Shasta crayfish, a California native

Shasta crayfish, *Pacifastacus fortis*

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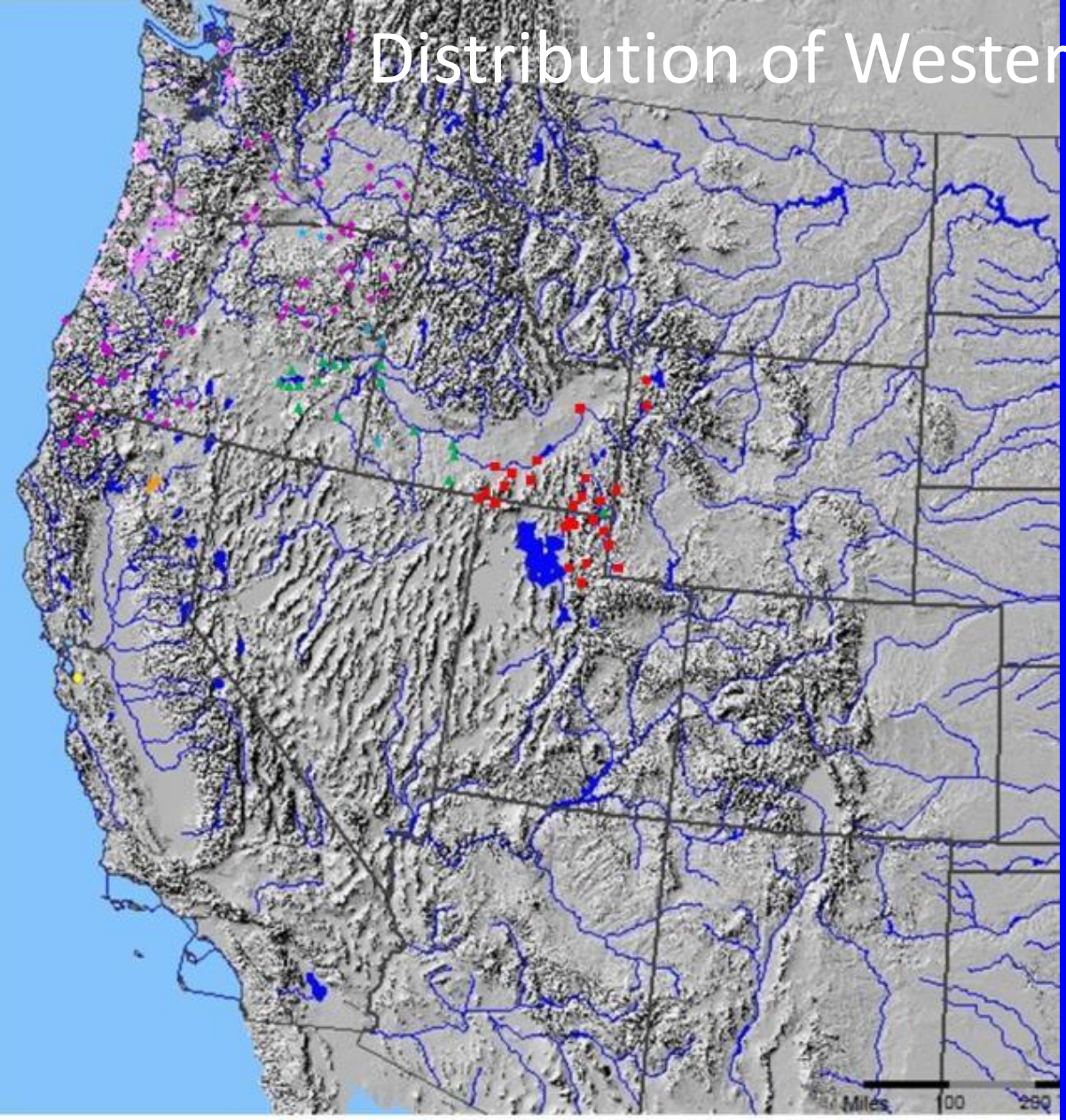
Distribution of Western Crayfishes



- 321 species native to the United States and Canada
- 5 species west of the Continental Divide
  - 1 presumed extinct
  - 1 endangered
- 3 species native to California

