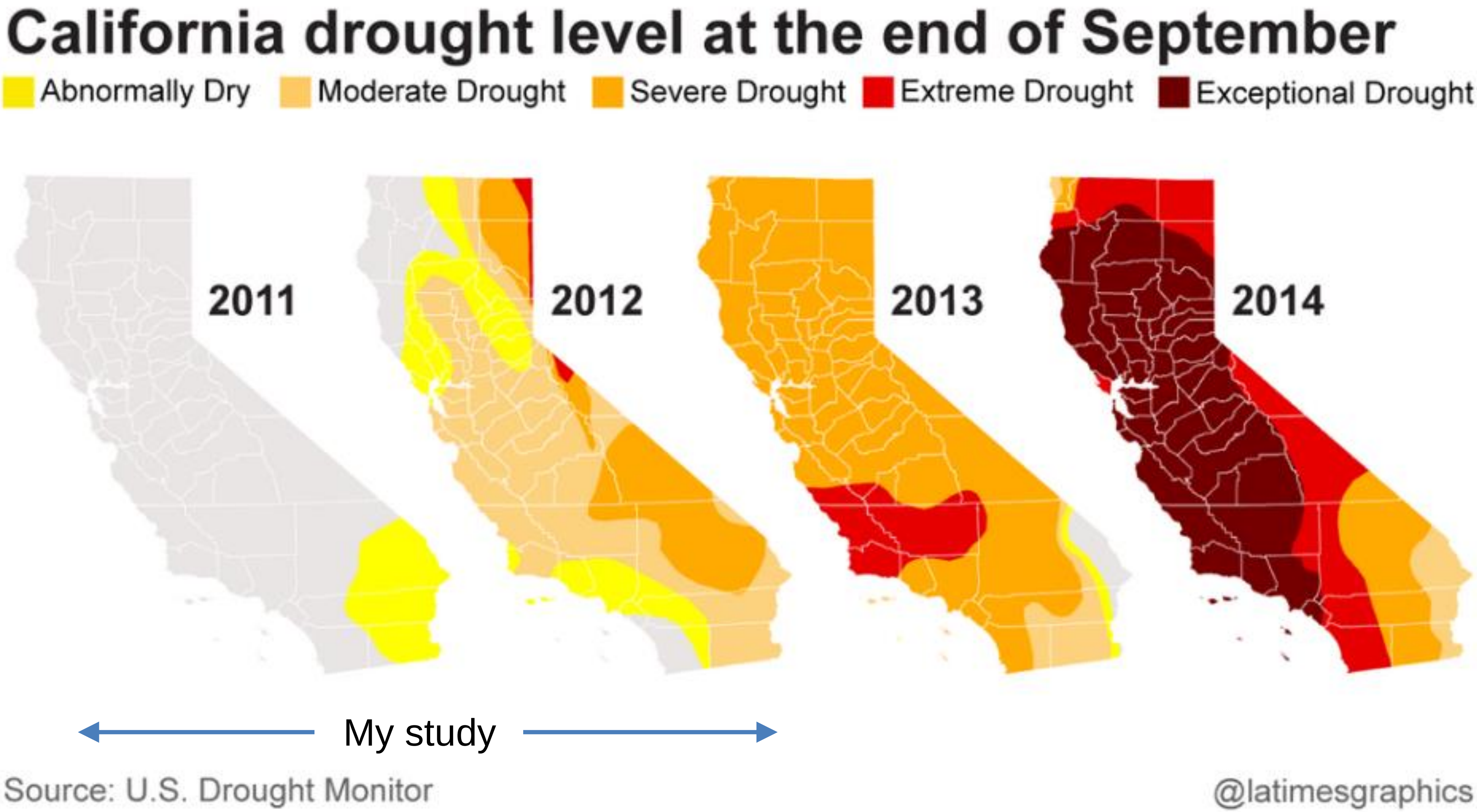


Wet Years

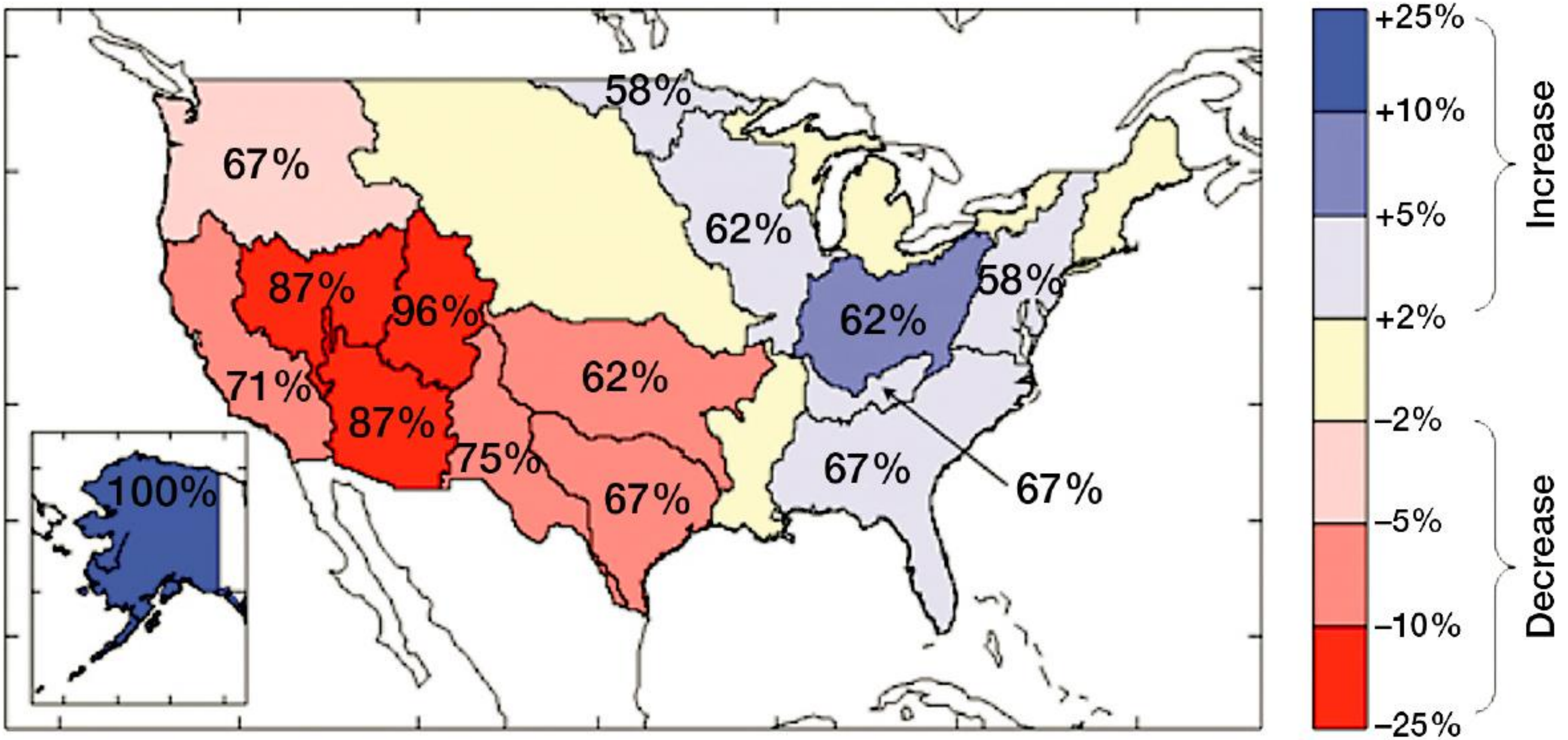
Cumulative Survival: 0.44

Dry Years

Cumulative Survival: 0.19


California drought level at the end of September
Abnormally Dry
Moderate Drought
Severe Drought
Extreme Drought
Exceptional Drought
2011
2012
2013
2014
My study
Source: U.S. Drought Monitor
@latimesgraphics

Climate Change and Streamflow



Projected median changes in streamflow due to climate change by 2050 across the U.S., as determined by multiple global change models, are shown in colors. Percentages refer to the number of models that agree on the direction of the change. Source: Climate Change Science Program Synthesis and Assessment Product 4.3

Figure Credit: http://forr.us/wp-content/uploads/2012/02/CC22.jpg

Conclusions

1. Fragmentation occurred earlier during dry years
2. Entire sections of the creek varied in their propensity to dry
3. Pool drying closely linked to antecedent rainfall
4. Steelhead resistant to drought to an extent

Acknowledgements

Thanks to:

PhD Committee Members

Vincent Resh, Mary Power

The University of California
College of Natural Resources
Environmental Leadership Pathway

Joanie Ball
Mike Bogan
Mat Buoro
Kristina Cervantes
Sibyl Diver
Theressa Flaherty
Kaua Fraiola
Jose Gonzalez
Ted Grantham
Sandy Gutierrez
Jessica Hernandez
David Hines
Eric Huber

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