HABITAT SUITABILITY CRITERIA FOR THE FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*) IN THE NORTHERN SIERRA NEVADA AND COAST RANGES OF CALIFORNIA

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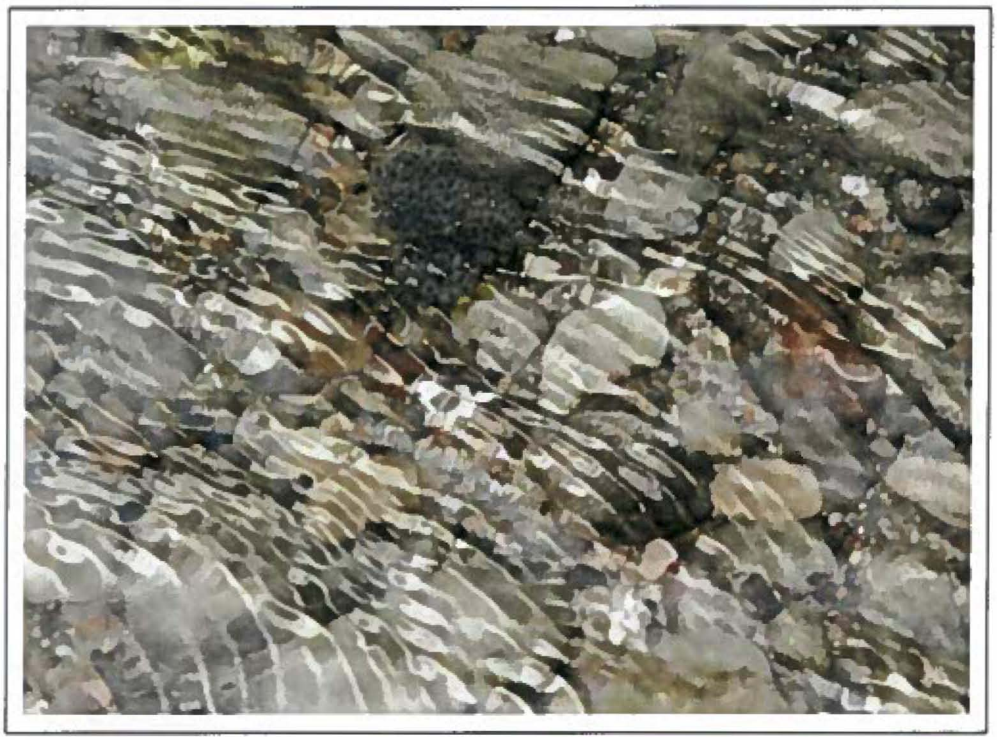
Foothill yellow-legged frog Habitat Suitability Criteria Technical Workgroup
(This final version was prepared by Amy Lind and Sarah Yarnell)



ABSTRACT

The condition and suitability of key habitat elements is one component of status assessments for species at risk. The foothill yellow-legged frog (*Rana boylii*) inhabits a variety of lotic ecosystems, many of which have undergone substantial alteration of hydrologic regimes as a result of water storage, diversion, and hydroelectric power generation projects. Because of its declining status, *R. boylii* has become a focal species in recent Federal Energy Regulatory Commission (FERC) re-licensings of hydroelectric projects. In addition to direct population monitoring, habitat assessments and instream flow modeling are being conducted for *R. boylii* and other aquatic species during FERC re-licensings in California. Using pre-existing data from four Sierra Nevada and one Coast Range river, we developed suitability criteria for three aquatic habitat variables (water depth, water velocity, and substrate) for pre-metamorphic life stages (egg masses and tadpoles) of *R. boylii*. We focused on egg masses and tadpoles because of the ample existing data and because effects of changes in hydrologic regimes and river habitats were thought to be more severe for these highly aquatic life stages. Three suitability levels (high, marginal, and not suitable) were developed for each life stage and habitat variable. These levels were based on the range of water depth, water velocity, and substrate values observed for 90%, 10%, and 0% of egg masses or tadpole groups, respectively. Consistent with previous natural history accounts and studies, shallow water, slow water velocity, and large substrates represented the highest suitability. These criteria will ultimately be used in a 2-dimensional hydrodynamic model to determine habitat suitability at a variety of water flow release levels for particular river reaches. Next steps are to validate the criteria in other rivers and to explore the development of similar criteria for post-metamorphic life stages.

INTRODUCTION

Purpose and Context

Habitat associations or suitability models provide one method for assessing effects of environmental changes on a focal species. The primary, though often unverified, assumption is that habitat conditions strongly influence species population dynamics and stability. Such models can range from single variable, categorical criteria to multiple variable curves defining ranges of suitability with associated errors/confidence. Assuming data are taken over a range of environmental conditions, suitability is typically defined by the relative use of particular conditions or habitats by focal species. During Federal Energy Regulatory Commission (FERC) re-licensing of hydroelectric projects, studies of focal species typically record data on distribution, relative abundance, habitat associations and conditions, and flow regime effects. These data provide the initial information needed to develop suitability criteria for populations in individual rivers and potentially for larger geographic regions.

This report provides a set of habitat suitability criteria (HSC) for early life stages (pre-metamorphic) of the foothill yellow-legged frog (*Rana boylii*). We focused on the early life stages because these lifestages are the most aquatic, the most likely to be influenced by changes in flow regimes, and there were substantial existing habitat data. Further justification on this focus is provided below. The criteria were developed specifically for use in the re-licensing of Pacific Gas and Electric Company's (hereafter, PG&E) DeSabla-Centerville Project (FERC #803). The criteria were developed by the Foothill Yellow-legged Frog Habitat Suitability Criteria Technical Workgroup (hereafter, HSCTW) through a series of group meetings and via the work of individual members between meetings (Appendix A lists the HSCTW members). The intent is to use these criteria in conjunction with River2D, a 2-dimensional hydrodynamic model (Steffler and Blackburn 2002), developed for one or more river reaches where *R. boylii* occurs, to determine habitat availability under different flow regimes.

Rana boylii Status and Natural History

Rana boylii historically occurred in foothill and mountain streams from northern Baja California to southern Oregon west of the Sierra-Cascade crest, to 1830m (6000 ft) in elevation. This species is currently listed as a California State Species of Special Concern and USDA Forest Service California Region Sensitive Species (California Department of Fish and Game 2006) due to significant population declines, especially in the southern part of its range (southern Sierra Nevada and south coastal California) (Jennings and Hayes 1994, Jennings 1996, Lind 2005). *Rana boylii* is almost exclusively associated with stream environments. Breeding and oviposition occur in the spring (typically March through June, depending on latitude, elevation, and hydrologic regime) and females deposit a single egg mass which consists of several hundred to over 1000 eggs. Eggs are typically laid in relative shallow, low water velocity areas of streams and attached to rocky substrates, though sometimes logs or live trees are used. Tadpoles (larvae) develop in and near oviposition areas and metamorphose in late summer through early autumn (July through September) (Jones et al. 2005). Recent research has documented selection of these types of environments (shallow, low water velocity areas) for oviposition and tadpole rearing (Kupferberg 1996, Lind 2005, Yarnell 2005).

The main threats and possible causes of declines of *R. boylii* are human activities that alter hydrologic regimes of streams. Documented effects have been most pronounced for the egg and larval stages of this frog as they occur in very specific conditions of water temperature, velocity, depth, and substrate (Fuller and Lind 1992, Kupferberg 1996a&b, Lind 2005). Human activities such as dams and diversions, mining, and livestock grazing, can have significant effects on hydrologic regimes (Lind et al. 1996, Lind 2005).

Because of its strong ties to stream environments and sensitive early life history stages, *R. boylii* has become a focal species in recent FERC re-licensing of many hydropower projects. Even minimal changes in flow regimes can have detrimental effects if they occur during the critical oviposition and rearing seasons. A recent study of egg and larval life stages and associated habitats found that these life stages can be scoured, desiccated, or stranded by aseasonal pulse flows depending on the timing, duration, and magnitude of those flows (Kupferberg et al. 2007). Habitat suitability criteria for *R. boylii*, when used in conjunction with 2 dimensional hydrodynamic models will allow evaluation and prediction of effects of potential changes in flow regimes on this species. Hydrodynamic models are based on detailed mapping of stream channel topography and allow the simulation of different discharges and predictions of water depths, velocities, and other hydrologic indices for particular portions of the river channel (e.g., *R. boylii* oviposition areas). The resulting predictions can inform the setting of new license conditions for hydroelectric and other dam/diversion projects.

APPROACH AND TECHNICAL METHODS

Habitat Associations of *R. boylii* and Suitability Criteria

At our first meeting, the HSCTW developed a list of all the environmental variables that define and influence *R. boylii* habitat. We defined each variable, indicated its ecological/management relevance, and put it in to one of three categories: (1) variables related to hydrodynamic models (e.g. 2D model), (2)variables influenced by flow regime, but not typically part of hydrodynamic models, (3) variables not influenced by flow regime (reach-scale and greater) (Appendix B). These three categories were used to focus the set of variables we would use to develop habitat suitability criteria. Three variables, representing habitat conditions of water depth, water velocity and substrate, were selected from category 1 to become the focal variables for subsequent habitat suitability criteria development. These three variables were selected for two primary reasons: (1) evidence from descriptive natural history studies and recent research indicates that they are representative of conditions selected by frogs for oviposition and tadpole rearing and (2) they could be readily used in hydrodynamic models. Several different measurements of these variables were available in some of the datasets (water velocity at egg mass, mid-column water velocity, surface water velocity); selection of final focal variables is discussed in the next section.

To avoid losing sight of the larger context of habitat suitability, we also developed a conceptual framework model of *R. boylii* habitat requirements relative to environmental conditions (Figure 1). This draft framework is a much simplified depiction of the environmental conditions that provide suitable *R. boylii* breeding and rearing habitats and influence successful recruitment. It was based on the set of variables developed by the HSCTW (Appendix B) as well as an unpublished envirogram for this species (Lind 2004). The framework is included in this report to emphasize that the simple habitat criteria that we developed, while important, must be considered in the larger set of influences on *R. boylii* populations and habitats.

Datasets and Lifestages

We evaluated 31 datasets available from previous studies conducted for FERC re-licensing projects (including the DeSabla-Centerville Project, FERC #803) and other research or monitoring (Appendix C). Datasets were provided by PG&E, environmental consultants, or researchers. In order to be evaluated initially, datasets had to include information on at least one lifestage of *R. boylii* with associated data on one or more of the focal habitat variables, water depth, water velocity, and substrate. Pre-metamorphic lifestages were egg masses and tadpoles and post-metamorphic lifestages were young of the year, juveniles, or adults. After an initial evaluation of datasets, we decided to focus on the pre-metamorphic lifestages for the following reasons:

- Post-metamorphic lifestages are less aquatic than pre-metamorphic and are likely selecting habitat based on both the aquatic and terrestrial conditions. Also, since the primary application of this HSC is use in a hydrodynamic model, variables representing aquatic habitat conditions with measurable effects on *R. boylii* were needed.
- Data on post-metamorphic lifestages was limited to only a few rivers and time and funding were not available for additional field data collection. Development of HSC for post-metamorphic lifestages needs further exploration (see Discussion section below).

We used tadpole groups (1 or more individuals located in the same microsite) rather than individual tadpoles because most data was collected for groups (rather than individuals) in the field. Even though a count was typically available for each group, we didn't want to artificially inflate sample sizes by using replicate individuals that were essentially in the same microsite.

None of the datasets had "negative" or availability data (i.e. data on focal variables in areas **not** used by *R. boylii*). This shortfall could lead to erroneous conclusions about habitat suitability. For example, no *R. boylii* egg masses were found at depths greater than 1m. Was that because those areas weren't searched or because they were searched and *R. boylii* wasn't found at those depths? We partially addressed this concern by evaluating and characterizing the sampling methods for each river (Appendix C). In general we concluded that surveys were conducted over a broad enough range of habitat conditions to conclude that the HSC's we developed were representative of the majority of suitable habitats. However, future work should address this question more directly by including non-use areas to confirm habitat selection (see Discussion section below).

HSC Methods

Preliminary Analyses and Focal Variable Evaluation

Of the 31 datasets initially evaluated, datasets from 5 rivers (Butte Creek, West Branch Feather River, South Fork Feather River, Pit River, and South Fork Eel River) contained reasonable samples sizes for the focal aquatic variables (water depth, water velocity, and substrate) for egg masses and/or tadpole groups (Table 1, Appendix C). We conducted several preliminary analyses to assess relationships among variables. The goal of these analyses was to determine if: (a) a subset of variables could be used to describe habitat conditions for each lifestage, and (b) if data varied among rivers sufficiently to warrant the development of river-specific habitat criteria versus regional habitat criteria.

Egg mass data were graphically compared among rivers by producing simple histograms for: depth of water at egg mass, total water depth at egg mass, depth of water at egg mass as a percentage of total depth, velocity of water at egg mass, mid-column velocity of water at egg mass, egg mass attachment substrate, microhabitat at egg mass, and macrohabitat at egg mass. To determine if velocity at egg locations varied with habitat type, velocity at egg mass and mid-column velocity were compared to macrohabitat types using boxplots. Data for histograms and boxplots were sorted by: all rivers and survey years combined, river, and river and survey year. Sample sizes varied, as data on some variables was not collected on all rivers and/or years. To assess differences among rivers, means for depth of water at egg mass, total water depth at egg mass, velocity of water at egg mass and mid-column velocity of water at egg mass were compared using one-way ANOVAs. The relationship between velocity at egg mass and mid-column velocity was explored using regression.

For the tadpole group data, simple histograms were produced for total depth and velocity at tadpole group. To determine if velocity at tadpole locations varied by habitat type, velocity at tadpole group was compared to macrohabitat type using boxplots. Data for histograms and boxplots were sorted by: all rivers and survey years combined, river, month of survey, tadpole group stage, and average length of tadpoles in the group (by length classes). Sample sizes varied, as data on some variables were not collected on all rivers and/or years. Means for total depth and velocity at tadpole group were compared among rivers using one-way ANOVAs.

Table 1. Summary of data manipulations and analyses for *Rana boylii* HSC development.

Dataset Information	**Egg Masses**	**Tadpole Groups**
Sample Size	n=251 (109 of 251 total samples (43%) were from the DeSabla datasets)	n=405 (184 of 405 total samples (45%) were from the SF Eel dataset)
Rivers - Years Represented	-South Fork Feather River – 2005 -Butte Creek – 2006 -West Branch Feather River – 2006 -Pit River – 2002, 2003, 2004	-Butte Creek – 2006 -West Branch Feather River – 2006 -SF Eel River – 1991, 1992, 1993
Variables Included	-River surveyed -Survey date -Site -Depth of water at egg mass, in meters -Total water depth at egg mass, in meters -Depth at egg mass as a percentage of total depth -Velocity of water at egg mass, in meters per second -Mid-column velocity of water at egg mass, in meters per second -Surface velocity of water at egg mass, in meters per second -Egg mass attachment substrate -Microhabitat at egg mass -Macrohabitat at egg mass	-River surveyed -Survey date -Site -Estimated number of tadpoles in group (each group was treated at one sample) -Average length of tadpoles in the group, in millimeters -Tadpole stage -Total depth of water at tadpole group, in meters -Velocity of water at tadpole group, in meters per second -Substrate at tadpole group -Microhabitat at tadpole group -Macrohabitat at tadpole group

Dataset Information	Egg Masses	Tadpole Groups
Data Manipulations	- For velocity at the egg mass, 35 samples were removed prior to analysis, as each was greater than the corresponding mid-column velocity of water recorded at the egg mass: 2 samples SF Feather, 2005 survey; 33 samples Pit River, 2004 survey - For mid-column velocity, two samples were removed from the 2005 SF Feather River survey data, as they exceeded the mean by a magnitude greater than 10. 33 samples from the Pit River, 2004 survey were removed because values for velocity at egg mass were greater than the corresponding mid-column velocity values.	-None required

Focal Variables and River Specific Criteria

Based on the analyses of focal variables above and the preliminary analyses (Appendix D), we made the following decisions: (1) Develop suitability criteria for total water depth, mid-column water velocity, and substrate because these variables were consistently available for each lifestage (Appendix C). These are also the focal variables used in hydrodynamic modeling (Figure 1, Appendix B); (2) Develop suitability graphs/criteria for water depth and water velocity for each river (river-specific criteria) as well for all rivers combined (combined data). Sample size limitations necessitated developing criteria for substrate from combined data. Most of the data we have are from northern Sierra Nevada rivers; there is one dataset on tadpoles from a Coast Range river. Final analyses with combined data do **not** include the Coast Range river; data from that river is presented separately.