Geologic History

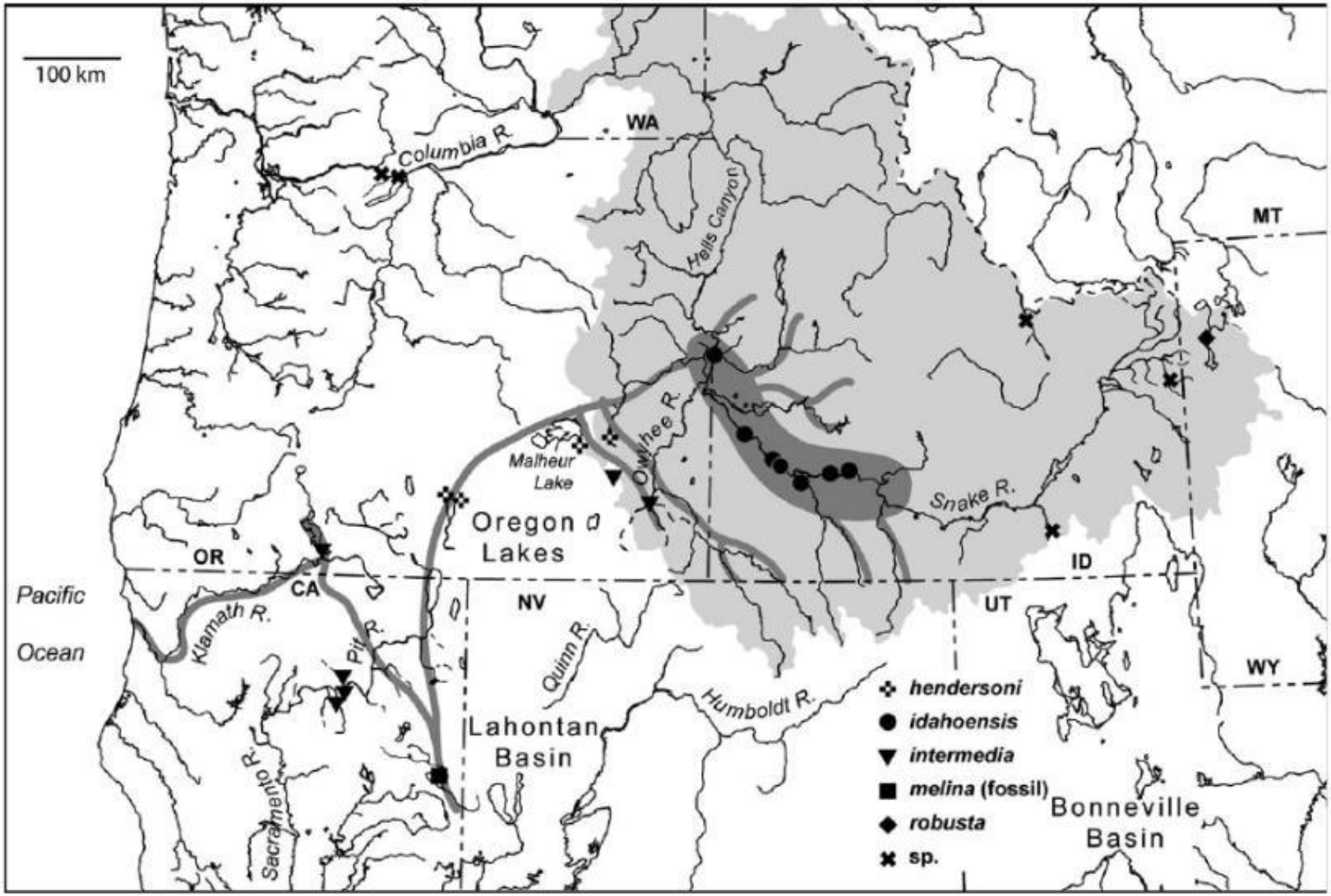
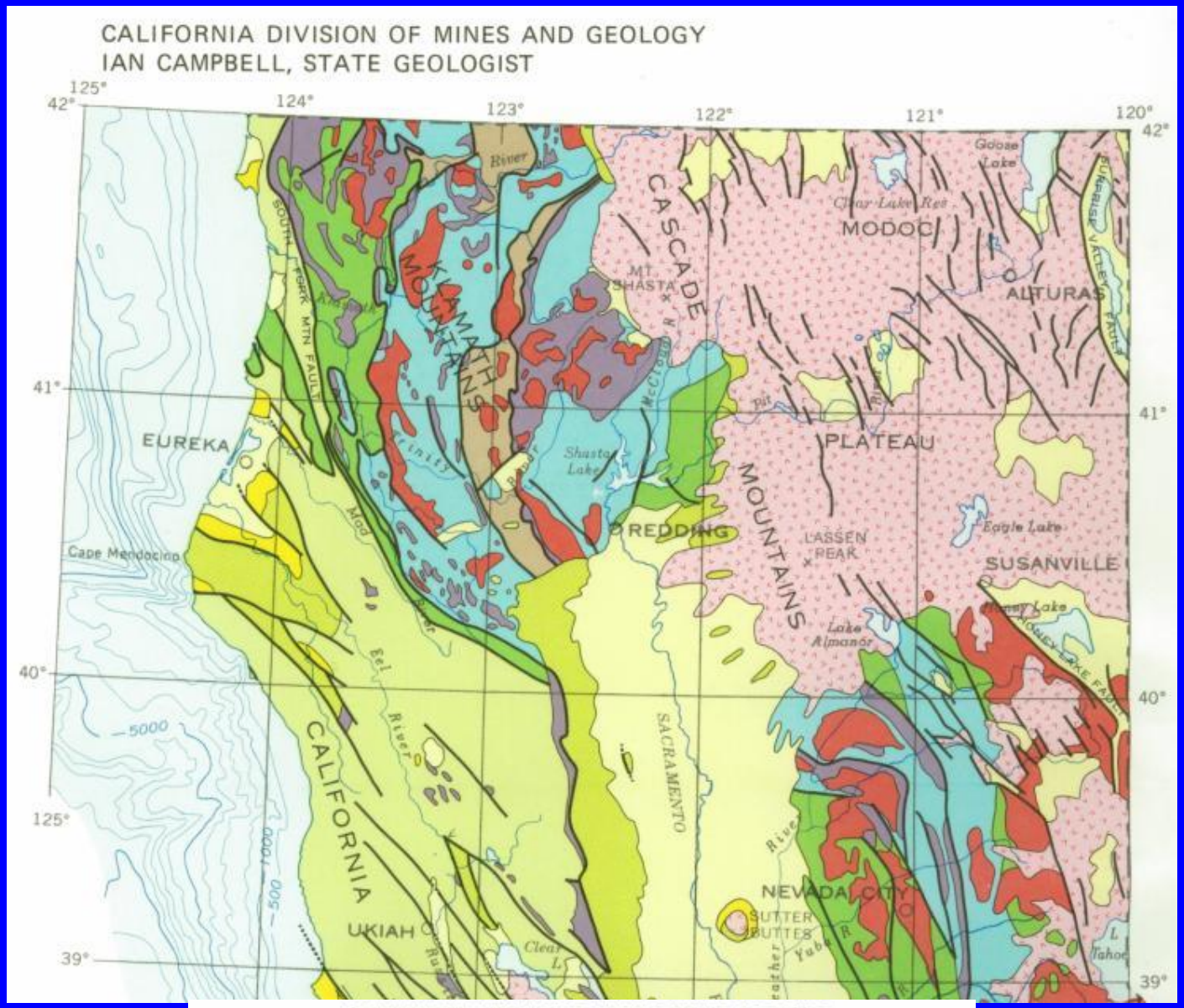


Fig. 1. Map showing location of sampled *Pyrgulopsis* (*Natricola*) populations and fossil *P. melina*. The lightly shaded area delineates the modern Snake River Basin while the hypothesized route of the ancestral Snake River (from Taylor and Bright, 1987, Fig. 5) is more darkly shaded.

Geomorphic Provinces of Northeastern California



SEDIMENTARY AND VOLCANIC ROCKS

Cenozoic nonmarine (continental) sedimentary rocks and alluvial deposits

Cenozoic marine sedimentary rocks

Cenozoic volcanic rocks

Prime Shasta
Crayfish Habitat

Rough sculpin, *Cottus asperrimus*

Bigeye marbled sculpin, *Cottus klamathensis macrops*

Juga species (Family Pleuroceridae)
Fluminicola species (Family Hydrobiidae)

