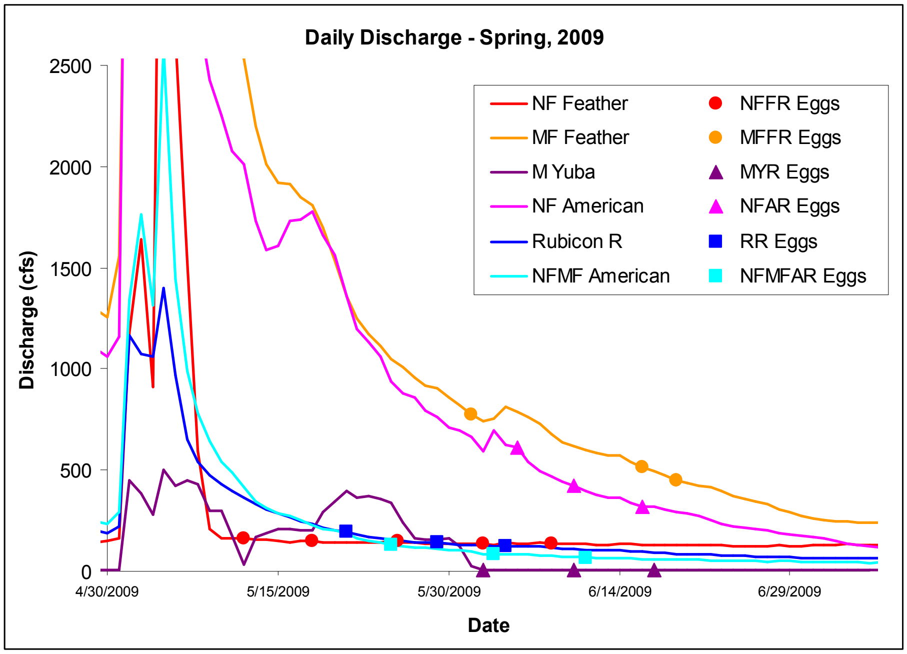
Assessment of Risks to Sierra Nevada Populations of Foothill Yellow-Legged Frogs (*Rana boylii*) Under Varying Snow-Melt Hydrograph Recession Rates in Rivers

A. Lind, USDA Forest Service, Pacific SW Research Station, Davis, CA
S. Yarnell, Center for Watershed Sciences, University of California, Davis

24 March 2011 (update)

Background and Assumptions

- Foothill yellow-legged frogs (FYLF) breed, lay eggs (oviposit), and tadpoles develop during the spring and summer of each year in a variety of stream environments from small creeks to large rivers.
- In the Sierra Nevada, FYLF have evolved with and are adapted to the snow-melt run-off/recession period and typically oviposit during the middle to the tail end of that period (e.g., Figure 1)
- Cues for breeding/oviposition appear to be a combination of day length, water temperature, and local habitat suitability (e.g., water velocity and depth).
- The primary risks during the snow-melt recession period are scouring and stranding. Scouring can occur if water flows increase substantially after eggs have been laid. Stranding can occur if recession rates are too fast relative to water depth and egg development time. Here we focus on stranding risk only.
- This assessment focuses on the egg mass lifestage only within relative large Sierran rivers. This lifestage would be present from approximately mid-April through mid-July, depending on water year conditions.
- Recession rates are defined in this assessment as change in stage per week at representative oviposition sites. When evaluated with data on the channel morphology of oviposition sites in a given river reach, this recession rate can be translated to a change in discharge over time for that reach.



Average rate of change in discharge during FYLF oviposition season in 2009		
NF Feather	3 cfs/day	27 days
MF Feather	25 cfs/day	19 days
M Yuba	0 cfs/day	15 days
NF American	25 cfs/day	11 days
NFMF American	4 cfs/day	16 days
Rubicon	5 cfs/day	15 days

Figure 1 – Snow-melt recession hydrographs (daily discharge versus date) from 6 Sierran rivers showing timing of first oviposition by FYLF and a table showing average rate of change in discharge during FYLF breeding season; from Bondi, Yarnell, and Lind (unpublished data, 2009).