Mechanics of Calculating Suitability Criteria

As information on habitat preference (defined in relation to habitat availability) is lacking, the working group felt development of a traditional criteria curve with varying suitabilities was inappropriate. Instead, categorical suitabilities that bracketed the range of observed velocities and depths would be a more prudent or conservative approach. Specifically, three categories of suitability were designated: suitable, marginally suitable, and unsuitable. Each category was assigned a suitability value roughly proportional to the observed use. 'Suitable' values encompass the numerical range of 90% of observed values and are assigned a suitability of 1.0. 'Marginally suitable' values encompass the remaining 10% of observations and are assigned a suitability of 0.1. All values outside the suitable and marginally suitable ranges are considered 'unsuitable' and are assigned a suitability of 0. Details for egg masses and tadpole groups area provided below.

- **Egg Masses**
  - **Mid-column Velocity** - Mid-column velocities ranged from 0.0-0.25 m/s across all rivers analyzed, with the bulk of observations at or just above 0.0 m/s. Incidences of egg masses at the higher velocities were rare. Therefore, suitability for mid-column velocity is presented as the following categories:
    - Suitability of 1.0 = numerical range from 0.0 m/s to the 90th percentile of observations.
    - Suitability of 0.1 = numerical range from the 90th to 100th percentile of observations.
    - Suitability of 0.0 = values outside of the ranges of Suitability 1.0 and 0.1 categories.

  - **Total Depth** - Total depth values ranged from 0.00-0.90 m across all rivers analyzed. As egg masses require submersion in water to be viable, but have the ability to flatten out some in very shallow depths (shallower than the average diameter of an egg mass), zero depths were considered unsuitable and very shallow depths considered marginally suitable. The incidence of egg masses occurring at large depths was rare, so large depths were also considered marginally suitable. Therefore, suitability for mid-column velocity is presented as the following categories:
    - Suitability of 1.0 = numerical range from the 5th to the 95th percentile of observations.
    - Suitability of 0.1 = numerical range that the lowest depth greater than zero to the 5th percentile and numerical range from the 95th to 100th percentile of observations.
    - Suitability of 0.0 = values outside of the ranges of Suitability 1.0 and 0.1 categories.

  - **Substrate** - Attachment substrates ranged across all categories, but not all categories were observed on all rivers. The coarser substrate categories were dominant on all rivers however. Therefore, suitability for attachment substrate is presented as the following categories based on ranking categories from highest to lowest:
    - Suitability of 1.0 = sum of the percent observed within the most frequent substrate categories totaling 90% of observations.
    - Suitability of 0.1 = all remaining substrate categories with observations (totaling 10% or less of observations).
    - Suitability of 0.0 = substrate categories without observations.

- **Tadpole Groups**
  - **Mid-column Velocity** - Mid-column velocities ranged from 0.0-0.24 m/s across all rivers analyzed, with the bulk of observations at or just above 0.0 m/s. Incidences of tadpoles at the higher velocities were rare. Therefore, suitability for velocity at tadpole group is presented as the following categories:
    - Suitability of 1.0 = numerical range from 0.0 m/s to the 90th percentile of observations.
    - Suitability of 0.1 = numerical range from the 90th to 100th percentile of observations.
    - Suitability of 0.0 = values outside of the ranges of Suitability 1.0 and 0.1 categories.

  - **Total Depth** - Total depth values ranged from 0.01-1.0 m across all rivers analyzed. As tadpoles must remain submerged in water and are approximately 0.01 m in height, depths less than 0.01 m were considered unsuitable. The incidence of tadpoles occurring at large depths was rare, so large depths were considered marginally suitable. Therefore, suitability for total depth is presented as the following categories:
    - Suitability of 1.0 = numerical range from 0.01 m to the 90th percentile of observations.
    - Suitability of 0.1 = numerical range from the 90th to 100th percentile of observations.
    - Suitability of 0.0 = values outside of the ranges of Suitability 1.0 and 0.1 categories.

  - **Substrate** - Tadpole substrates ranged across all categories, but not all categories were observed on all rivers. The coarser substrate categories were dominant on all rivers however. Therefore, suitability for tadpole substrate is presented as the following categories based on ranking categories from highest to lowest:
    - Suitability of 1.0 = sum of the percent observed within the most frequent substrate categories totaling 90% of observations.
    - Suitability of 0.1 = all remaining substrate categories with observations (totaling 10% or less of observations).
    - Suitability of 0.0 = substrate categories without observations.

Habitat suitability criteria are presented in Tables 2, 3, and 4 below and graphically in Figure 2. Appendix E contains histograms of raw data for each river, lifestage, and variable (water velocity, water depth, and substrate). Differences among rivers are apparent, though a large proportion of the variation was likely due to river size. For example, Butte Creek is a low order (small) river dominated by shallow depths and slow water velocities and the Pit River is a high order (large) river with a large range of water depths and velocities. Thus, suitabilities can vary based on the range of conditions available in each river. More work is needed to better understand this variation.

Table 2. *Rana boylii* egg mass habitat suitability criteria. n = valid sample size for depth/velocity/substrate if they differed among variables; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable. See text for detailed description of how criteria were derived.

		Total Depth (m) Suitability[1]			**Mid-column Water Velocity (m/sec) Suitability**[2]			**Substrate Suitability**[2]		
River	**n**	**0**	**0.1**	**1**	**0**	**0.1**	**1**	**0**	**0.1**	**1**
All Rivers Combined	223/ 192/ 248	<0.02, >0.90	0.02-0.05, 0.48-0.90	0.06-0.47	>0.25	0.10-0.25	0.0-0.09	Small or large woody debris, other	Silt/clay/ mud, sand, bedrock	Cobble, gravel/pebble, bedrock
Butte Creek	59	<0.02, >0.64	0.02-0.04	0.05-0.64	>0.07	0.06-0.07	0.00-0.05			
West Branch Feather River	49	<0.09, >0.90	0.65-0.90	0.10-0.64	>0.17	0.13-0.17	0.00-0.12			
South Fork Feather	28	na	na	na	>0.25	0.14-0.25	0.00-0.13			
Pit River	114/ 80	<0.06, >0.49	0.06-0.09, 0.32-0.49	0.10-0.30	>0.15	0.10-0.15	0.0-0.09			

1 - All Rivers for total depth = Butte, West Branch Feather, Pit.
2 - All Rivers for mid-column water velocity and substrate = South Fork Feather, Butte, West Branch Feather, Pit.

Table 3. *Rana boylii* tadpole habitat suitability criteria. n = valid sample size for depth/velocity/substrate if they differed among variables; 0 = not suitable, 0.1 = marginally suitable, 1 = suitable. See text for detailed description of how criteria were derived.

		Total Depth (m) Suitability[1]			**Mid-column Water Velocity (m/sec) Suitability[1]**			**Substrate Suitability[1]**		
River	**N**	**0**	**0.1**	**1**	**0**	**0.1**	**1**	**0**	**0.1**	**1**
All Rivers Combined	154/ 145/ 155	<0.02, >1.00	0.45-1.00	0.02-0.44	> 0.24	0.12-0.24	0.00-0.11	Small or large woody debris, other	Silt/ clay/ mud, boulder	Sand, cobble, gravel/pebble, bedrock
Butte Creek	114/ 105	<0.02, >1.00	0.45-1.00	0.02-0.44	> 0.23	0.09-0.23	0.00-0.08			
West Branch Feather River	40	<0.05, >1.00	0.36-1.00	0.05-0.35	> 0.24	0.11-0.24	0.00-0.10			
South Fork Eel River	184	<0.01, >0.70	0.21-0.70	0.01-0.20	> 0.08	0.04-0.08	0.03-0.08			

1-All Rivers = Butte, West Branch Feather (South Fork Eel **not** included).

Table 4. Frequency data for *Rana boylii* egg mass attachment substrate and tadpole group habitat substrate derived from 248 egg masses and 155 tadpole groups. Highlighted (yellow) cells represent the ranked (highest to lowest) substrate types used to reach a total of 90% of the observations. Data are from the following rivers: Egg Masses - Butte, West Branch Feather, South Fork Feather, Pit; Tadpoles - Butte, West Branch Feather (South Fork Eel not included).

Substrate Category	**Egg Masses (%)**	**Tadpole Groups (%)**
Silt/Clay/Mud	0.4	2.6
Sand	0.8	10.3
Gravel/Pebble	10.9	22.6
Cobble	72.6	40.6
Boulder	13.7	7.1
Bedrock	1.6	16.8
Other	0.0	0.0

DISCUSSION AND APPLICATIONS

Assumptions and Limitations of Data

As with any data collected by different parties for different reasons, there are likely some observer and instrumental biases associated with the data collection within each dataset. For example, how categorical variables are assigned in the field may differ among personnel, or use of different types of flow meters may result in velocity values rounded with differing precision. This last example appears to be the case for velocity at tadpole group in the SF Eel dataset. The lack of velocity values at 0.01 m/s and 0.04 m/s may be real or may more likely be due to precision error with the meter.

Seasonal and year-to-year variation in climate, flow conditions and population status may also have an indirect effect on the data collected. Depending on the conditions at the time of oviposition for eggs or the time of survey for tadpoles, data may differ. Only with larger sample sizes through time could these types of errors be resolved.

With regard to developing habitat suitability criteria, perhaps the largest assumption is that observed habitat association or utilization is indicative of individual preference. Without associated habitat availability data describing the full range of habitat conditions available for selection at the time observations are made, it is uncertain whether the observed utilization of habitat reflects true preference or choices are limited, and thus biased, by what is available. For example, it may be that frogs prefer to lay eggs in depths greater than 0.5m, but if that habitat is unavailable, that preference would not be observed in the data. Since none of the datasets had associated habitat availability data, we partially accounted for this potential bias by limiting the suitability criteria to broad categories (suitable vs. marginally suitable), rather than partitioning observed utilization into many narrow categories and assigning varying degrees of suitability (as in a traditional curve). In addition, we developed criteria specific to each river, which can be contrasted among rivers to aid in assessing whether such a bias may occur. Future research to address the degree to which habitat availability might affect observed habitat utilization for eggs and tadpoles is needed.

The data analyzed and presented in this report, while comprehensive, were not comprehensive enough to address the following issues. Data from the SF Eel and NF Feather indicate differences in tadpole habitat utilization by tadpole size and/or Gosner stage may occur; additional data collected throughout the summer as tadpoles disperse to adjacent habitats in multiple locations would help to address this issue. Differences in both egg and tadpole habitat utilization of microhabitat and macrohabitats may occur, but categorical descriptions of the habitat were too coarse or varied among rivers to delineate such a preference. However, since most macrohabitats are distinguished by depth and velocity, it may not be necessary to assign criteria based on habitat type. Data from a greater number of sites might shed light on this issue. Differences among years were graphically assessed within the Poe and Cresta datasets, but the results were ambiguous at best. In general, mean values were roughly the same, but variation about the mean differed. Additional data collected at multiple sites over longer time scales would help to tease apart patterns in annual variation within and among rivers. Lastly, the working group discussed the idea that habitat preference for egg masses is really determined at the time of oviposition. Subsequent surveys of egg mass habitat conducted days or weeks after oviposition reflect conditions at the time of the survey, not necessarily at the time of oviposition when flows may have been higher or lower. As a result, differences in observed egg mass habitat utilization may vary by Gosner stage. Although some data on egg mass Gosner stage was available in the selected datasets, time constraints precluded any analysis. Future analysis on this issue is needed.

Applicability of Criteria to DeSabla-Centerville Project and Other Re-licensing's in California
We feel confident that the HSC developed in this report are relevant to *Rana boylii* populations that occur within the DeSabla-Centerville project. Data specific to the river reaches within the project were used in the development of the HSC and the majority of the other data used was from rivers that while somewhat larger, were in close geographic proximity to the DeSabla-Centerville project area.

Because most of the data included in the HSC development derived from Sierra Nevada rivers, we feel that the combined river criteria could be used in other Sierra Nevada rivers but we recommend caution in applying these criteria to other geographic areas in the range of *Rana boylii*. A final step, which is outside of the scope of this project, is to validate the criteria we developed for other Sierra Nevada rivers and for rivers in other geographic regions (see below, Information Gaps and Next Steps).

In addition, we can't emphasize enough the importance of considering the larger environmental context as depicted in Figure 1. *Rana boylii* population occurrence and abundance is undoubtedly influenced by many factors in addition to the local aquatic conditions that we focused on to develop these HSC. More work is needed to understand the relative influences of these factors and how they interact to determine frog population outcomes (see below, Information Gaps and Next Steps).

Use in Related Habitat Assessment Work (e.g., 2D-Modeling)
The HSC developed here are intended for use in conjunction with River2D (Steffler and Blackburn 2002) to determine habitat availability under different flow regimes. A recently completed study by Kupferberg et al. (2007) included an evaluation of River2D in relation to *R. boylii* habitat. The results showed that the model performed reasonably well, depending upon the nature and scale of management questions addressed. For questions regarding relative change in local hydraulic habitat conditions, such as potential for scour from a high pulse flow in occupied breeding habitat or flows that cause entrainment or exhaustion of tadpoles, the model provided useful information. However, the model was not useful in predicting exact impacts to microscale habitats due to low precision in point velocities. For example, the model could not precisely predict "suitable" tadpole habitat, defined as 0.0-0.05 m/s, but it could resolve "tolerable" tadpole habitat, defined as 0.0-0.1 m/s, since this range encompassed the model error. Topographic survey resolutions at both modeled study sites ranged from 0.25 m^2 to 2.0 m^2, and mean error for velocity ranged from -0.04 m/s to 0.03 m/s depending on location within the modeled reach. With finer topographic survey resolution, these errors would likely be reduced.

Some of the HSC developed here span a range large enough to encompass potential model error (e.g. WB Feather egg velocity suitability of 1 = 0.0 – 0.12 m/s), but some, for example Butte

Creek egg velocity suitability, are < 0.05 m/s. Whether these HSC can be incorporated into River2D and produce useful information will depend on the nature of the modeled site. Specifically, channel shape, substrate sorting and topographic survey resolution of the site among other site-specific factors will contribute to the level of error in model predictions. It is necessary that users of River2D with the associated HSC understand the precision, accuracy and limitations of the model, and interpret the model results appropriately within the scope in which they apply. Table 5 provides a preliminary assessment of the consequences of developing narrow to broad suitability criteria for different river sizes.

Table 5. Potential consequences of narrow versus broad habitat suitability criteria by river type for hydrodynamic modeling.

	Habitat Suitability Criteria	
River Type	Narrow	Broad
Small, shallow, slower water velocities	Model will predict moderate suitability; probably okay	Model will show lots of suitable areas; not very refined
Large, deep, faster water velocities	Model will predict less suitable habitat than reality	Model will predict moderate suitability; probably okay

<u>Information Gaps</u>

During HSCTW meetings and throughout the data analyses and writing of this report, several remaining information needs were identified. Below we provide a brief listing of those needs to guide future habitat suitability criteria development and validation in other venues.

- Further exploration of differences in habitat suitability for different developmental (Gosner) stages of eggs and tadpoles.
- Data on habitat associations for post-metamorphic (juvenile and adult) lifestages.
- Validation of suitability criteria in different river systems, including incorporation of habitat data for areas not used by *Rana boylii*.
- Research on relative role and importance of habitat conditions in determining overall distribution and abundance, especially where populations are small or isolated (e.g. Figure 1).
- Studies on how the influences of lifestage-specific habitat conditions fit into a limiting factors framework and ultimate influences on population size and stability (decline or growth).