Northwestern pond turtle, *Actinemys marmorata marmorata*

Early Collections/Studies of *Pacifastacus fortis*

1898 United States Fish Commission — Rutter and Chamberlain
(Rutter 1903, 1908, Faxon 1914)

1934 University of Michigan — C. Hubbs
(Goodnight 1940)

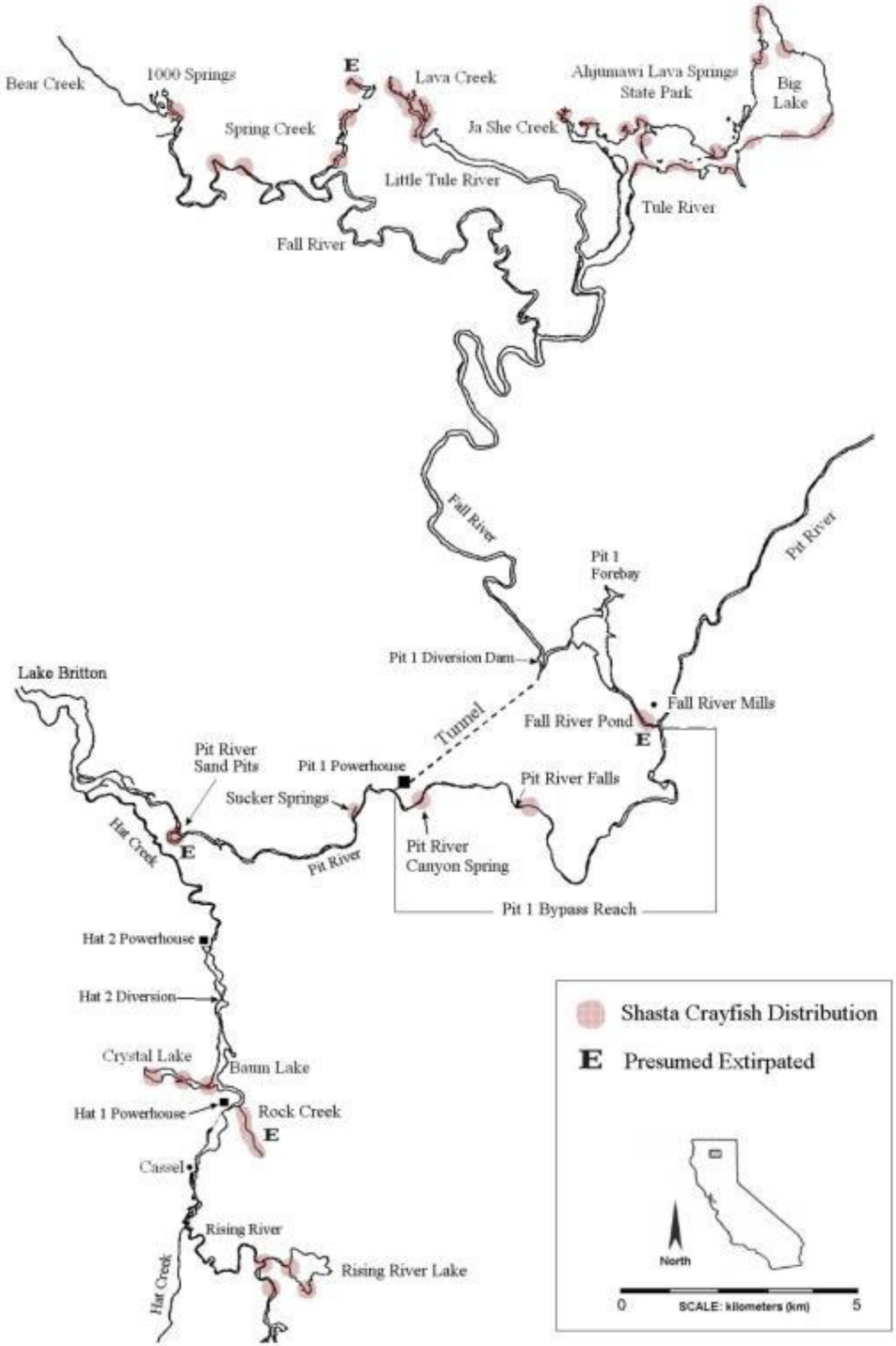
1959 University of California, Davis — Riegel
(Riegel 1959) no specimens found

1964 Virginia Polytechnic Institute — P. Holt
(Holt 1967, 1981)

1974 University of California, Davis — R. Daniels
(Moyle and Daniels 1982, Daniels 1980)
- 1st record of Orconectes virilis — Pit River & Hat Creek at Lake Britton

1975 University of Northern Alabama/USFWS — R. Bouchard
(Bouchard 1977a, 1977b, 1978)

1978 University of California, Davis — R. Daniels
(Daniels 1980, Eng and Daniels 1982)
- 1st record of Pacifastacus leniusculus — Baum Lake and Burney Creek
- 1st P. leniusculus in Crystal Lake (ovigerous female in November 1978)



1990 – 1996

- In 1990, Pacific Gas and Electric Company (PG&E) initiated the most thorough and extensive surveys ever undertaken in the area.
- The survey was completed under contract with CDFG.
- Surveyed the entire Fall River subdrainage, the lower Hat Creek subdrainage from the spring-fed Rising River subdrainage, and the reach of the Pit River connecting these two subdrainages.
  - 15 previously undiscovered locations of Shasta crayfish
  - 3 rediscovered, Shasta crayfish locations that had been presumed extirpated

1990 – 1991 UC Berkeley Shasta crayfish studies funded by USFWS and CDFG

- Snorkeling or scuba diving
- Mark-recaptures and other quantitative studies
- Nocturnal observations

- Shasta crayfish
  - Not in the open during daytime, unless sick, dying, or dead
  - Home range of Shasta crayfish was generally less than 100 meters
  - Few individuals were observed in the open at any time
  - Nocturnal activity was depressed by moonlight
- Signal crayfish
  - Commonly found in the open during the day
  - Commonly observed in the open walking upstream

- Shasta crayfish was described in 1914 from specimens collected in 1898, but the first actual study of the crayfish wasn't until 1975.
- Studies in 1975 and 1978 documented much of the range and distribution of Shasta crayfish, however, little was reported on the ecology and diet of the species.
- My doctoral research was looking at the effects of an invasion of non-native crayfish that was replacing a native endangered crayfish.
  - Natural history, ecology, and behavior of Shasta crayfish.
  - Determine the current distribution and to see how it had changed since the first invasions of signal crayfish, which were coincident with the last and only major survey of Shasta crayfish in 1978.
  - Determine the distribution and range of signal crayfish.
  - Document changes in species abundance in sympatric Shasta crayfish populations following signal crayfish invasions.

Signal crayfish, *Pacifastacus leniusculus*

Northern crayfish, *Orconectes virilis*

- Secondary invasion of branchiobdellid worms carried by the non-native signal crayfish that were replacing the native branchiobdellidans on Shasta crayfish.

Signal crayfish with
Xironogiton victoriensis

QUESTIONS

- What are the mechanisms by which the species are interacting, e.g., Competition, Predation, or a combination?
- What are the size/age classes that are interacting, e.g., adult/adult, adult/juvenile, or juvenile/ juvenile?

- How do species interactions vary in environments with different species size compositions?