Evaluation of Potential Recession Rates

- Data needed to evaluate potential risks of different recession rates include:
  1. Length of time from oviposition to hatching and free-swimming tadpoles.
  2. Water temperatures during snow-melt recession and oviposition period.
  3. Distribution of water depths for typical egg mass locations in Sierran rivers.
  4. Effect of different rates of loss of egg masses on the overall population.
- By considering the above data simultaneously, it is possible to derive a risk of loss for different snow-melt recession rates.

- **Time to Hatching** – The graph below is based on an experiment conducted in 2008 in the South Fork Eel River and its tributaries (Figure 2, Kupferberg, unpublished data). Even though it is from a Coast Range population, it is it the best available data.

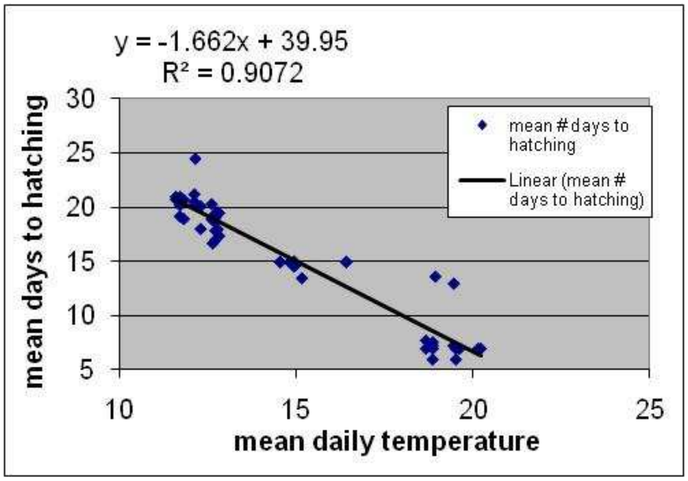


Figure 2 – Relationship between time to hatching and water temperature for FYLF frog eggs from Kupferberg (unpublished data, 2008).

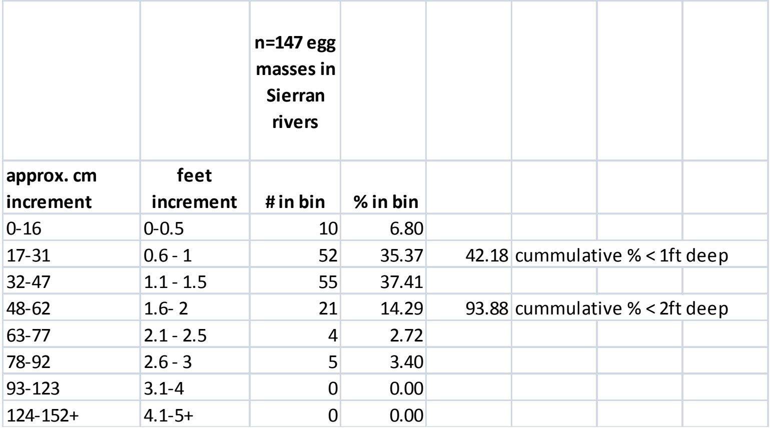
- **Water Temperatures During Snow-Melt Recession**
  A quick review of the Middle Yuba and South Yuba "Information Sheets" provided by Nevada Irrigation District (NID) and Pacific Gas and Electric Company (PG&E) summarizing data from released and forth-coming Technical Memos for the Yuba-Bear (Y-B) and Drum-Spaulding (D-S) Hydropower Relicensing Projects indicates that water temperatures where FYFL occur range from 10-15C (50-59F) in the early part of the breeding season (April-May) and 16-20C (61-68F) in the later part of the season (June-July). (*More detailed data from Y-B/D-S and Placer County Water Agency's Middle Fork American River project would help clarify differences in different water year types and rivers.*)

- **Water Depths of Egg Masses in Sierran Rivers** – the following data were summarized from two sources: (1) NID Yuba-Bear Project and PG&E Drum-Spaulding Project FYLF habitat suitability study for the Middle and South Yuba Rivers and (2) Bondi, Yarnell, and Lind FYLF habitat suitability study in eight Sierran rivers (4 regulated and 4 unregulated).