ACKNOWLEDGEMENTS

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FIGURES

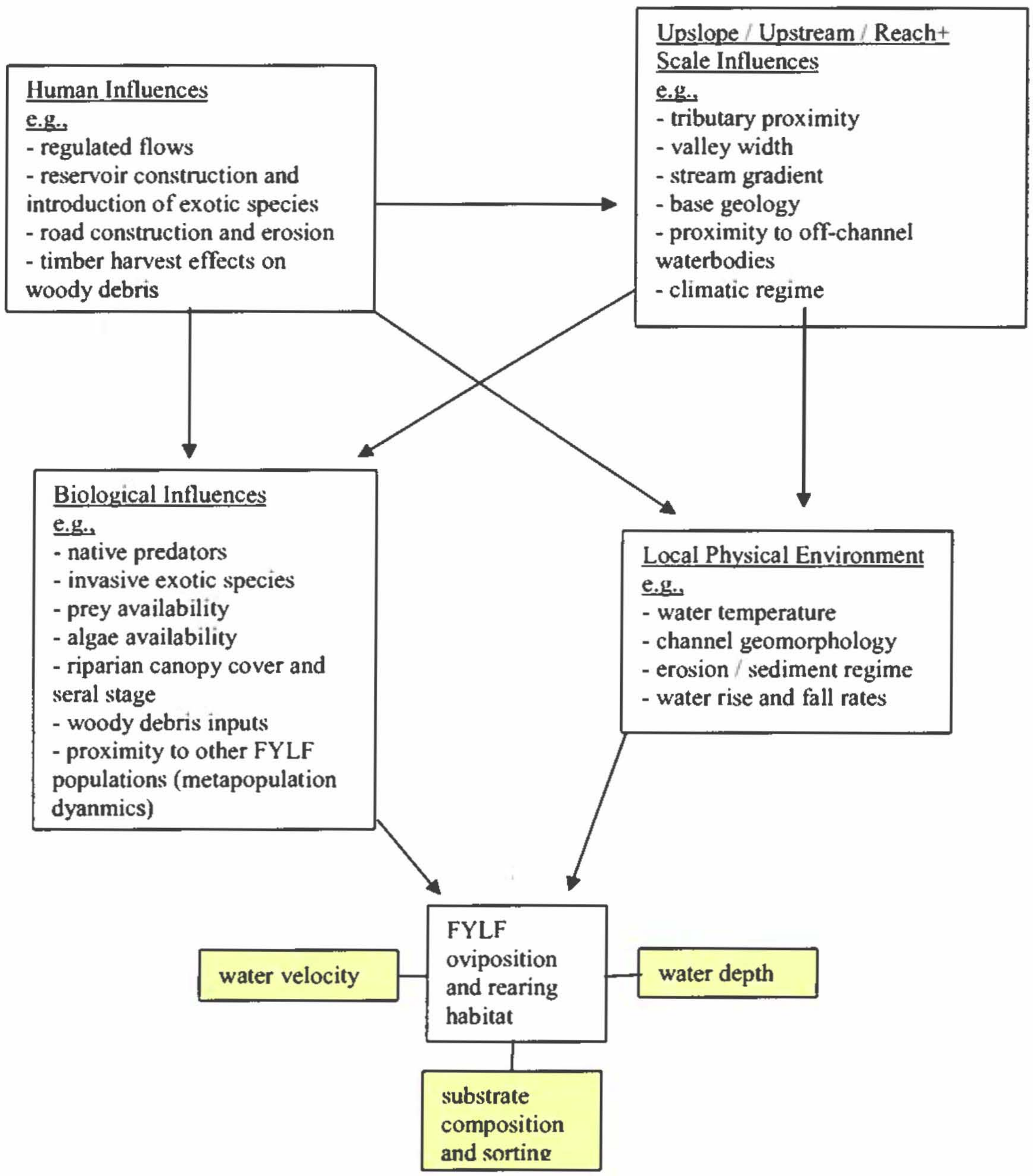
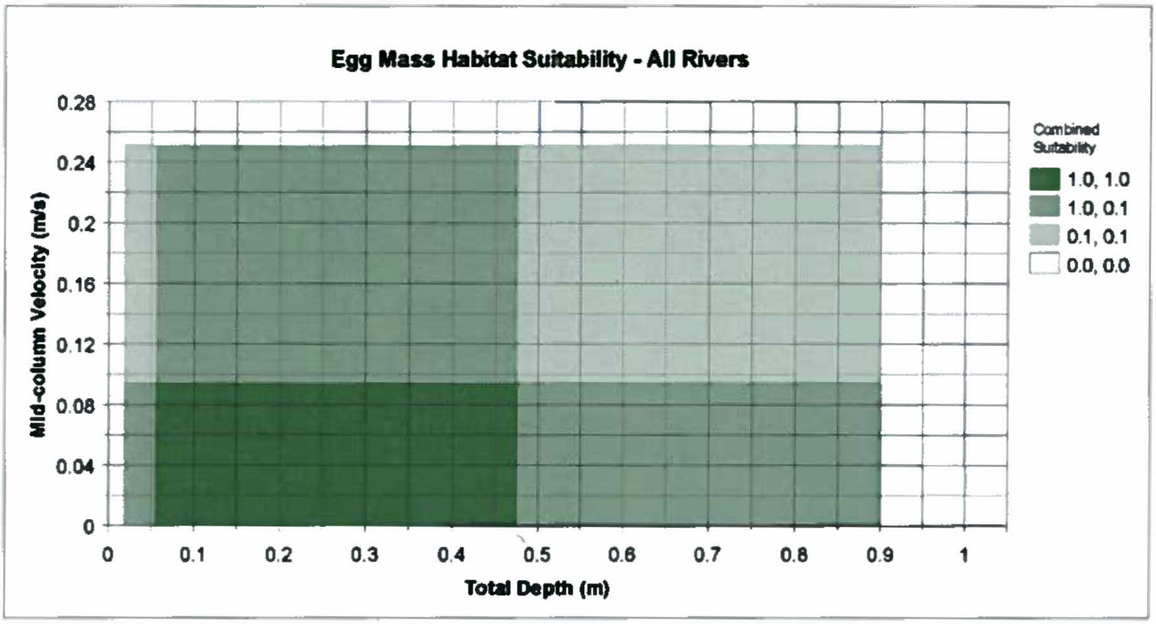


Figure 1. Conceptual framework for *Rana boylii* oviposition/rearing habitat associations in the context of other environmental influences. Highlighted (yellow) boxes depict variables included in habitat suitability criteria development for this report.

a.



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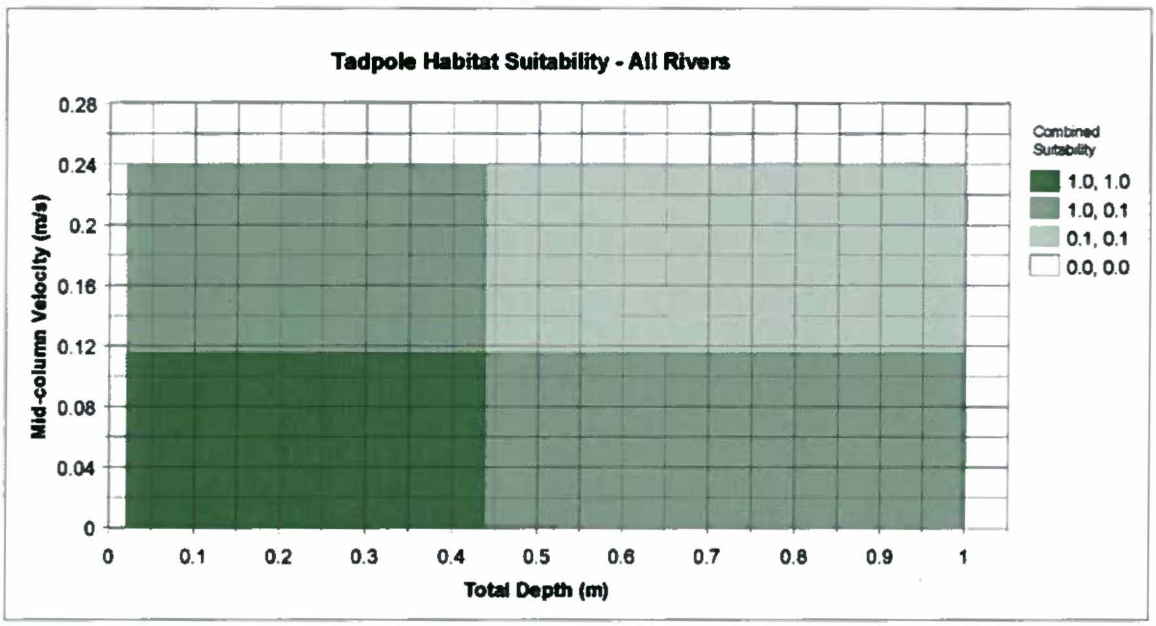


Figure 2. Habitat suitability criteria (mid-column water velocity and total depth) for foothill yellow-legged frogs (*Rana boylii*) for all rivers for (a) egg masses and (b) tadpoles. "All rivers" differ for each lifestage and variable – see Tables 2 and 3 for the included rivers. The darkest green shade represents velocity and depth conditions with the highest suitability (1.0). The lightest green represents velocity and depth conditions with marginal suitability (0.1) and white areas have a suitability of zero. Medium green represents mixed suitability levels for velocity and depth. For example, the upper left medium green quadrant in (a) represents high suitability for depth and marginal suitability for velocity.

APPENDICES

Appendix A. Foothill yellow-legged frog habitat suitability criteria technical workgroup members, DeSabla-Centerville Project (FERC #803).

Name	Affiliation
Christine Champe	Stillwater Sciences
Mark Gard	US Fish and Wildlife Service
Andie Herman	Pacific Gas and Electric Company
Sarah Kupferberg	Questa Engineering Corporation
Amy Lind	USDA Forest Service, Sierra Nevada Research Center
Jim Lynch	Devine-Tarbell and Associates
Mary Lisa Lynch	California Department of Fish and Game
Ryan Peek	Stillwater Sciences
Dennis Smith	USDA Forest Service – Regional Hydropower Assessment Team
Kathy Turner	USDA Forest Service – Lassen and Shasta National Forests
Scott Wilcox	Stillwater Sciences
Sarah Yarnell	Center for Watershed Sciences, University of California, Davis

Appendix B. Habitat variables discussed by the HSCTW for inclusion in habitat suitability criteria for foothill yellow-legged frogs (*Rana boylii*). Highlighted (yellow) variables are the set being used for egg and tadpole lifestage habitat suitability criteria.

1. Variables related to hydrodynamic models:

Habitat Variable	Definition	Relevance/Applicability
Local Depth	Water depth immediately at/adjacent to observation; total depth at egg mass; depth from surface to middle of egg mass; average water depth in microhabitat	Each lifestage has been observed/shown to select microhabitats with a specific range of depths (Kupferberg 1996, Lind and Welsh in rev., Van Wagoner 1996, Yarnell 2005). e.g. eggs often laid in shallow depths b/w 5-35 cm, tads often in shallow near-shore environments, adult females adjacent to deeper pools. As depth varies with flow, suitability for various lifestages will vary.
Local Velocity	Velocity immediately at/adjacent to observation; velocity at egg mass; mid-column velocity at/above egg mass; average velocity in microhabitat (both vertically and horizontally)	Each lifestage has been observed/shown to select microhabitats w/a specific range of velocities (Kupferberg 1996, Lind and Welsh in rev., Van Wagoner 1996, Yarnell 2005). e.g. eggs laid in low velocities b/w 0-10cm/s, adults in velocities up to 40 cm/s. As velocity varies with flow, suitability for various lifestages will vary.
Substrate Size	Length of intermediate axis of particle (D_i); Median particle size (D_{50}); Categorical class size: Boulder (>256mm), Cobble (64-256mm), Gravel (2-64mm), Sand (<2mm), silt (smooth b/w fingers); 'Roughness height' - height above channel bed in z-direction (measurement from bed to top of boulder thru water column perpendicular to water surface plane)	Some lifestages select microhabitats with specific substrate sizes (same refs as above). Eggs often attached to larger cobble substrate; juveniles often in smaller cobble/gravel substrates. Knowledge of substrate size could help determine likelihood of observing certain lifestages, although variability is high, and larger substrates provide more refuge against varying flows.
Froude #	Fr = v/sq.rt(gd) = velocity/square root of gravity x depth;	Froude # describes the conditions of flow – it is a ratio between velocity and depth, two habitat variables for each lifestage, and has been correlated to microhabitat type in previous studies (Panfil and Jacobson 2005). Since lifestages are associated with certain microhabitat types, velocities and depth, Froude # may be a useful single variable that incorporates and correlates w/all 3.
Hydraulic Radius (or other metric of cross-sectional area)	R = A/wp = cross-sectional area/wetted perimeter. wp = 2d + w = (2 x depth) + width = length of wetted channel perpendicular to flow	Hydraulic Radius (R) is one metric that relates to and describes cross-section shape. In most cases, smaller R corresponds to a shallower, wider channel. Eggs have been shown to prefer channel shapes with a shallow overbank area where depth and velocity fluctuate less as flow changes (Kupferberg 1996, Yarnell 2005). Areas w/smaller R values may have better suitability in fluctuating flows.

Habitat Variable	Definition	Relevance/Applicability
Mid-column velocity:substrate size ratio	Ratio of mid-column velocity (vs vel near the bed or at egg mass) to substrate size or roughness height (see def for substrate, roughness above)	In areas where roughness is greater, particularly where substrate sizes are larger creating sizable eddies and no flow regions on the lee side of the particles, there is a greater potential for refuge areas or suitable oviposition sites. A ratio between the mid-column velocity (output from the hydro-model) and the substrate size or roughness height might indicate potential areas of suitability that mid-column velocities alone might suggest were unsuitable.