HYPOTHESIS: Competition by signal crayfish results in decreased activity, growth rate, fecundity, and survival of Shasta crayfish

CONCLUSIONS:

- Competition by signal crayfish results in decreased growth rate of Shasta crayfish
- Shasta crayfish decrease activity and non-aggressive contacts and increased the time spent burrowing and resting in the presence of signal crayfish
- Since fecundity and survival are generally size-dependent, decreased growth rate is likely to result in decreased fecundity and survival of Shasta crayfish in the presence of signal crayfish

HYPOTHESIS: Interspecific predation by signal crayfish further reduces survivorship and recruitment of Shasta crayfish

CONCLUSIONS:

- Large signal crayfish are predators of Shasta crayfish
- The importance of intraguild predation by large signal crayfish in the species replacement of Shasta crayfish in the natural system remains a question

HYPOTHESIS: Interspecific competition and predation by signal crayfish on Shasta crayfish is exacerbated by increasing size differences between these two species

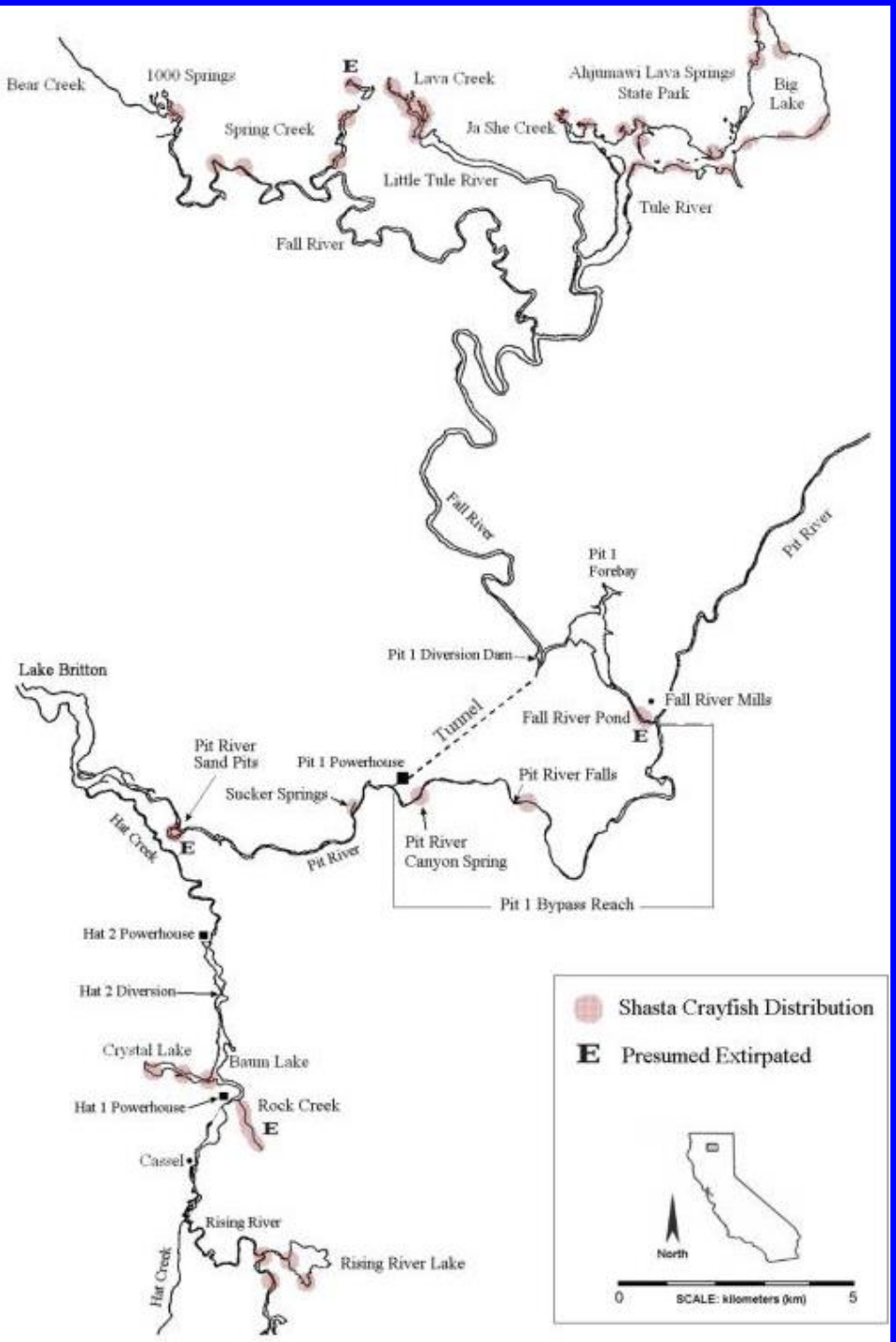
CONCLUSIONS:

- Large signal crayfish were the most aggressive and active species-size class
- Competition by large signal crayfish resulted in the greatest decrease in the growth rate of Shasta crayfish
- Shasta crayfish modified its behavior the most in the presence of large signal crayfish with decreased activity and aggressive behavior and increased burrowing, avoidance behavior, and resting
- Intraguild predation of Shasta crayfish was only initiated by larger signal crayfish

HYPOTHESIS: Competition and/or predation by the non-native branchiobdellidan *Xironogiton victoriensis* results in decreased survivorship of the native branchiobdellidan, *Magmatodrilus obscurus* on Shasta crayfish

CONCLUSIONS:

- Predation by *Xironogiton victoriensis* results in decreased survivorship of *Magmatodrilus obscurus* on Shasta crayfish
- Survivorship of *M. obscurus* was lowest on the chelipeds, which is the preferred microhabitat of *X. victoriensis*
- Microhabitat use of the chelipeds by *M. obscurus* was reduced in the presence of non-native branchiobdellidans
- *Xironogiton victoriensis* is replacing *Magmatodrilus obscurus* on Shasta crayfish



1998

- USFWS Recovery Plan
- Distribution of Shasta crayfish within the range very fragmented
  - Primarily restricted to the headwater spring areas
- Fragmentation primarily due to habitat destruction and alterations in the past century
- Signal crayfish throughout most of the midreaches of the Pit River drainage
  - Replaced northern crayfish downstream of Pit 1 Powerhouse
- Ongoing invasions into several Shasta crayfish populations in the headwaters
- Abundance of Shasta crayfish decreased, often dramatically, in areas with ongoing signal crayfish invasions

Bear Creek Meadow Restoration Project (1999)

Spring Creek Road Crossing (2000)

Barrier Flume Study

January 2002 – July 2004

- Cooperative Effort funded by:
  - Department of Parks and Recreation (first phase)
  - USFWS (second phase)
  - Spring Rivers Ecological Sciences LLC
- Supported by several UCD departments:
  - Geology Department
  - Department of Environmental Design
  - Department of Environmental Science and Policy
  - Department of Civil and Environmental Engineering
  - U.C. Davis J. Amorocho Hydraulics Laboratory

Barrier Flume Study consisted of:

- Literature review and assessment of different materials that could be used for barrier construction
- Test of feasibility and efficacy of different barrier designs to transport bedload sediment
- Test of different designs with:
  - Crayfish
  - Trout
  - Sculpin
  - Different Flow levels