(1) NID Yuba-Bear and PG&E Drum-Spaulding and 2008/2009 FYLF habitat suitability data.

		n=123 egg masses in MY, SY			
approx. cm increment	feet increment	# in bin	% in bin		
0-16	0-0.5	21	17.07		
17-31	0.6 - 1	31	25.20	42.28	cummulative % < 1ft deep
32-47	1.1 - 1.5	24	19.51		
48-62	1.6- 2	15	12.20	73.98	cummulative % < 2ft deep
63-77	2.1 - 2.5	15	12.20		
78-92	2.6 - 3	2	1.63		
93-123	3.1-4	8	6.50		
124-152+	4.1-5+	7	5.69		

(2) Bondi, Yarnell, and Lind (unpublished data, 2009)



		n=147 egg masses in Sierran rivers			
approx. cm increment	**feet increment**	**# in bin**	**% in bin**		
0-16	0-0.5	10	6.80		
17-31	0.6 - 1	52	35.37	42.18	cummulative % < 1ft deep
32-47	1.1 - 1.5	55	37.41		
48-62	1.6- 2	21	14.29	93.88	cummulative % < 2ft deep
63-77	2.1 - 2.5	4	2.72		
78-92	2.6 - 3	5	3.40		
93-123	3.1-4	0	0.00		
124-152+	4.1-5+	0	0.00		

- **Effects at the Population Level**

  Below are the results from several matrix population model runs which isolate the effects of egg mass stranding and scouring. The starting values for the reference model in this exercise were derived from long-term averages of observed rates of stranding (4 %) and scouring (20%) at the unregulated SF Eel River (Mendocino Co., CA; see reference model in Kupferberg et al. 2009). Each scenario below used these reference values as a starting point and changed either stranding or scouring rates but not both. A small variance term was assigned to the focal strand or scour rate allowing an assessment of each rate as if it were nearly a constant.

  This modeling exercise demonstrates that increasing the rate of stranding can have substantial effects on the long-term extinction probability of a population. With all other survival rates held constant, stranding rates of $\geq$40% , result in a ~ 13% chance that the population will go extinct in 30 years. That is more than 4x the simulated reference probability of extinction.

Relative increases (and decreases) in 30 year extinction probabilities under different egg mass stranding and scouring rates.

SCENARIO	**VALUES USED IN MODEL: AVERAGE PERCENT OF EGG MASSES….**	**POPULATION OUTCOME: 30 YEAR EXTINCTION PROBABILITY AND MULTIPLICATIVE CHANGE FROM SCENARIO E. (‘*REFERENCE*’)**
A. 10% strand rate	stranded = 10 scoured = 20	0.0574 probability of extinction over 30 years; 1.7x higher than ‘reference’
B. 20% strand rate	stranded = 20 scoured = 20	0.0640, 1.9x higher
C. 40 % strand rate	stranded = 40 scoured = 20	0.1344, 4.1x higher
D. 10% scour rate	stranded = 4 scoured = 10	0.0264, 1.3x lower
E. 20% scour rate (analogous to unregulated SF Eel River-based reference model from Kupferberg et al. 2009)	stranded = 4 scoured = 20	0.0332, ‘reference’
F. 40% scour rate	stranded = 4 scoured = 40	0.0654, 2.0x higher

- **Conclusions from best available data**
    1. If water temperatures are warm (18-20C, 64-68F), eggs can develop in less than a week, but in cool to moderate temperatures (12-16C 54-61F), development time ranges from 2-3 weeks. These cooler temperatures are more typical of breeding season.
    2. The majority of egg masses (74-94%) are deposited in water depths less than 2 feet and at least 40% are deposited in water depths less than 1 foot.
    3. If 40% or more of egg masses are stranded each year, the probability of extinction of the local population increases substantially and may be as much as 4x that of a population with limited egg mass stranding.