2. Variables influenced by flow regime:

Habitat Variable	Definition	Relevance/Applicability
Water Temperature	Local point temperature at surface or mid-column near shore; average daily temperature of near shore or mid-channel	Oviposition begins once water temperatures reach a daily average of about 13C (Kupferberg 1996b, Lind in rev). Tadpoles are also often found in warmer shallow microhabitats and have been shown to develop faster in warmer water (Kupferberg 1996b). As flows fluctuate and potential water temp fluctuations occur during pulses or late summer releases, suitability for early lifestages may vary.
Canopy Cover	Percent cover over wetted channel (measured or quantile);	Most lifestages have been observed in open, sunny to partially shaded areas – particularly eggs & tads – where solar input is high facilitating warmer water temps and faster development (Kupferberg 1996b, Van Wagoner 1996, Yarnell 2005). Vegetation encroachment can limit solar input and increase embeddedness and silt deposition on cobble bars, decreasing suitability for early lifestages (Lind and Welsh in rev.). Fluctuating flows and presence of high spring flows promote scour and deposition of larger substrate particles, opening the canopy and increasing suitability for most lifestages.
Vegetation Serial Stage	Degree of vegetative succession along riparian banks, often correlated with canopy cover – categorical: open bar/no veg, early stage willows only, mixed willows/alders, late stage mature alders.	Relating to vegetation encroachment, the serial stage of riparian succession indicates the frequency of scour/deposition events and the degree of canopy cover over shallow near shore areas. Bare cobble bars with little to no shrub vegetation receive the greatest degree of solar input, thus increasing suitability for most lifestages.
Substrate Composition or Sorting	A measure of the range of substrate sizes present – quantititative: ratio of D_{50} to D_{90} or standard deviation of D_i; categorical: poorly sorted, well sorted or gravel/boulder mix.	Substrates w/a range of sizes present are most likely to have greater roughness height and a greater difference between height of larger and smaller particles on channel bottom, creating more low velocity refuge and oviposition sites on the channel bottom. In near shore areas, tadpoles and juveniles have been seen to sometimes associate with poorly sorted smaller particles where interstitial spaces are small but numerous, while adults have been seen

Habitat Variable	Definition	Relevance/Applicability
		associating with well sorted larger particles where interstitial spaces are larger (Yarnell 2000). As flows fluctuate and sediment composition potentially varies with sediment transport, habitat suitability may vary.
Microhabitat Type	Categorical description of channel morphology and flow type. Most common types are pool, riffle and bar, but many classifications exist. e.g. USFSR5 or Hawkins et al.	Certain microhabitat types have by definition characteristic depth/velocity conditions and thus, like observed lifestage preferences for depth and velocity, may indicate suitability. As flows fluctuate microhabitat types shift in type and location, and suitability for lifestages may vary.
Presence of Invasive Species	Presence or absence of invasive species within surveyed reach or some set distance/radius of surveyed reach	Invasive species, particularly bullfrogs and crayfish, have been shown to have both direct (competition and predation) and indirect (food web changes) impacts on all lifestages (Kupferberg 1996a, Lind and Welsh in rev). Flow regimes that discourage or are unsuitable for invasive species may increase suitability for most lifestages.
Invertebrate Density/Abundance	Quantitative – EPT index, IBI, density or abundance counts; Categorical – low, med, high.	High densities or abundance of invertebrates indicate a 'healthy' or productive fluvial system, suggesting fluvial conditions and flows are likely suitable for all lifestages. Observations suggest if invertebrate densities are low or decreasing, suitability for *R. boylii* is also low or unsuitable (Kupferberg 1996a)
Algal Density/Abundance	Quantitative – biomass estimates, percent cover on substrate; Categorical – low, med, high.	High density or abundance of algae promotes tadpole development and can be an indicator of a productive fluvial system. As flows fluctuate algal production may vary, resulting in varying suitability for tadpoles.
Natural Predation	Presence/abundance of native predators within focal reach or some set distance of surveyed reach.	Natural predators (e.g. garter snakes, riparian-associated birds) can impact *R. boylii* populations, though effects relative to other stressors have not been well-studied.
Berm Conditions	Existence and extent of riparian formed berms within focal reach.	Berms that develop due to controlled/reduced flows and riparian vegetation encroachment result in channelization of rivers and loss of shallow breeding/rearing areas for *R. boylii*
Ramping Rate / Fall Rate	Can be derived from gauge data in both regulated and unregulated rivers. Typically recorded as cubic feet/second at 15 min to 1 hour intervals.	In both regulated and unregulated systems, this rate may determine the degree of scouring and stranding of *R. boylii* eggs and tadpoles.

3. Variables NOT influenced by flow regime (reach-scale and greater):

Habitat Variable	Definition	Relevance/Applicability
Tributary Proximity	Distance to nearest tributary measured along stream length.	In larger river systems, perennial tributaries provide overwintering habitat and refuge from high flows in spring, and provide foraging habitat in summer and late fall (Jones et al.

Habitat Variable	Definition	Relevance/Applicability
		2005). In moderate and some small river systems, tributaries provide increased variability in hydraulic and geomorphic inputs (e.g. sediment supply), increasing habitat diversity at the confluence. *R. boylii* have been shown to prefer reaches with greater habitat diversity in small and moderate sized streams (Yarnell 2005).
Valley Width	Average valley width from topo maps or DEMs.	In moderate and small river systems, reaches with greater valley widths often have developed floodplains or space for overbank flows to create scour and deposition, resulting in increased habitat diversity. *R. boylii* have been shown to prefer reaches with greater habitat diversity in small and moderate sized streams (Yarnell 2005).
Stream Gradient	Channel bed slope – difference in elevation between the upstream and downstream ends of a reach along the thalweg; Water surface slope – average slope of the water surface at bankfull (or mean annual) flow along a reach.	Stream gradient correlates with channel morphology and observed habitat types. e.g. high gradient reaches are dominated by cascades, plunge pools and very coarse sediment, while low gradient reaches are dominated by riffles, mid-channel pools and gravel bars. Certain lifestages have been shown to associate with certain morphological features and substrates (see above).
Reach Type	Classified usually by stream gradient, ranging from high gradient cascades to low gradient dune-ripples (Montgomery and Buffington).	Each reach type is characterized by certain dominant morphological features and substrates, and exhibits generally similar flow characteristics. Certain lifestages have been shown to associate with certain morphological features and substrates (see above), and some reach types have been showed to be preferred by all lifestages (Yamell 2005).
Proximity to off-channel water bodies	Distance to nearest off-channel water body measured via most direct route.	Off-channel water bodies, such as ponds, canals, drainage pits or tunnels, have been known to provide refuge and overwintering habitat for adults and juveniles, particularly in areas where in-stream refuges may be limited.

Appendix C. Datasets evaluated with brief descriptions of associated field sampling methods and rationale for selection of dataset for habitat suitability criteria development. Highlighted (green) datasets were chosen and used to develop HSC's.

					HABITAT VARIABLES AND LIFESTAGE FOR AVAILABLE DATA[4]							
DATASET NAME	REACH and RIVER or CREEK	YEARS OF FIELD WORK [1]	MAX. N E / T[2]	GENERAL FIELD METHODS[3]	mid-column water velocity	surface velocity	velocity at	total depth	depth at (E only)	habitat substrate	attachment substrate (E only)	RATIONALE FOR SELECTION OF DATASET
Chicago Park 2003	Bear	2003	107 / 13	VES (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Chicago Park 2004	Bear	2004	11 / 38	VES (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Chicago Park 2005	Bear	2005	79 / 9	VES (Seltenrich and Pool 2002)			E	E, T	E	E, T	E	Not selected – no mid-column velocity
Clear Creek 1993-1995	Clear Creek	1993-1995	~30 / 0	VES			E	E			E	Not selected – no mid-column velocity and no tadpole data
DeSabla Butte 2006	Butte Creek	2006	60 / 115	VES with snorkeling (Seltenrich and Pool 2002; Appendix B updated in 2006)	E, T		E, T	E, T	E	E, T	E	Selected – all variables available and in project area
DeSabla WBFR 2006	West Branch Feather	2006	49 / 39	VES with snorkeling (Seltenrich and Pool 2002; Appendix B updated in 2006)	E, T		E, T	E, T	E	E, T	E	Selected – all variables available and in project area
Hurdygurdy 2003-2004	Hurdygurdy	2003-2004	46 / 0	VES			E	E				Not selected – no mid-column velocity
Mokelumne 2003-2005	Mokelumne	2001-2006	5/~50	VES all years; snorkeling in 2003 only (Seltenrich and Pool 2002)		E,T	E	E,T	E	E,T	E	Not selected – data not available electronically at time of HSC development, could pursue in future efforts.
Pit 2002	Pit	2002	23 / 0	VES	E	E	E	E	E	E	E	Selected for eggs – potentially different from Sierran rivers, no tadpole data

					HABITAT VARIABLES AND LIFESTAGE FOR AVAILABLE DATA[4]							
DATASET NAME	REACH and RIVER or CREEK	YEARS OF FIELD WORK [1]	MAX. N E / T[2]	GENERAL FIELD METHODS[3]	mid-column water velocity	surface velocity	velocity at	total depth	depth at (E only)	habitat substrate	attachment substrate (E only)	RATIONALE FOR SELECTION OF DATASET
Pit 2003	Pit	2003	30 / 101	VES	E	E	E, T	E, T	E	E, T	E	Selected for eggs – potentially different from Sierran rivers, tadpole data lacks mid-column velocity
Pit 2004	Pit	2004	61 / 17	VES	E	E	E, T	E. T	E	E. T	E	Selected for eggs – potentially different from Sierran rivers, tadpole data lacks mid-column velocity
Pit 2005	Pit	2005	24 / 0	VES		E	E	E	E	E	E	Not selected – no mid-column velocity, different from Sierran rivers, no tadpole data
Poe 2001	Poe Reach, North Fork Feather	2001	26 / 32	VES (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Poe 2002	Poe Reach, North Fork Feather	2002	28 / 35	VES (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Poe 2003	Poe Reach, North Fork Feather	2003	47 / 48	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Poe 2004	Poe Reach, North Fork Feather	2004	48 / 4	VES with snorkeling (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
Poe 2005	Poe Reach, North Fork Feather	2005		VES with snorkeling (Seltenrich and Pool 2002)								Data unavailable
Poe 2006	Poe Reach, North Fork Feather	2006	76 / 46	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity

					HABITAT VARIABLES AND LIFESTAGE FOR AVAILABLE DATA[4]							
DATASET NAME	REACH and RIVER or CREEK	YEARS OF FIELD WORK [1]	MAX. N E / T[2]	GENERAL FIELD METHODS[3]	mid-column water velocity	surface velocity	velocity at	total depth	depth at (E only)	habitat substrate	attachment substrate (E only)	RATIONALE FOR SELECTION OF DATASET
RCC 2002	Cresta Reach, North Fork Feather	2002	11 / 46	VES (Seltenrich and Pool 2002)			E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
RCC 2003	Cresta Reach, North Fork Feather	2003	20 / 99	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
RCC 2004	Cresta Reach,North Fork Feather	2004	28 / 35	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
RCC 2005	Cresta Reach, North Fork Feather	2005	21 / 14	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
RCC 2006	Cresta Reach, North Fork Feather	2006	5 / 10	VES with snorkeling (Seltenrich and Pool 2002)		E	E, T	E, T	E	E, T	E	Not selected – no mid-column velocity
SF Eel 1994-2006	South Fork Eel	1991-2006	100+ / 183	VES for eggs; removal sampling within 1m quadrats for tadpoles	E, T		E	E, T	E	E, T	E	1991-1993 Selected for tadpoles, because one of the few datasets with both velocity and total depth measurements. Not selected for egg masses because data not available electronically.
SF Trinity 1992-1995	South Fork Trinity	1992-1995	52 / 22	VES			E, T	E, T		E, T	E	Not selected – no mid-column velocity
SFWPA 2004	South Fork Feather	2004	5 / 0	VES				E	E	E	E	Not selected - no mid-column velocity and small sample size
SFWPA 2005	South Fork Feather	2005	28 / 58	VES	E		E	T	E	E, T	E	Selected for eggs only, no velocity for tadpoles

					HABITAT VARIABLES AND LIFESTAGE FOR AVAILABLE DATA[4]							
DATASET NAME	REACH and RIVER or CREEK	YEARS OF FIELD WORK [1]	MAX. N E / T[2]	GENERAL FIELD METHODS[3]	mid-column water velocity	surface velocity	velocity at	total depth	depth at (E only)	habitat substrate	attachment substrate (E only)	RATIONALE FOR SELECTION OF DATASET
Shady Creek 2003	Shady	2003	24 / 0	VES	E		E	E	E	E	E	Not selected - small sample size, creek has atypical morphology
Spring Gap 2003	Middle Fork Stanislaus	2003	6 / 0	VES (Seltenrich and Pool 2002)			E	E	E	E	E	Not selected – no mid-column velocity and small sample size
Trinity 1991-1994	Trinity	1991-1994	77 / 3	VES			E, T	E, T		E, T	E	Not selected – no mid-column velocity
UARP 2003	American	2003	2 / 3	VES			E, T	E,T	E	E,T	E	Not selected – small sample size

1 - Some datasets combine years and some are by individual years primarily due to sample size limitations. Ultimately all years were combined for analyses by river.
2 - Maximum sample size for egg masses (E) and tadpole groups (T). Missing data for some variables may result in smaller sample sizes for development of HSC's.
3 - VES = Visual encounter survey.
4 - Data available for egg masses (E) and/or tadpole groups (T).

Appendix D. Preliminary analyses to determine focal variables for *Rana boylii* HSC development.

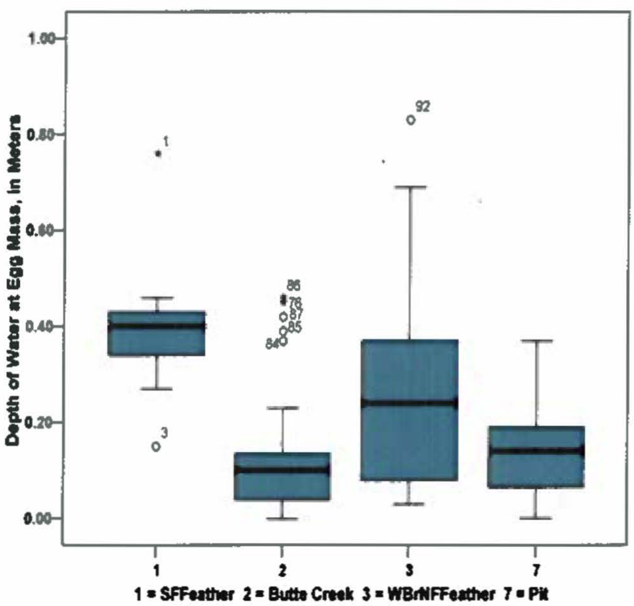
WATER DEPTH AND VELOCITY

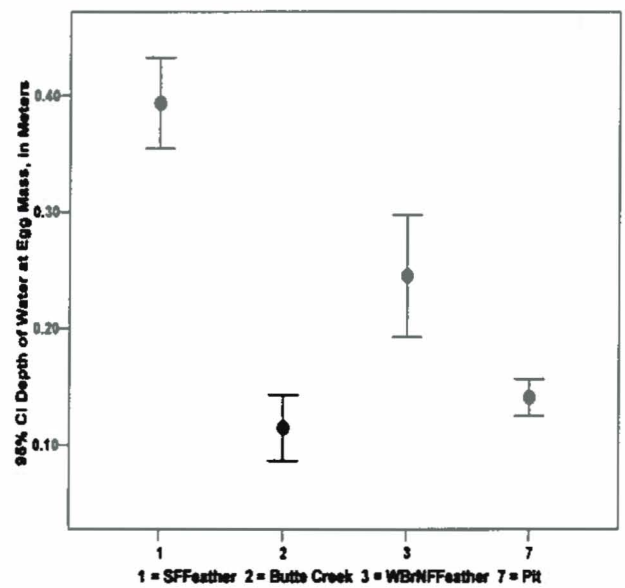
Egg Masses

Graphical and statistical comparisons were made between total depth and depth at egg mass as well as velocity at egg mass and mid-column velocity for all rivers combined and each individual river. Summaries of the data for each variable are presented below using boxplots. A comparison of the means among rivers was plotted for each variable and is presented below with the results from the ANOVA analyses.

In summary, mean values of total depth and depth at egg mass differed among rivers, but the pattern and magnitude of difference was similar for both values. Mean values of velocity at egg mass and mid-column velocity also varied among rivers, but differences were small in magnitude. The data showed no consistent relationship between velocity at egg mass and mid-column velocity; however, mean values for both variables were low across all rivers. As a result, the HSCTW decided to develop suitability criteria for mid-column velocity and total depth for each river (river-specific criteria) as well for all rivers combined (lumped data).