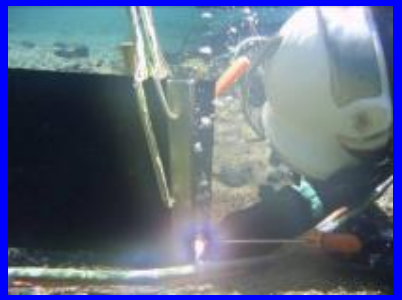
U.C. Davis Flumes

Results of the Barrier Flume Study

- Both physical and velocity barriers can be effective at keeping crayfish from moving upstream
- Slick surfaces (such as stainless steel or aluminum) can be effective stillwater barriers when placed vertically
- Slick surfaces can be effective when placed horizontally in faster water
- Signal crayfish were not seen to swim over barriers; they will climb if they are able to get purchase on the barrier material or seams
- We were unable to come up with a design that would pass sediment and be maintenance-free
  - Not a deal breaker in the systems we are concerned with

- Pacific Gas and Electric Company
  - Hat Creek Hydroelectric Project — 2002 FERC License
  - Pit 1 Hydroelectric Project — 2003 FERC License
  - License requirement to establish a technical review committee to assist PG&E in the design and implementation of the terms and conditions required in the biological opinions for Shasta crayfish
- Shasta crayfish Technical Review Committee (TRC)
  - Established in April 2003
  - PG&E, CDFW, USFWS, and other resource agencies and interested stakeholders
  - Academia, Spring Rivers, and California Department of Parks and Recreation

Upper Fall River
Crayfish Barrier Project (2007)



Sucker Springs Creek Restoration

- CDFG abandoned the hatchery in 1997
- CDFG removed concrete walkway and other hatchery infrastructure in 1999

Non-Native Crayfish Removal Efforts ongoing since 1996

- CDFG trapping and hand removal from 1997 – 2000

Five Years after Hatchery Infrastructure Removal

Sucker Springs Creek Crayfish Barriers

Pond 4 Crayfish Barrier

Pond 5 Crayfish Barrier

Non-Native Crayfish Removal

- 2001 – 2013
- 8118 signal crayfish have been captured and removed from Sucker Springs Creek

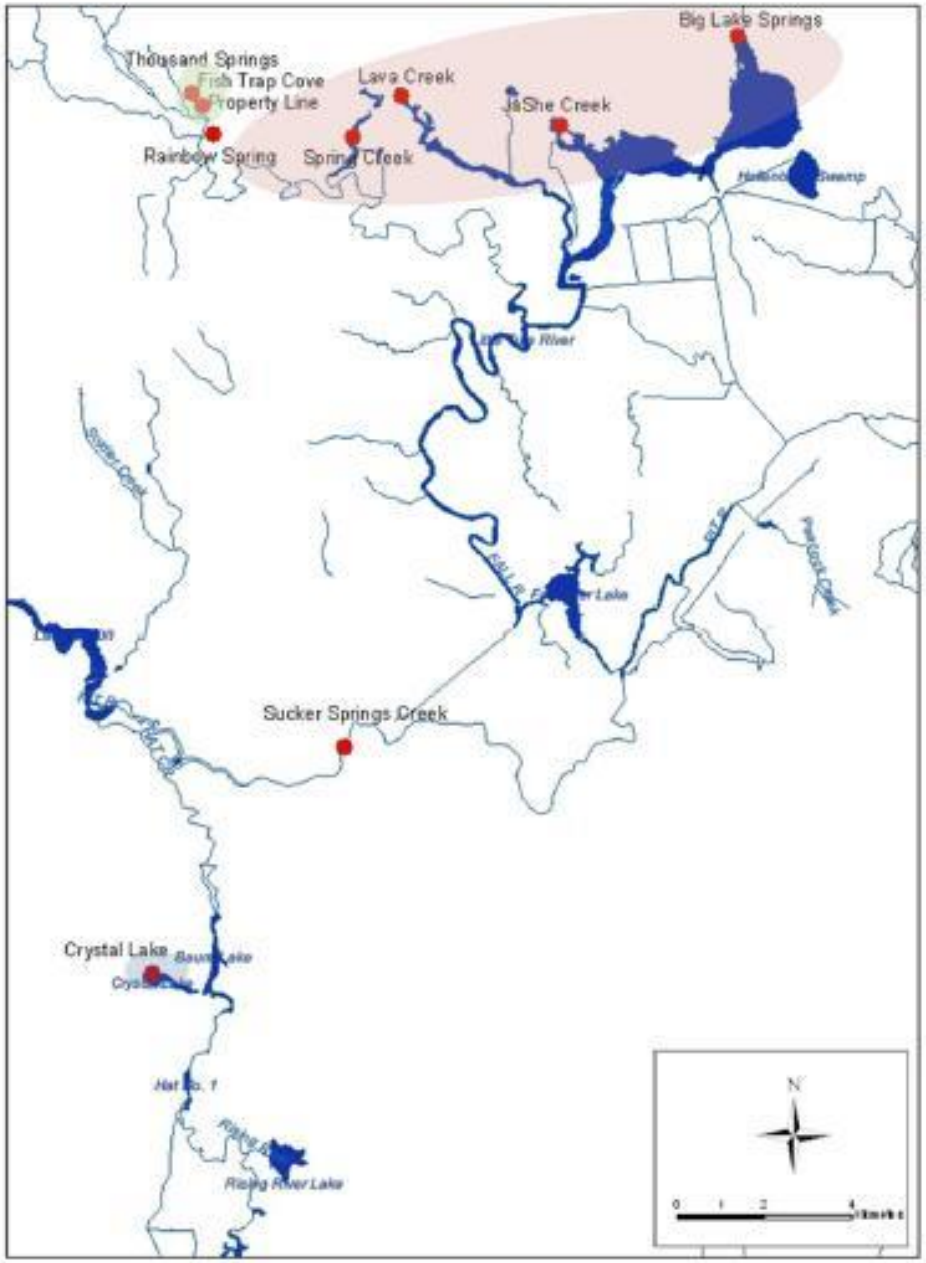


Figure 1. Map of Shasta crayfish habitat with genetic sampling locations indicated by red dots. The three genetic clusters are shaded (Red = Big Lake cluster, Green = Thousand Springs cluster, Blue = Crystal Lake). Figure taken from USFWS (1998).