  **** Thus to protect at least half of all egg masses from stranding and to reduce local population extinction risk, the recession rate would need to be less than 1 foot over 3 weeks or 1/3 foot per week.***

<u>Caveats</u>

- Eggs are not always laid on the bottom of streams, so the total depth that is typically measured during HSC work may over-estimate the actual depth of egg masses. Data from a FYLF HSC analysis completed for the PG&E Desabla-Centerville project indicated depths at egg masses were typically 80% of the total depth (e.g. total depth =1ft, depth at egg mass = 0.8 ft)(Lind, Yarnell, and others 2008).
- The existing data may underestimate depth to some extent because egg masses are not always found right at oviposition time. I.e., natural reduction in flows between oviposition date and survey date may result in survey depths being less than actual oviposition depths.
- Once eggs hatch, it may take several days to a week or more for the young tadpoles to develop enough so that they are free-swimming and can follow a receding shoreline.
- The population level effects modeled for this summary should be considered relative values only – i.e., for comparison to each other. These estimates should <u>not</u> be used as absolute values or actual probabilities of extinction for any given population. In order to derive such estimates for a particular population, all of the population-specific survival rates (tadpole survival, adult survival, etc.) would need to be known (or estimated with great confidence).
- These recession rates are best applied in moderately wide and shallow stream channels; the topography of narrow, deep channels with steep banks or channels with perched “benches” may have a greater risk of stranding.
- Rates that are needed over a 3-4 week period could be implemented on a weekly basis. There is a concern that a guideline like “1 foot over 3 weeks” could be interpreted as dropping the flows 1 foot at the end of any given three week period rather than dropping them incrementally over days or weeks to achieve a more gradual rate of recession.
- There is some preliminary evidence that FYLF may lay eggs at deeper depths earlier in the spring when unimpaired recession rates are slightly higher and at shallower depths later in the spring when natural recession rates are slower. So the timing of when recession rates are implemented is critical and should be considered (e.g., Figure 1).

References

Bondi, C., S. Yarnell, and A. Lind 2010. Development of regional foothill yellow-legged frog (Rana boylii) habitat suitability criteria for oviposition and tadpole rearing in the northern Sierra Nevada, California. Annual Report to the California Energy Commission, PIER, 44 pp (April).

Garcia and Associates. 2008. Identifying microclimatic and water flow triggers associated with breeding activities of a foothill yellow-legged frog (*Rana boylii*) population on the North Fork Feather River, California. Final Report to the California Energy Commission, PIER., CEC-500-2007-041, 74 pp (January).

Kupferberg, Sarah J. Personal communication and unpublished data, 24 August 2010.

Kupferberg, S., A. Lind, and W. Palen. 2009. Pulsed flow effects on the foothill yellow-legged frog (*Rana boylii*): Population modeling. Final Report to the California Energy Commission, PIER., 80 pp (August).

Lind, A.J., Yarnell, S.M., and other members of the Habitat Suitability Criteria Technical Workgroup. 2008. Habitat suitability criteria for the foothill yellow-legged frog (*Rana boylii*) in the northern Sierra Nevada and Coast Ranges of California. Final Report to the Pacific Gas and Electric Company's DeSabla-Centerville Project (FERC #803). 41 pp. (February).

Nevada Irrigation District and Pacific Gas and Electric Company. 2010. Technical Memorandum 3-6, Foothill yellow-legged frog surveys. Yuba-Bear Hydroelectric Project (FERC Project No. 2266-096) and Drum-Spaulding Project (FERC Project No. 2310-173). 76pp + appendices (April).

Wheeler, C. A., and H. H. Welsh, Jr. 2008. Mating strategy and breeding patterns of the Foothill Yellow legged Frog (*Rana boylii*). Herpetological Conservation and Biology 3:128-142.