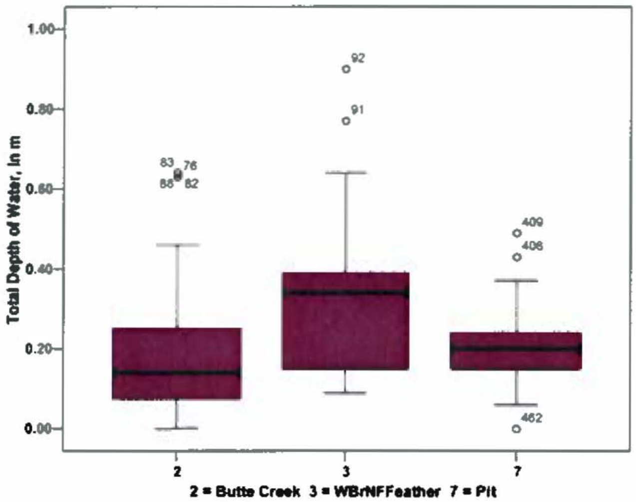
Depth at Egg Mass

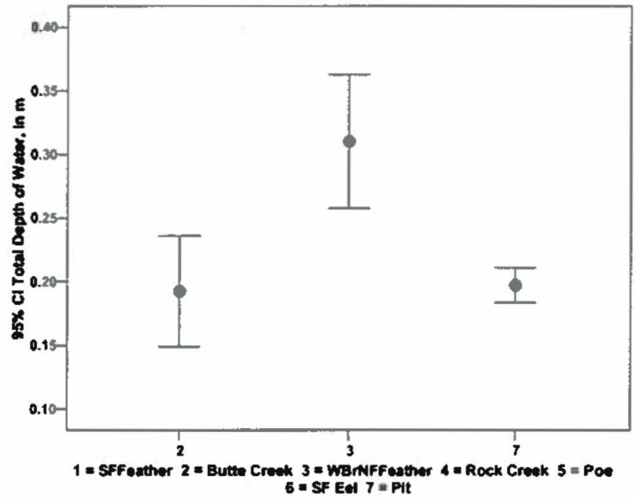




Mean values for depth at egg mass across all rivers were significantly different ($F=44.91$, $p<0.001$). Mean values for the Butte Creek and Pit datasets were statistically similar (Bonferroni, $p=1.0$), and they were different from the remaining two datasets (Bonferroni, $p<0.001$). Mean depth at egg mass on the SF Feather was significantly different from the other three datasets, as was mean depth at egg mass on the WB Feather (Bonferroni, $p<0.001$).

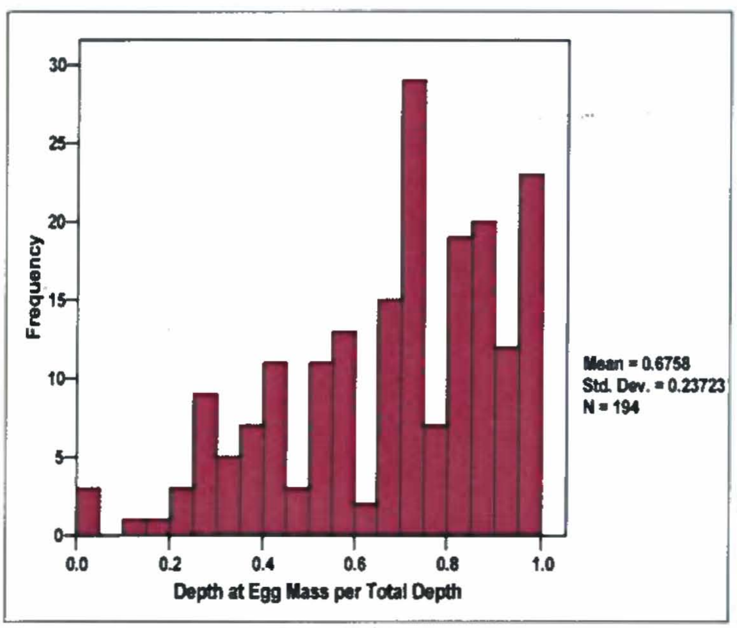
Total Depth





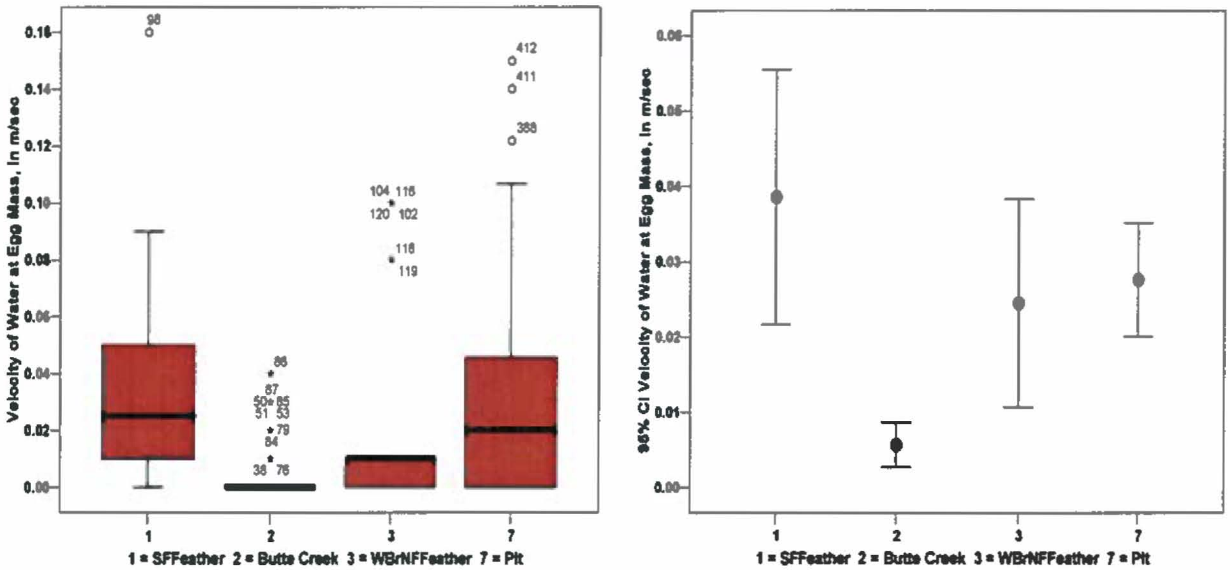
Mean values for total depth across all rivers were significantly different ($F=14.24$, $p<0.001$). Mean values for the Butte Creek and Pit River datasets were statistically similar (Bonferroni, $p=1.0$), and they both differed from the WB Feather dataset (Bonferroni, $p<0.001$).

Total depth vs. Depth at Eggs



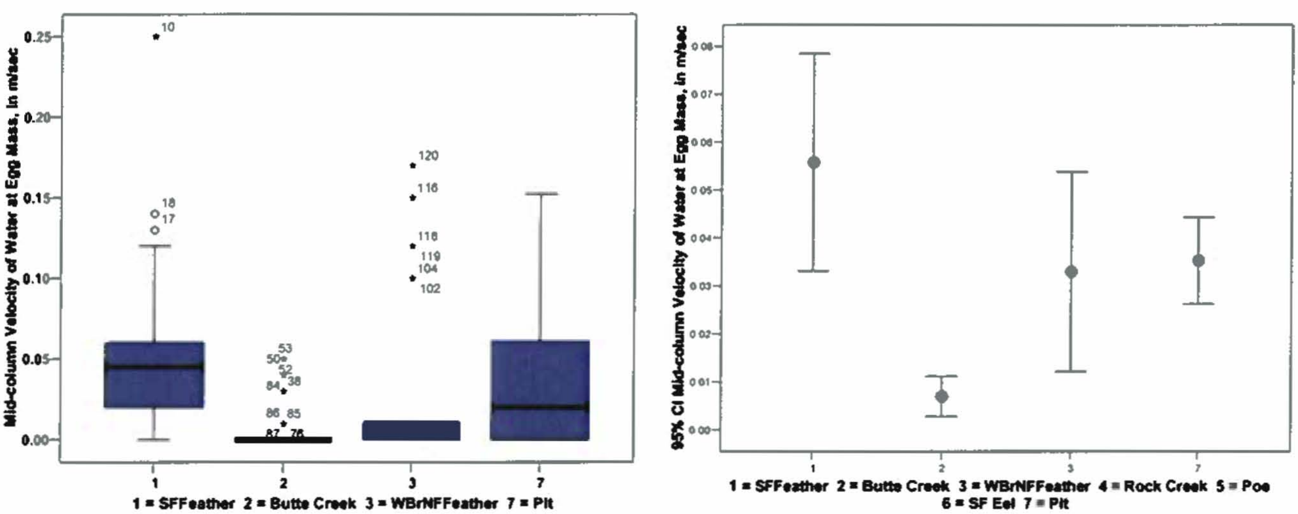
Data from all rivers combined showed that depth at egg mass was approximately 68% of the total depth on average. Generally, in rivers where mean total depth is low (~0.2m or less), eggs are attached at or immediately above the substrate. In these cases, a two-thirds difference between the two depth measurements would be about 5-8 cm and reflects the difference in measuring to the bottom of an egg mass (total depth) and to the middle of the egg mass (depth at egg mass).

Velocity at Egg Mass



Mean values for velocity at egg mass across all rivers were significantly different (F=9.13, p<0.001). Mean velocities at egg mass for the SF Feather, WB Feather and Pit datasets were statistically similar (Bonferroni, p>0.53), and they each differed from the Butte Ck dataset (Bonferroni, p<0.01 all comparisons).

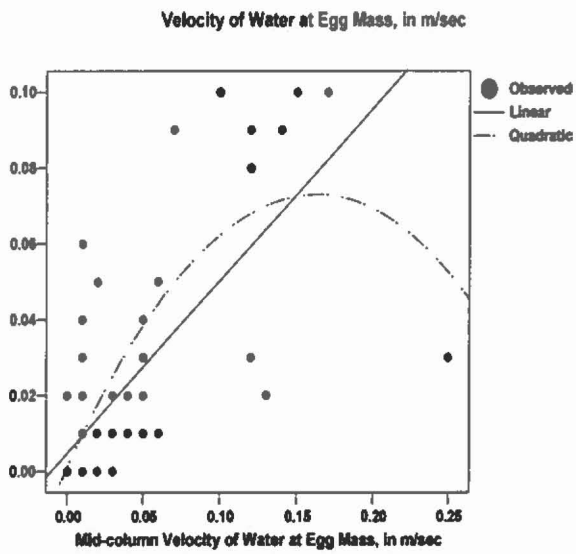
Mid-column Velocity

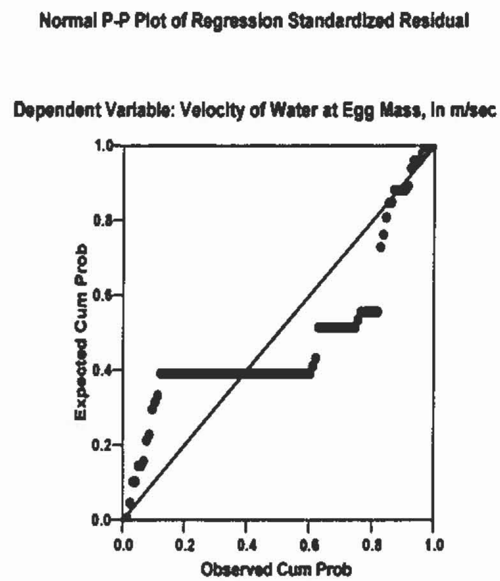


Mean values for mid-column velocity across all rivers were significantly different (F=10.76, p<0.001). Mean mid-column velocity for the Butte Creek dataset was significantly different from the remaining datasets (Bonferroni, p<0.03 for all comparisons). Mean mid-column velocities for the SF Feather, WB

Feather and Pit datasets were statistically similar (Bonferroni, p=0.228 for SF Feather and WB Feather, p=0.141 for SF Feather and Pit, and p=1.0 for WB Feather and Pit).

Mid-column Velocity vs. Velocity at Eggs





The relationship between mid-column velocity and velocity at egg mass for all Sierran datasets combined was statistically significant in a regression (adjusted $R^2 = 0.57$, $p<0.001$); however, the relationship was not strong. The majority of samples had similar low mid-column and at-egg velocities. On each of the three Sierran rivers, Butte Ck, WB Feather and SF Feather, mean mid-column velocities were 0.008 m/s, 0.03 m/s and 0.05 m/s, compared to mean velocity at egg mass of 0.006 m/s, 0.025 m/s and 0.04 m/s, respectively. The plot of standardized residuals, which does not cluster about the y=x line, shows how poor the regression relationship was.

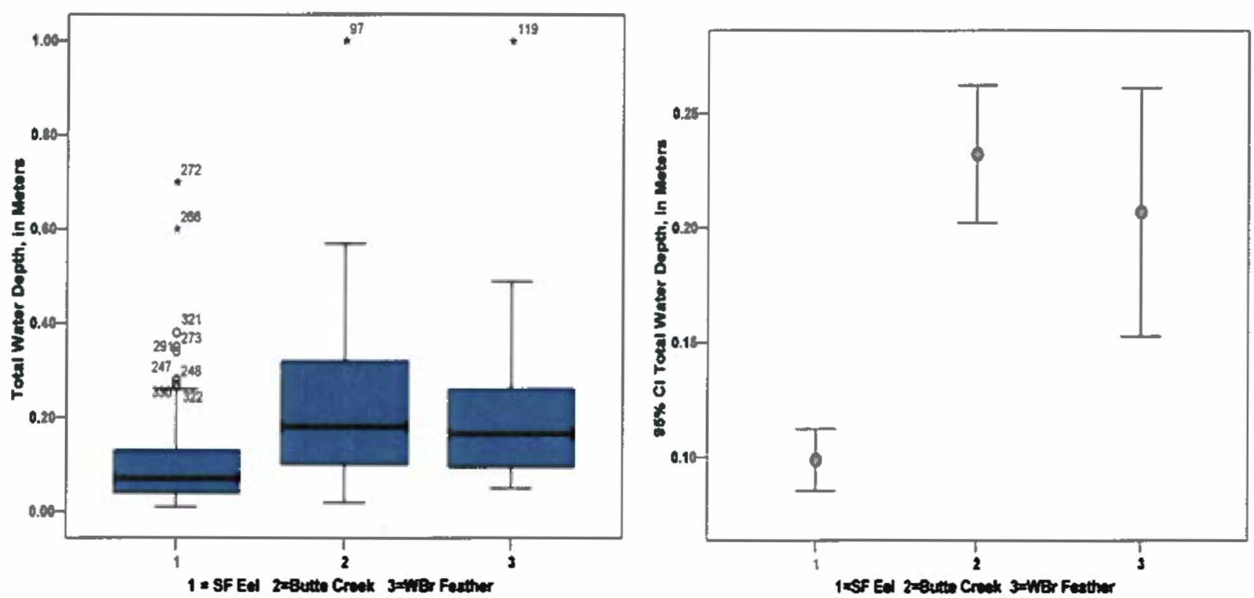
Although some differences between velocity at egg mass and mid-column velocity occurred, mean values for both mid-column velocity and velocity at egg mass were low, <0.05 m/s for both variables. While it may have been possible to develop suitability criteria for velocity at egg mass and subsequently convert that velocity to a mid-column velocity for use with an instream flow model, the lack of a robust relationship between the two variables would create large uncertainty and potentially large error. Therefore, the HSCTW decided to develop suitability criteria directly for mid-column velocity only.

Tadpole Groups

Graphical and statistical comparisons were made between total depth and mid-column velocity at tadpole group for all rivers combined and each individual river. Summaries of the data for each variable are presented below using boxplots. A comparison of the means among rivers was plotted for each variable and is presented below with the results from the ANOVA analyses.

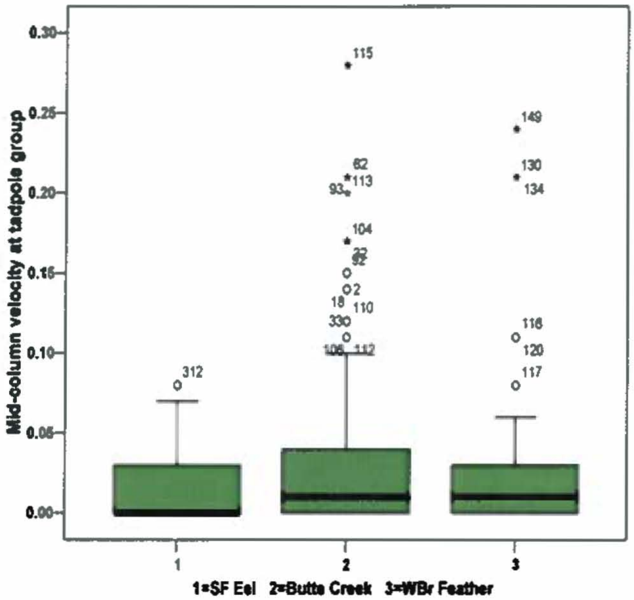
In summary, mean values of total depth and mid-column velocity differed among rivers, but differences for velocity were very small in magnitude. A comparison between different lengths of tadpoles using data from the North Fork Feather River did show a potential difference in depth utilization between early and late tadpoles, but the data were too sparse to accurately quantify the perceived difference (data from the NF Feather was not used in other tadpole analyses). As a result, the HSCTW decided to develop suitability criteria for all tadpoles (not delineated by size) for total depth and mid-column velocity for each river (river-specific criteria) as well for all Sierran rivers combined (lumped data).