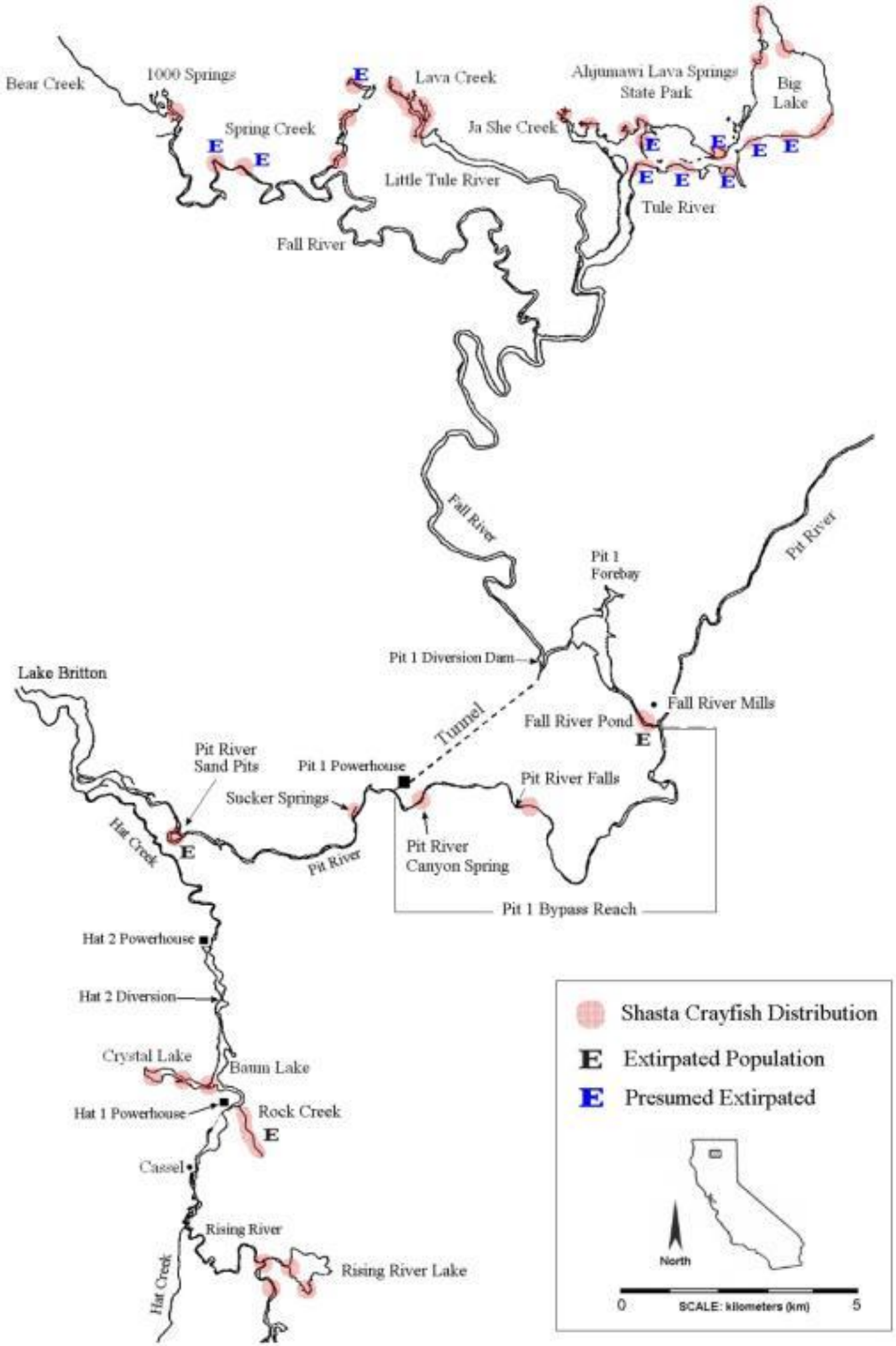
2003 – 2012 CDFG Genetics Study

Jessica Petersen, Ph.D.
Bernie May, Ph.D.
Genomic Variation Laboratory
University of California, Davis

- Genotype 9 microsatellite loci
  - 235 individual crayfish
  - 9 sampling locations
- Three different genetic clusters
  - (1) Crystal Lake
  - (2) Big Lake
  - (3) upper Fall River
- Crystal Lake greatest genetic diversity and uniqueness
- upper Fall River relatively homogenous

- Mitochondrial DNA confirmed the diversity of the Crystal Lake population and the homogeneity of the upper Fall River samples
- Heteroplasmy — individual Shasta crayfish exhibited more than one type of mitochondrial DNA

- Shasta Crayfish Genetic Management Plan
  - Conserve 90% genetic diversity over 100 year period
  - Factors impacting genetic diversity
  - Recommendations to help inform management decisions
  - Refugia development and source populations


Bear Creek
1000 Springs
Spring Creek
Lava Creek
Algumawi Lava Springs State Park
Big Lake
Ja She Creek
Little Tule River
Tule River
Fall River
Fall River
Pit River
Pit 1 Forebay
Pit 1 Diversion Dam
Tunnel
Fall River Mills
Fall River Pond
Lake Britton
Pit River Sand Pits
Pit 1 Powerhouse
Pit River Falls
Sucker Springs
Hat Creek
Pit River
Pit River Canyon Spring
Pit 1 Bypass Reach
Hat 2 Powerhouse
Hat 2 Diversion
Crystal Lake
Baum Lake
Hat 1 Powerhouse
Rock Creek
Cassel
Rising River
Rising River Lake
Hat Creek
Shasta Crayfish Distribution
Extirpated Population
Presumed Extirpated
North
0
SCALE: kilometers (km)
5

Safe Harbor Agreement

- Federal Safe Harbor Agreement policy was developed in 1999
- California adopted a Safe Harbor Agreement policy in January/February 2011
- USFWS developed a Safe Harbor Agreement to be used for the Kerns property in 2011
- Kerns Pond Safe Harbor Agreement was approved and signed during a refuge site visit and ceremony on March 23, 2012
- State consistency determination was signed on August 9, 2012
- Kerns Pond Safe Harbor Agreement is the first joint federal and state Safe Harbor Agreement in California.
- Template for other landowners and property, including PG&E for the Rock Creek Restoration and Reintroduction Project

Kerns Pond
Safe Harbor Agreement

Sacramento Fish & Wildlife Office

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A Safe Place for the Endangered Shasta Crayfish

CLICK TO ENLARGE

Being out competed by a non-native is no fun. Luckily, the endangered Shasta crayfish is about to get a new home thanks to private landowners and a Safe Harbor Agreement.
Photo courtesy of Kem G. H. Brandwold

The Shasta Crayfish is an endangered species native to northeast California. The crayfish is usually dark brown with spots of orange. They live in freshwater ponds and rivers in the Rocky Mountains and eat the slime that covers the rocks. The species is endangered, in part, because non-native Signal crayfish are taking over their range. With only a few small populations left, most Shasta crayfish may be gone in the near future.