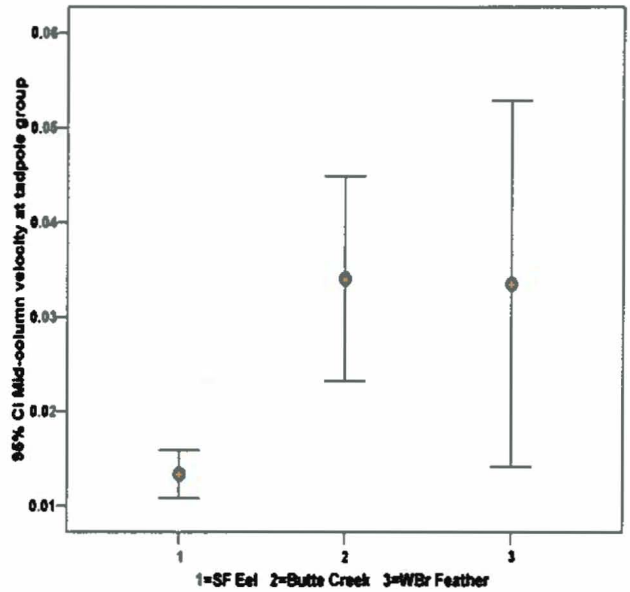
Total Depth



Mean values for total depth across the three rivers were significantly different ($F=40.51$, $p<0.001$). Mean values for the Butte Ck and WB Feather datasets were statistically similar (Bonferroni, $p=0.88$), and both differed from mean total depth for the Pit dataset (Bonferroni, $p<0.001$).

Mid-column Velocity





Mean values for mid-column velocity across the three rivers were significantly different ($F=10.57$, $p<0.001$), although mean values for the Butte Ck and WB Feather datasets were statistically similar (Bonferroni, $p=1.0$). Mean mid-column velocity for the SF Eel dataset was significantly different from each of the two Sierran datasets (Bonferroni, $p<0.01$ for all comparisons).

To determine if habitat utilization varied with tadpole size, we completed a graphical comparison of depth and velocity at tadpole group (mid-column velocity not available) by month, stage and length using data from the North Fork Feather River. The data were inconsistent or sparse among river reaches to make any conclusions, but there did appear to be a slight trend towards shallower depths for longer tadpoles. Mean depth for tadpoles 0.001-0.02m in length was 0.29m, mean depth for tadpoles 0.02-0.04m in length was 0.12m, and mean depth for tadpoles >0.04m was 0.11m.

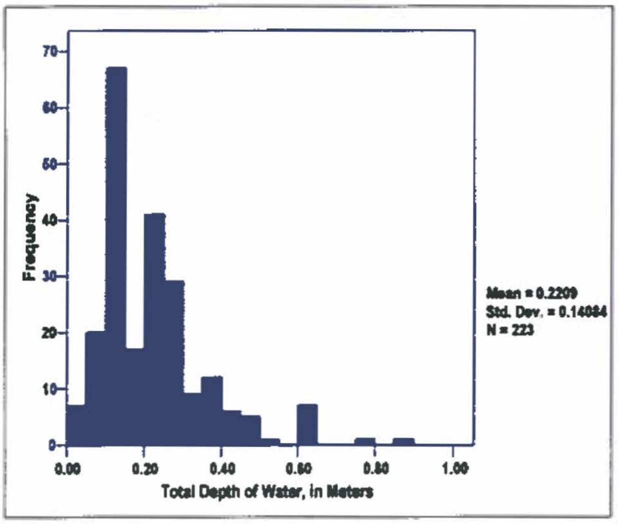
SUBSTRATE
Egg attachment substrates and tadpole substrates were dominated by cobble and boulder size categories on all rivers with little difference observed among rivers. As a result, the HSCTW decided to develop egg and tadpole suitability criteria for substrate for all rivers combined together.

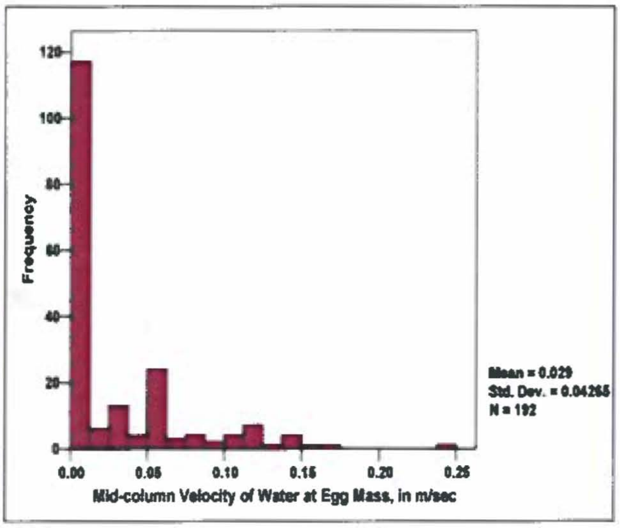
HABITAT TYPE
Graphical comparisons of microhabitat and macrohabitat types for egg masses and tadpoles among rivers were not conclusive. Definitions of microhabitat varied slightly among rivers and many datasets were missing data. Micro- and macrohabitats on the SF Feather were dominated by the 'other' category, and data was missing for the Butte Ck and WB Feather datasets. As a result, the HSCTW made the decision to not include habitat type in suitability criteria development.

Appendix E– Histograms of habitat data used to develop suitability criteria.

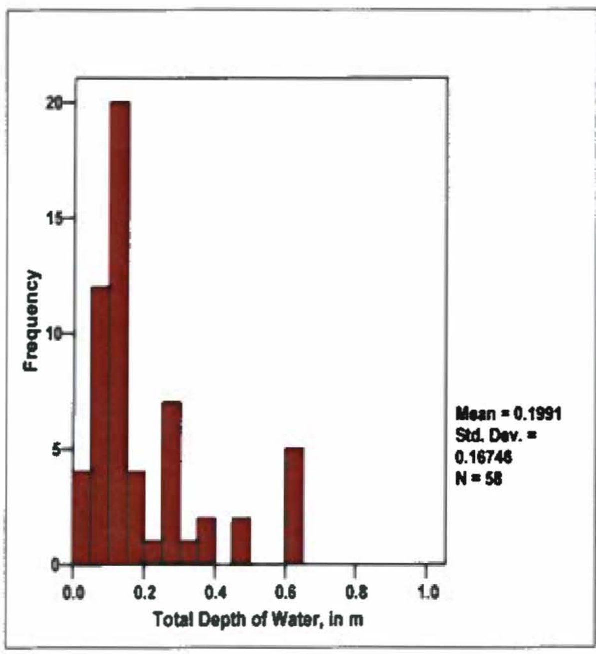
EGG MASSES

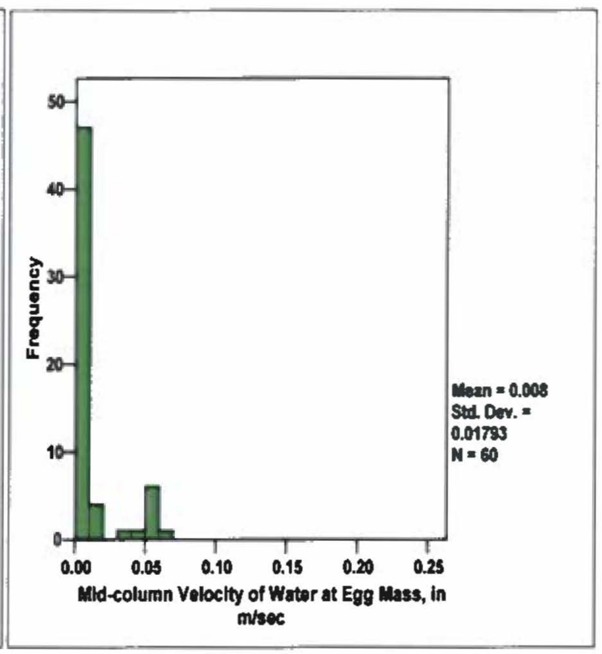
All Rivers – Butte Creek, West Branch Feather, South Fork Feather, Pit





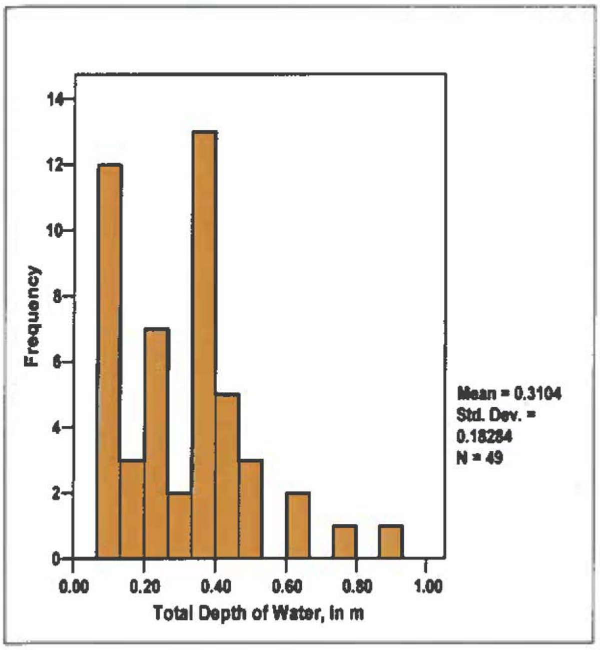
Butte Creek

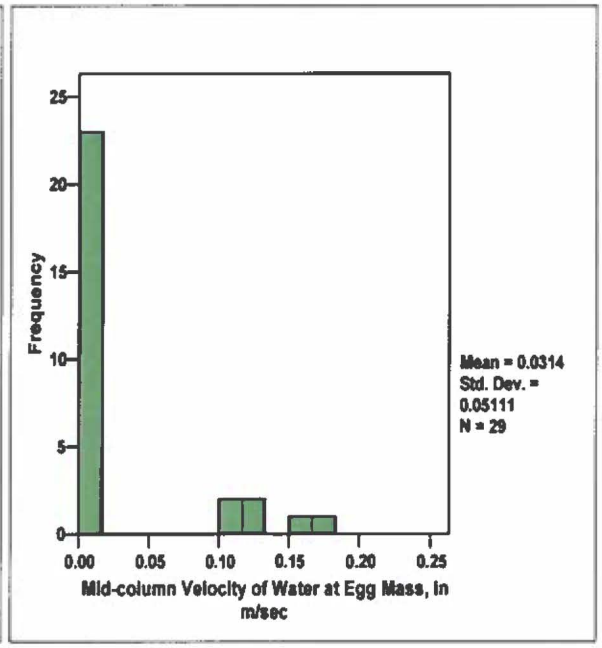




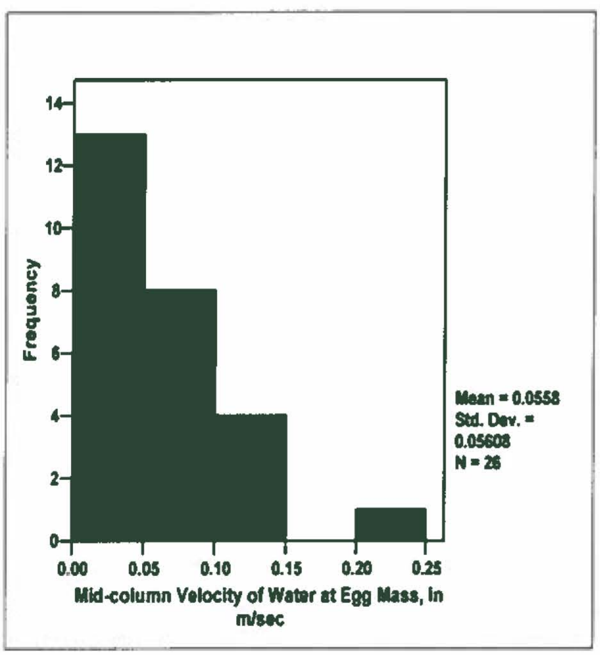
EGG MASSES

West Branch Feather River



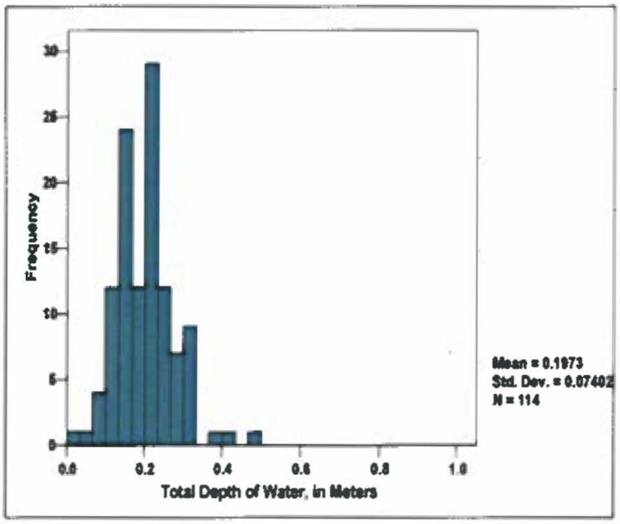


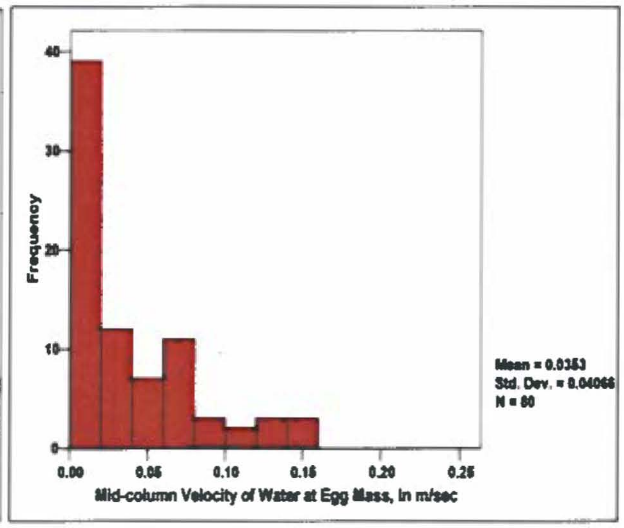
South Fork Feather



EGG MASSES

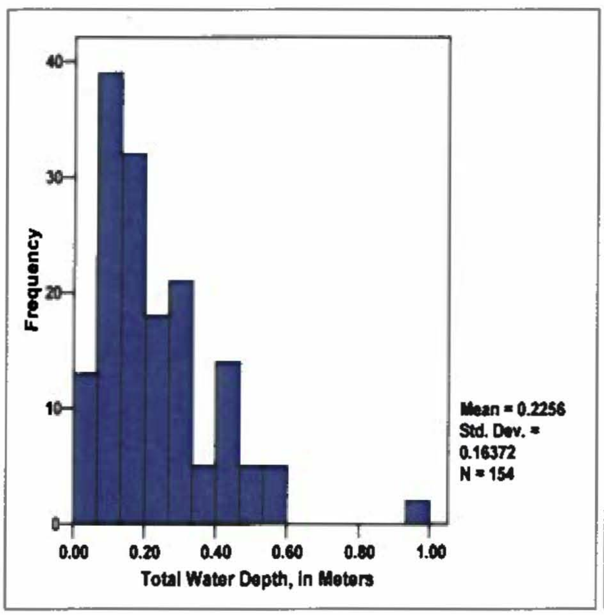
Pit River

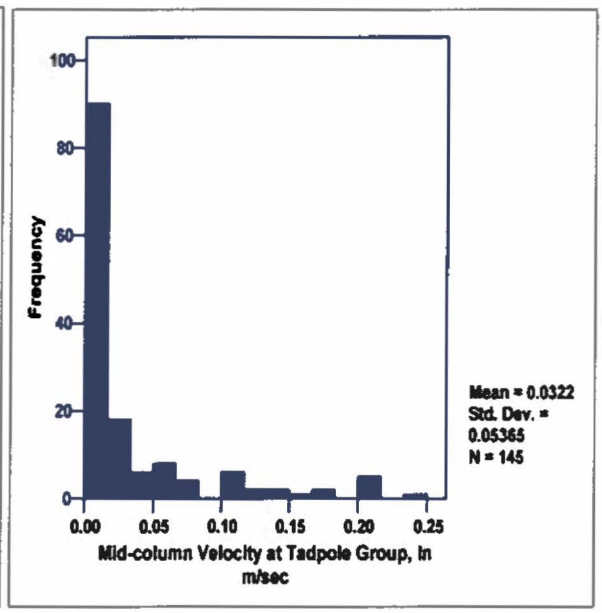




TADPOLES

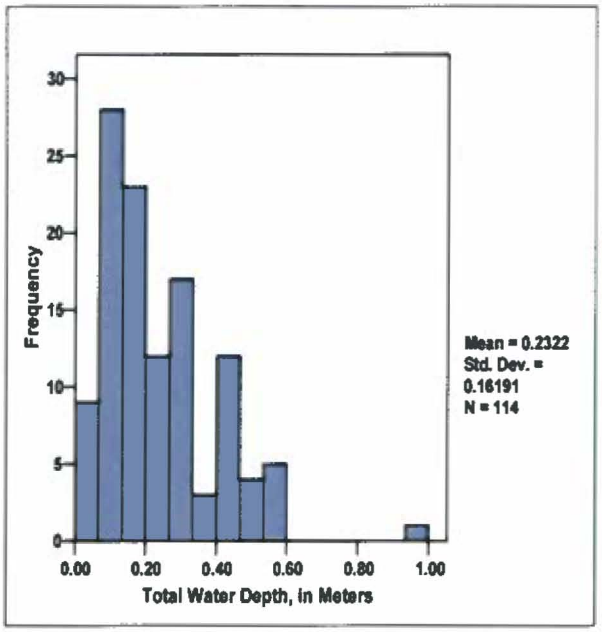
All Rivers – Butte and West Branch Feather

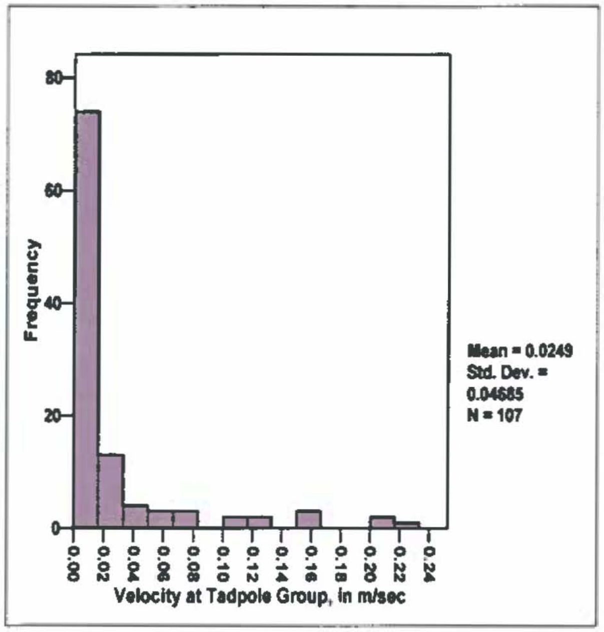




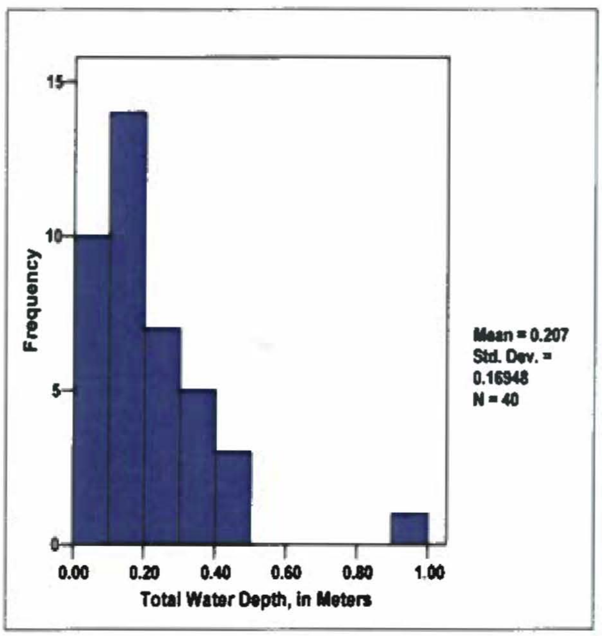
TADPOLES

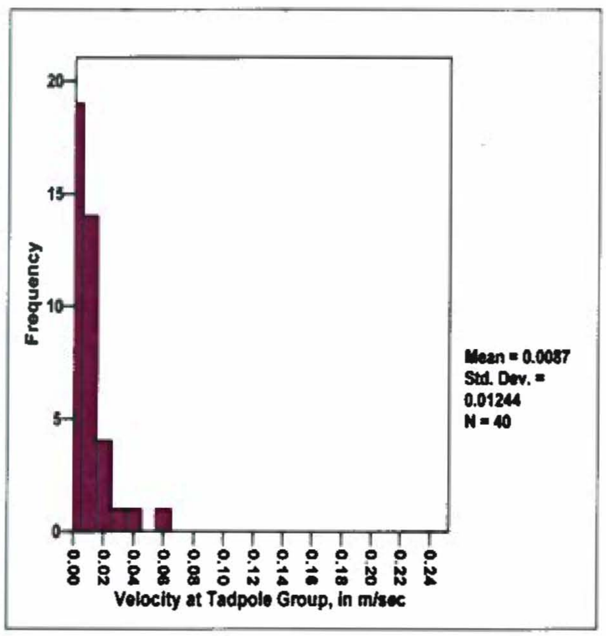
Butte Creek





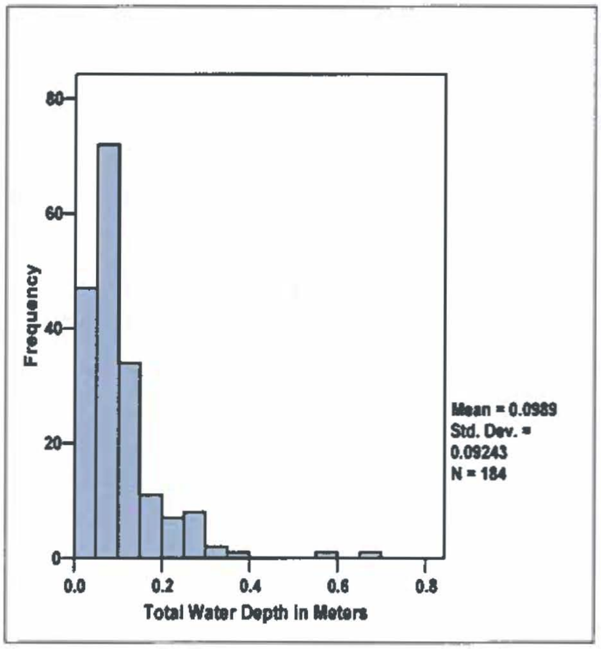
West Branch Feather

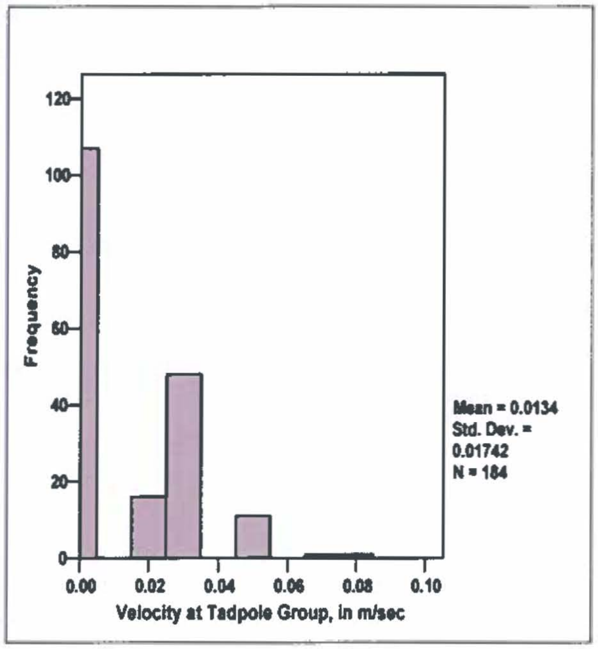




TADPOLES

SF Eel River





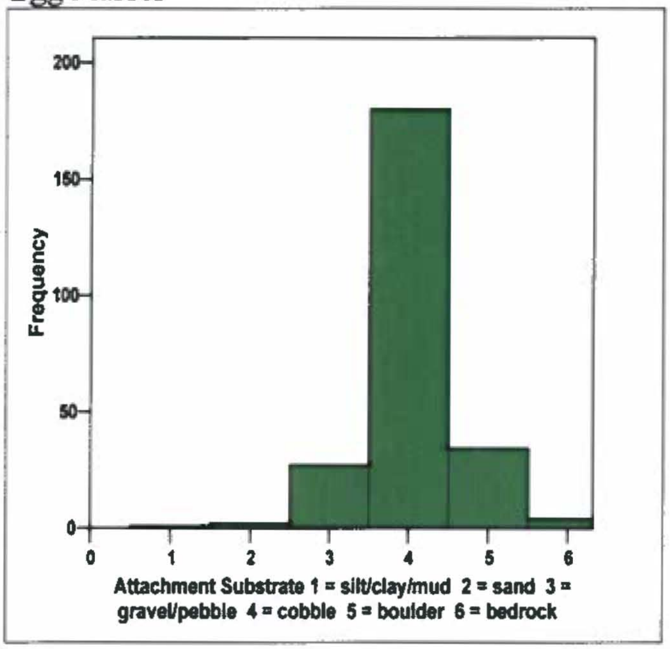
SUBSTRATE

ALL RIVERS

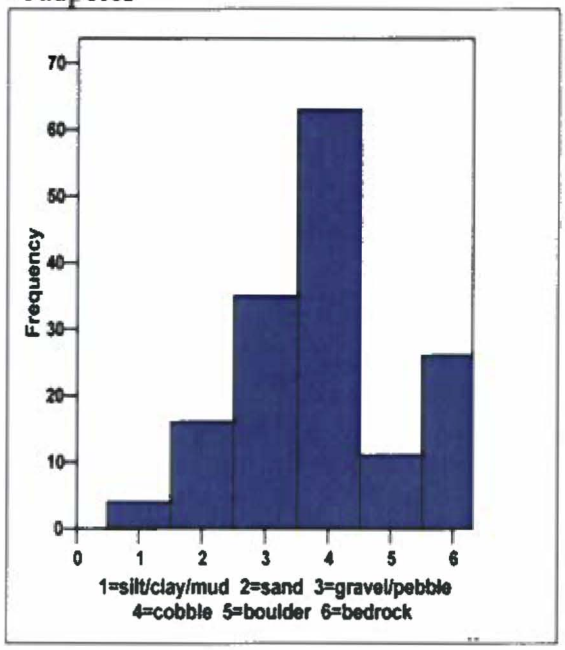
EGG MASSES - Butte Creek, West Branch Feather, South Fork Feather, Pit

TADPOLES – Butte Creek, West Branch Feather

Egg Masses



Tadpoles



Type of Restoration or Management	Action	Objectives served
5. RIVER CHANNEL CONSTRUCTION & REVEGETATION River channel construction	1.1.1 Construct new, smaller channel **R** *Actions 1.1.1, 1.2.1, 1.3.1, 2.1.1, 2.2.1, 2.4.1, 3.1.1, 3.2.1, 4.1.1, and 4.2.1*	1.1 Increase frequency of inundation 1.2. Increase stability of banks 1.3 Reduce maintenance by designing a geomorphically stable channel. 2.1 Increase flood storage on floodplain to increase sediment deposition. 2.2 Reduce streambank 2.4 Filter runoff on meadows 3.1 Enhance habitat for aquatic wildlife 3.2 Enhance habitat for terrestrial wildlife 4.1. Increase wet meadow plant communities. 4.2 Increase montane riparian scrub vegetation.
Channel design considerations	3.1.3 Enhance fish passage by removing or modifying low water crossing and modifying sewer line crossing. **R**	3.1.3 Enhance aquatic habitat
	3.1.4 Enhance instream cover with vegetation, woody debris or other appropriate elements. **R**	3.1 Enhance aquatic wildlife habitat
	3.4.5 Maintain cover density of trees and minimize gap length across valley (consider channel footprint).	5.3 Provide river access compatible to resources
	5.3.1 Maintain access for boaters by designing slack water conditions at appropriate put-in/take-out (Elks Club Blvd & Hwy 50). **R**	3.4 Maintain connectivity along river and across valley
Bank stabilization and lateral control	Install lateral control structures where new channel crosses old to prevent lateral migration leading to channel recapture. **R**	1.2 Increase stability of banks
	Use other bioengineering techniques or installation of wood/rock to achieve bank stabilization, if necessary. **R**	1.2 Increase stability of banks 2.2 Reduce streambank erosion
Revegetate banks and disturbed areas	1.2.3 Plant native vegetation to stabilize banks and enhance riparian habitat. **R**	1.2 Increase stability of banks **2.2** Reduce streambank erosion 3.1 Enhance habitat for aquatic wildlife 3.2 Enhance habitat for terrestrial wildlife

Type of Restoration or Management	Action	Objectives served
		3.4 Maintain connectivity for wildlife along river and across valley 4.2 Increase montane riparian scrub vegetation
6. SEZ 6.1 River channel **6.2** Riparian vegetation	Maintain restored river channel Maintain riparian vegetation planted in channel restoration) Actions 1.2.3, 2.2.2, 3.1.2, 3.2.2, 3.4.2, 4.2.2	1.2 Increase stability of banks **2.2** Reduce streambank erosion 3.1 Enhance habitat for aquatic wildlife 3.2 Enhance habitat for terrestrial wildlife 3.4 Maintain connectivity for wildlife along river and across valley 4.2 Increase montane riparian scrub vegetation
6.3 Plant Meadow willow clumps	2.1.2 Increase cover of meadow vegetation with plantings (e.g. clumped plantings of willows) to increase floodplain roughness and enhance sediment deposition Actions 2.1.2,2.4.2, 4.1.2	2.1 Increase flood storage on floodplain to increase sediment deposition 2.4 Filter stormwater runoff on meadows 4.1 Increase wet meadow plant communities
7. WILDLIFE & FISH 7.1 Aquatic habitat	Maintain river channel and Maintain riparian vegetation from channel construction, monitor aquatic habitat	3.1 Enhance habitat for aquatic wildlife
7.2 Terrestrial habitat	3.1.5 and 3.2.4 Create pond habitat from former channel that are attractive for amphibians and will not increase wildlife hazard risk for FAA. **R**	3.1 Enhance habitat for aquatic wildlife 3.2 Enhance habitat for terrestrial wildlife
	3.2.2 Plant native vegetation to enhance riparian corridor. (Action 1.2.3) **R**	3.2 Enhance habitat for terrestrial wildlife
	3.2.3 Maintain vegetative cover, snags and large woody debris for terrestrial habitat in forested areas. (Action 3.2.3) **M**	3.2 Enhance habitat for terrestrial wildlife
7.3 Wildlife corridor and connectivity	3.4.1 Promote growth of vegetative cover (desirable conifers or willows) in wildlife corridor at southern end of MPA. **M**	3.4 Maintain connectivity along river and across valley 4.4 Promote growth of desirable conifers in forest areas
	3.4.4 Track status of priority parcels in the wildlife corridor for potential acquisition from willing	3.4 Maintain connectivity along river and across valley