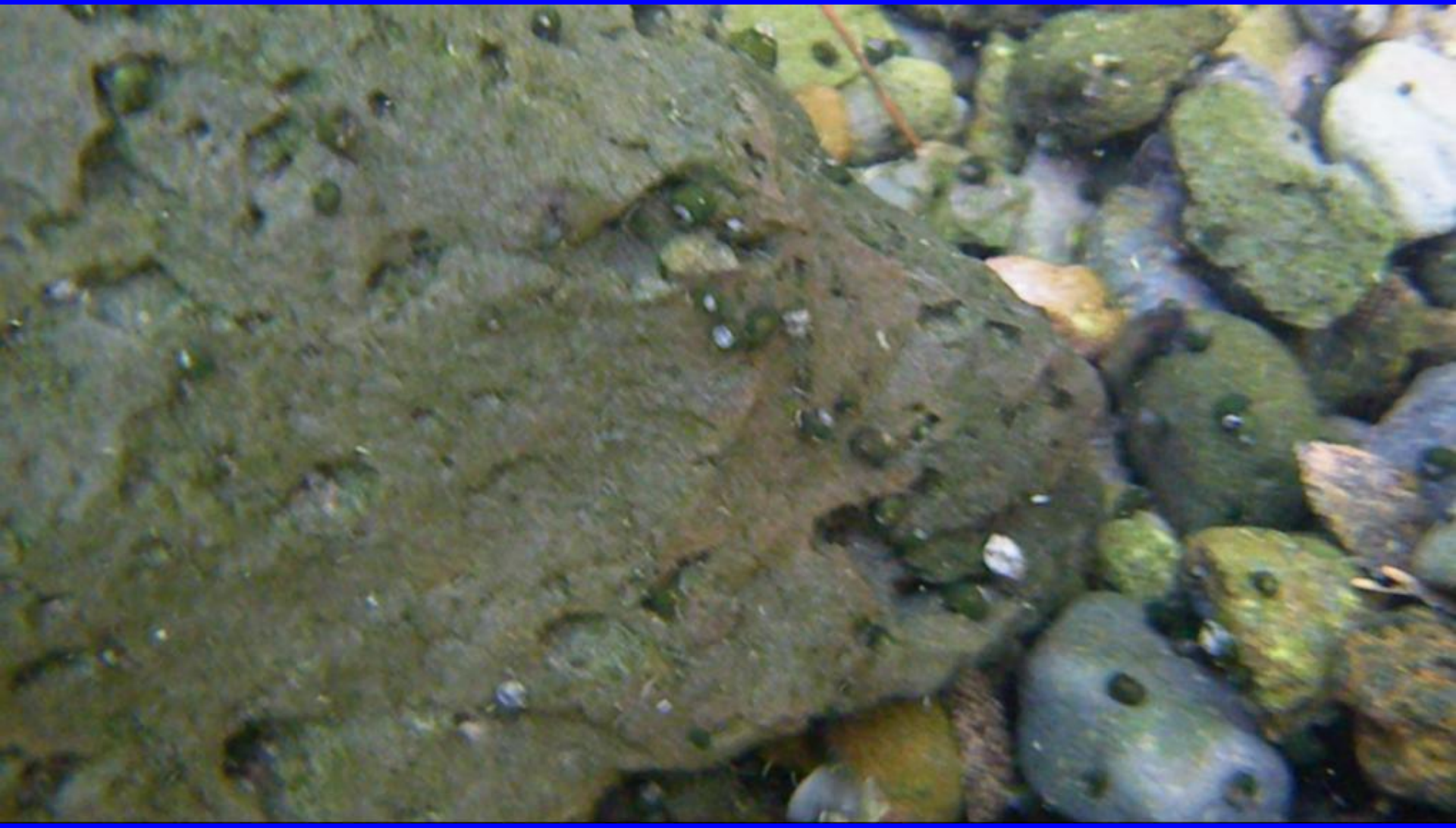
The species needs help and thanks to willing landowners and the US. Fish and Wildlife Service's Safe Harbor Program they are going to be getting some new space this summer. A Safe Harbor Agreement (SHA) is a voluntary agreement involving private or other non-federal property owners whose actions contribute to the recovery of threatened or endangered species. In exchange, participating property owners receive formal assurances from the Service that if they fulfill the conditions of the SHA, the Service will not require any additional or different management activities by the participants without their consent.

With this project the Service hopes to encourage recovery of the Shasta crayfish and restoration of its habitat. They want to create places where the non-native and more aggressive crayfish can't reach this endangered species.

Now there is a SHA to help Shasta Crayfish between the Kern family, the Springs River Foundation, the California Department of Fish and Game, and the Service. The Kern family has a cold, spring-fed pond with a volcanic gravel and rock bottom on their property which is the perfect habitat for the Shasta crayfish. No non-native crayfish or other fish live in the pond. The Kern family is allowing the endangered crayfish to be put in their pond, and with the SHA, they know that in the future they can have them removed with no penalty.

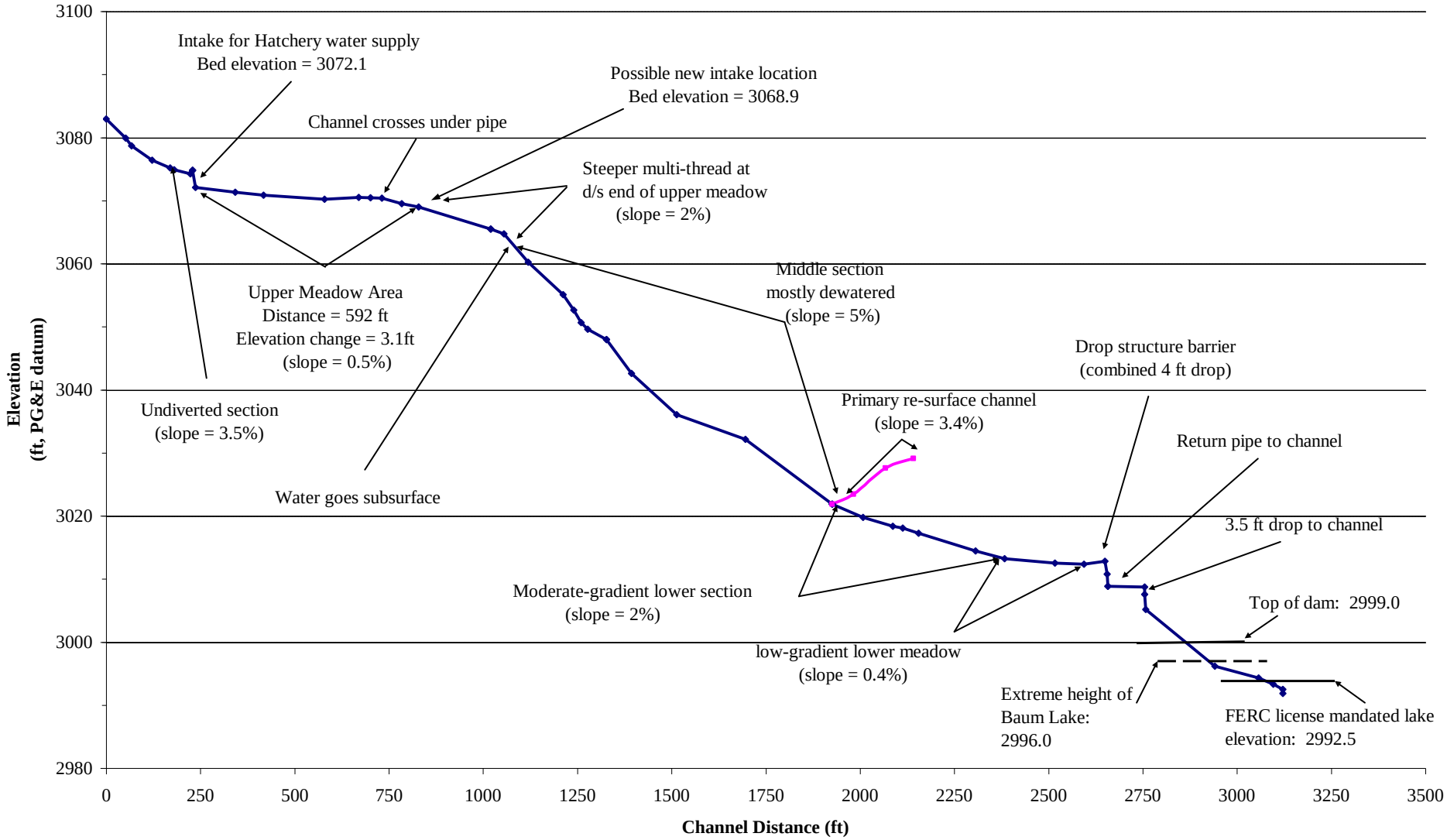
Maria Ellis works for the Spring Rivers Foundation, which works to save endangered species like the Shasta crayfish. Ellis thought it would be a good idea to use the Kern pond for the Shasta Crayfish. Because of her, this particular safe harbor was able to happen. "The SHA executed between the Kern family and the Service is a watershed event for the endangered Shasta crayfish," Ellis remarked. "Although it occurred quietly and without fanfare, this agreement is precedent setting, and opens the door to a more hopeful future for the species. Thanks to the Kern family and all at the Service for making this happen."