Type of Restoration or Management	Action	Objectives served
	sellers. **M**	
7.4 Invasive wildlife	3.1.6 and 3.2.5 Track presence and assess effects of invasive species **M**	3.1 Enhance habitat for aquatic wildlife 3.2 Enhance habitat for terrestrial wildlife
8. FOREST **8.1 Forest health**	4.3.1 Selective removal of conifers (lodgepole pine?) in aspen stands. **M** 4.3.2 Define management goals for lodgepole pine forest and wet meadow 4.3.3 Identify and implement methods for managing the lodgepole pine stands	4.3 Reduce conifer encroachment in aspen stands and wet meadow habitat
	3.2.3 and 4.4.2 Maintain vegetative cover, snags and large woody debris for terrestrial habitat in forested areas	3.2 Enhance habitat for terrestrial wildlife 4.4 Improve upland forest habitat structure
	3.4.1 and 4.4.1 Promote growth of desirable conifers in forest areas. **M**	3.4 Maintain connectivity along river and across valley 4.4 Improve upland forest habitat structure
	4.4.3 Conduct forest thinning as necessary to achieve desired forest habitat structure. **M**	4.4 Improve upland forest habitat structure
8.2 Fuels management	4.5.1 and 4.5.2 Implement fuels management (mechanical or Rx fire)	4.5 Reduce wildfire threat near residential areas
9. LAND MANAGEMENT **9.1 Upland erosion control**	2.3.1 Restore eroding areas on the Sunset Stables property and revegetate with appropriate native plants (e.g. headcuts in finger meadow, gullies west of river). **R**	2.3 Reduce erosion from uplands and floodplain
	2.3.2 Remove fill materials from disturbed areas (i.e. old stable site along Hwy 50), recontour surface and revegetate with appropriate native plants. **R**	2.3 Reduce erosion from uplands and floodplain
	2.3.3 Restore Elks Club property, install parking area (will reduce erosion from dirt lot while providing public area	2.3 Reduce erosion from uplands and floodplain
	2.3.4 and 5.2.4 Map trail network and prioritize eroded and/or redundant informal trails for consolidation.	2.3 Reduce erosion from uplands and floodplain

Type of Restoration or Management	Action	Objectives served
	Reduce erosion from trails by consolidating redundant trails, upgrading active trails as necessary, and restoring retired trail segments. Recontour, fencing/barriers, signage to prevent disturbance. **R&M** **Put this in erosion control section, recreation management, or both?**	5.2 Direct activities away from sensitive habitat
9.2 Invasive weeds	4.6.1 Monitor for presence of priority invasive species. Locate, map, and evaluate invasive plant species (at least once every 3 years). **M** 4.6.2 Develop and implement a weed control program (treatment and monitoring). Potential measures may include mechanical (e.g. mowing, grazing) and/or chemical control. **M** 4.6.3 Coordinate with basin-wide efforts such as the Lake Tahoe Basin Weed Coordinating Group (e.g. share survey data, update priority species lists and hotspot locations) . **M**	4.6 Control and manage invasive plant spp
9.3 Recreation	2.2.4 Protect banks and riparian vegetation from disturbance from trails and boating (look at portage trails and instream debris) **M** **Is this an SEZ action, recreation, or both?**	2.2 Reduce streambank erosion by protecting banks and enhancing riparian vegetation
	3.3.1 and 5.1.1 Coordinate with Greenway project on alignment/design of bike path and trails. **M**	3.3 Protect sensitive habitats from excessive disturbance 5.1 Direct activities away from sensitive habitats
	3.3.2 and 5.1.2 Identify appropriate locations on the restored channel for walking access to the river. Site selection criteria will include recreational qualities (i.e. beaches that form on inside bend, visual aesthetics) and avoidance of sensitive habitats. **M**	3.3 Protect sensitive habitats from excessive disturbance 5.1 Direct activities away from sensitive habitats 5.2 Provide access to the river that enhances the recreational experience while reducing impacts to riparian and meadow habitat
	2.3.4 and 5.1.3 Map trail network and prioritize eroded and/or redundant informal trails for consolidation. Reduce erosion from trails by consolidating redundant	5.1 Direct activities away from sensitive habitats

Type of Restoration or Management	Action	Objectives served
	trails, upgrading active trails as necessary according to BMPs, and restoring retired trail segments to native vegetation. Use recontouring, fencing, barriers, and/or signage to prevent disturbance. **R&M** **Put this in erosion control section, recreation management, or both?**	
	3.3.3 and 5.1.4 Direct recreational activity away from sensitive habitats through public education, signage, and/or fencing at selected trails. **M**	3.3 Protect sensitive habitats from excessive disturbance 5.1 Direct activities away from sensitive habitats
	5.2.1 Maintain Elks Club property site as an access hub to consolidate more recreational use toward the south end of the MPA. **M**	5.2 Provide access to the river that enhances the recreational experience while reducing impacts to riparian and meadow habitat
	5.3.1 Coordinate with Greenway project to install interpretative signs and kiosks on natural values, threats to sensitive habitats, and permitted uses. **M**	5.3 Provide public education

OBJECTIVE	**ACTIONS** **(R = Restoration, M = Land Management)**
GOAL 1 – Restore properly functioning channel configuration based on geomorphic principles	
1.1 Increase frequency of inundation on floodplain to approximate estimated historic flood frequency (about 1.5-2 yr return interval)	1.1.1 Construct new, smaller channel (overbank at 1.5 year recurrence interval ~450 cfs) **R**
1.2 Increase stability of banks by increasing the elevation of groundwater and enhancing riparian vegetation.	1.2.1 Construct new, smaller channel (higher bed elevation) (Action 1.1.1). **R** 1.2.2 Install lateral control structures where new channel crosses old to prevent lateral migration leading to channel recapture. **R** 1.2.3 Plant native vegetation to stabilize banks and enhance riparian habitat. **R** 1.2.4 Use other bioengineering techniques or installation of wood/rock to achieve bank stabilization,

OBJECTIVE	ACTIONS (R = Restoration, M = Land Management)
	if necessary. **R**
1.3 Eliminate or reduce the need for maintenance by designing a geomorphically stable channel that is in dynamic equilibrium.	1.3.1 Construct new, smaller channel (in balance with existing hydrology and sediment load) (Action 1.1.1) **R**
GOAL 2 – Improve water quality by improving floodplain functionality and reducing erosion	
2.1 Increase storage of flood flows on and in floodplain to increase sediment deposition.	2.1.1 Construct new, smaller channel (overbank more often, increase retention time on floodplain, increase groundwater levels to support meadow vegetation) (Action 1.1.1) **R** 2.1.2 Increase cover of meadow vegetation with plantings (e.g. clumped plantings of willows) to increase floodplain roughness and enhance sediment deposition
2.2 Reduce streambank erosion by protecting banks and enhancing riparian vegetation.	2.2.1 Construct new, smaller channel (reduce bank instability, raise water table to support riparian vegetation) (Action 1.1.1) **R** 2.2.2 Plant native vegetation to stabilize banks and enhance riparian habitat. (Action 1.2.3) **R** 2.2.3 Use other bioengineering techniques or installation of wood/rock to achieve bank stabilization, if necessary. (Action 1.2.4) **R** 2.2.4 Protect banks and riparian vegetation from disturbance from trails and boating (look at portage trails and instream debris) **M**
2.3 Reduce erosion from uplands and floodplain	2.3.1 Restore eroding areas on the Sunset Stables property and revegetate with appropriate native plants (e.g. headcuts in finger meadow, gullies west of river). **R** 2.3.2 Remove fill materials from disturbed areas (i.e. old stable site along Hwy 50), recontour surface and revegetate with appropriate native plants. **R** 2.3.3 Restore Elks Club property, install parking area (will reduce erosion from dirt lot while providing public area) 2.3.4 Reduce erosion from trails by consolidating redundant trails, upgrading active trails as necessary, and restoring retired trail segments. Recontour, fencing/barriers, signage to prevent disturbance. **R&M** **The following action is future potential restoration (Appendix C)** 2.3.5 Reduce erosion from roads by removing sections of roads and revegetating with appropriate native plants.
2.4 Filter and store suspended sediment from surrounding lands on floodplain by restoring native wet meadow plant communities and redirecting stormwater runoff onto meadows	2.4.1 Construct new, smaller channel (increase groundwater levels to support meadow vegetation) (Action 1.1.1) **R** 2.4.2 Increase cover of meadow vegetation with plantings (e.g. clumped plantings of willows) to increase floodplain roughness and enhance sediment deposition (Action 2.1.2) **R**

OBJECTIVE	ACTIONS (R = Restoration, M = Land Management)
for infiltration.	**The following actions are future potential restoration (Appendix C)** 2.4.3 Install culverts under Elks Club Drive to convey runoff from meadows to river. 2.4.4 Create a more natural receiving system for stormwater runoff from Nottaway Drive. 2.4.5 Restore flea market area to meadow to improve infiltration (Elks Club property). 2.4.6 Redirect drainage from Hwy 50 and the surrounding neighborhoods in the Meadow Vale area back to the meadow south of Elks Club Drive. 2.4.7 Remove, regrade and revegetate part or all of Boca Raton Ditch.
GOAL 3 – Improve aquatic and terrestrial wildlife habitats	
3.1 Enhance habitat for aquatic wildlife	3.1.1 Construct new, smaller channel (restore nature pool-riffle dynamics, increase substrate sorting, increase cover and shading that will reduce range of temperature fluctuations) (Action 1.1.1) 3.1.2 Plant native vegetation to stabilize streambanks (resulting in more undercut bank habitat and shading) (Action 1.2.3) **R** 3.1.3 Enhance fish passage by removing or modifying low water crossing and modifying sewer line crossing. **R** 3.1.4 Enhance instream cover with vegetation, woody debris or other appropriate elements. 3.1.5 Create pond habitat from former channel that is attractive for amphibians and will not increase wildlife hazard risk for FAA. Planting densities favorable for amphibians. 3.1.6 Track presence and assess effects of invasive species (e.g. beaver).
3.2 Enhance habitat for terrestrial wildlife	3.2.1 Construct new, smaller channel (more frequent inundation and raised bed elevation increases water table levels to support riparian and wet meadow) (Action 1.1.1) **R** 3.2.2 Plant native vegetation to enhance riparian and floodplain habitat. (Action 1.2.3) **R** **3.2.3** Maintain vegetative cover, snags and large woody debris for terrestrial habitat in forested areas. **M** 3.2.4 Create pond habitat from former channel that are attractive for amphibians and will not increase wildlife hazard risk for FAA. 3.2.5 Track presence and assess effects of invasive species (Action 3.1.6)
3.3 Protect sensitive habitats from excessive disturbance	3.3.1 Coordinate with Greenway project on alignment/design of bike path and trails. **M** 3.3.2 Identify 2-3 locations on the restored channel for walking access to the river. Site selection criteria will include recreational qualities (i.e. beaches that form on inside bend, visual aesthetics) and avoidance of sensitive habitats. **M** 3.3.3 Direct recreational activity away from sensitive habitats through public education, signage, and/or fencing at selected trails. **M**
3.4 Maintain connectivity along river and across valley by maintaining and enlarging contiguous tracts of terrestrial habitat and	3.4.1 Promote growth of desirable vegetation in wildlife corridor at southern end of MPA. **M** 3.4.2 Plant native vegetation to enhance riparian corridor. (Action 1.2.3) **R** **3.4.3** Maintain vegetative cover, snags and large woody debris for terrestrial habitat in forested areas.

OBJECTIVE	ACTIONS **(R = Restoration, M = Land Management)**
reducing habitat fragmentation WUI wildlife-urban interface	(Action 3.2.3) **M** 3.4.4 Track status of priority parcels in the wildlife corridor for potential acquisition from willing sellers. **M** 3.4.5 Maintain cover density of trees and minimize gap length across valley (consider footprint of channel and pathway).
GOAL 4 – Improve riparian, meadow and upland vegetation	
4.1 Increase spatial extent and vigor of native wetland species and wet meadow plant communities.	4.1.1 Construct new, smaller channel (more frequent inundation and raised bed elevation increases water table levels to support wet meadow) (Action 1.1.1) **R** 4.1.2 Plant vegetation on meadow (willow clumping) (Action 2.1.2).
4.2 Increase spatial extent, canopy cover, and recruitment of montane riparian scrub vegetation.	4.2.1 Construct new, smaller channel (more frequent inundation and raised bed elevation increases water table levels to support riparian vegetation) (Action 1.1.1) **R** 4.2.2 Plant willows and sedges to stabilize banks and enhance riparian habitat. (Action 1.2.3) **R**
4.3 Reduce conifer encroachment in aspen stands and wet meadow habitat.	4.3.1 Selective removal of conifers (lodgepole pine?) in aspen stands. **M** 4.3.2 Define management goals for lodgepole pine forest and wet meadow 4.3.3 Identify and implement methods for managing the lodgepole pine stands
4.4 Improve upland forest habitat structure	4.4.1 Promote growth of desirable conifers in forest areas. **M** 4.4.2 Maintain snags and large woody debris for terrestrial habitat. **M** 4.4.3 Conduct forest thinning as necessary to achieve desired forest habitat structure. **M**
4.5 Reduce wildfire threat near residential areas	4.5.1 Implement mechanical fuels management BMPs under existing CTC and USFS programs, consistent with TRPA regulations. **M** 4.5.2 If necessary, implement prescribed fire measures under existing CTC and USFS programs, consistent with TRPA regulations. **M**
4.6 Control and manage existing invasive nonnative species, and prevent introduction and spread of new populations. (wording from UTR Marsh management plan)	4.6.1 Monitor for presence of priority invasive species. Locate, map, and evaluate invasive plant species (at least once every 3 years). **M** 4.6.2 Develop and implement a weed control program (treatment and monitoring). Potential measures may include mechanical (e.g. mowing, grazing) and/or chemical control. **M** 4.6.3 Coordinate with basin-wide efforts such as the Lake Tahoe Basin Weed Coordinating Group (e.g. share survey data, update priority species lists and hotspot locations) . **M**
GOAL 5 - Provide for appropriate public access opportunities that are compatible with natural resources	
5.1 Direct activities away from sensitive habitats (see Objective 3.4 Protect sensitive habitats from excessive disturbance)	5.1.1 Coordinate with Greenway project on alignment/design of bike path and trails. (Action 3.3.1) **M** 5.1.2 Identify appropriate locations on the restored channel for walking access to the river. Site selection criteria will include recreational qualities (i.e. beaches that form on inside bend, visual aesthetics) and avoidance of sensitive habitats. (Action 3.3.2) **M**

OBJECTIVE	ACTIONS **(R = Restoration, M = Land Management)**
Even w/o gway, the sewer line trail will need to be BMPd	5.1.3 Direct recreational activity away from sensitive habitats through public education on natural resource values, signage, and/or fencing at selected trails. (Action 3.3.3) **M** 5.1.4 Map trail network and prioritize eroded and/or redundant informal trails. Reduce erosion from trails by consolidating redundant trails, upgrading active trails as necessary according to BMPs, and restoring retired trail segments to native vegetation. Use recontouring, fencing, barriers, and/or signage to prevent disturbance. (Action 2.3.4) **R&M** 5.1.5 Maintain Elks Club property site as an access hub to consolidate more recreational use toward the south end of the MPA. **M**
5.2 Provide access to the river that enhances the recreational experience while reducing impacts to riparian and meadow habitat.	5.2.1 Maintain access for boaters by designing river channel restoration to have slack water conditions at appropriate put-in/take-out locations (Elks Club Blvd & Hwy 50). **R** 5.2.2 Identify appropriate locations on the restored channel for walking access to the river. Site selection criteria will include recreational qualities (i.e. beaches that form on inside bend, visual aesthetics) and avoidance of sensitive habitats. (Action 3.4.2) **M**
5.3 Provide educational information to recreational users	5.3.1 Coordinate with Greenway project to install interpretative signs and kiosks on natural values, threats to sensitive habitats, and permitted uses. **M**