Kerns Pond Shasta Crayfish Relocation

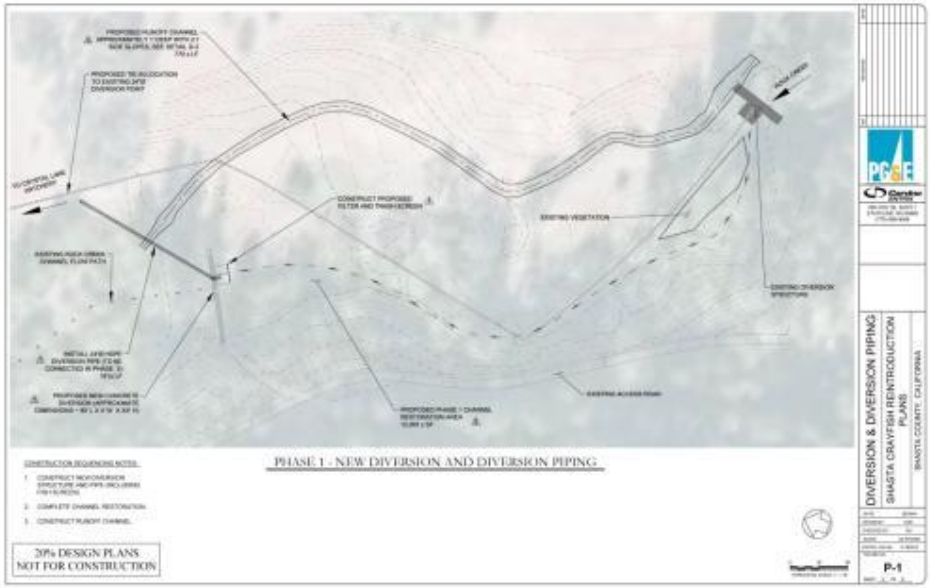


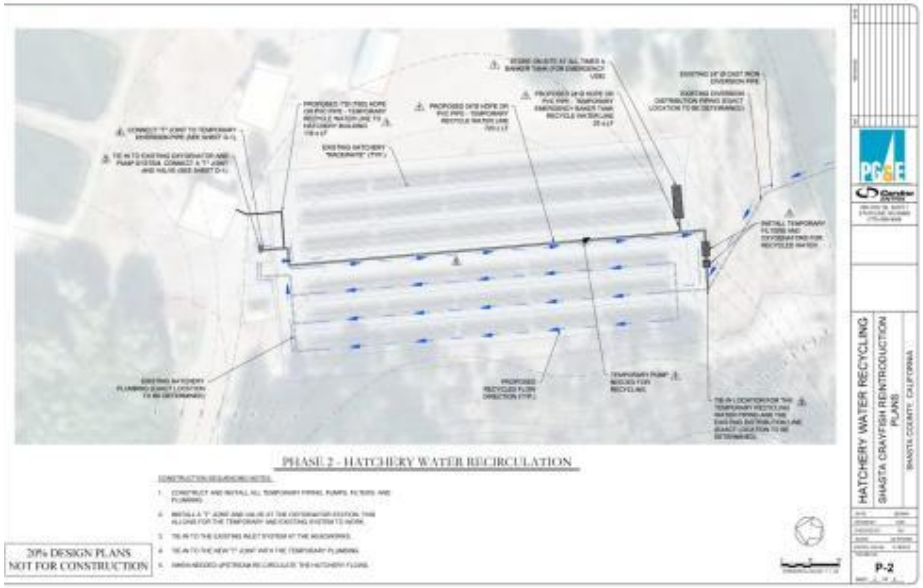
Rock Creek Meadow Restoration

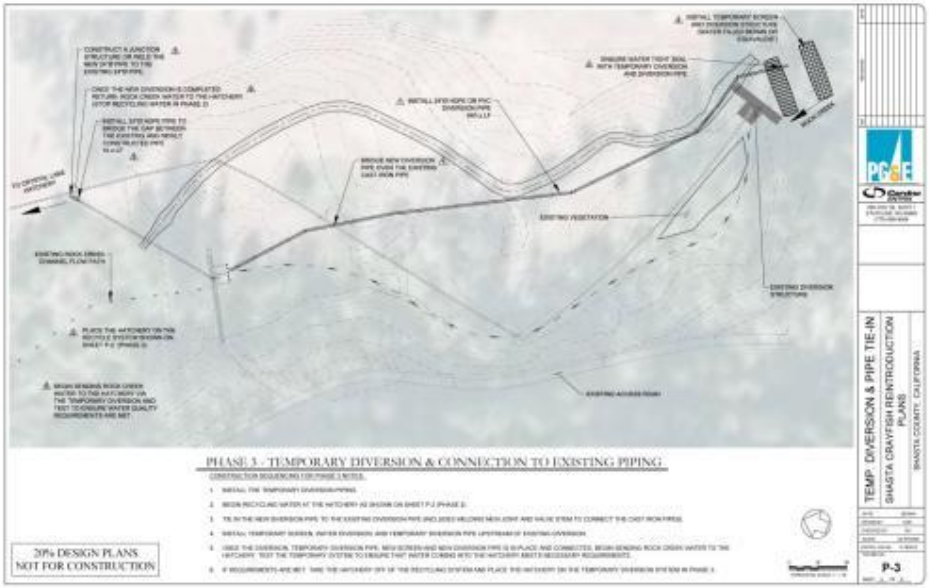
Longitudinal profile of Rock Creek

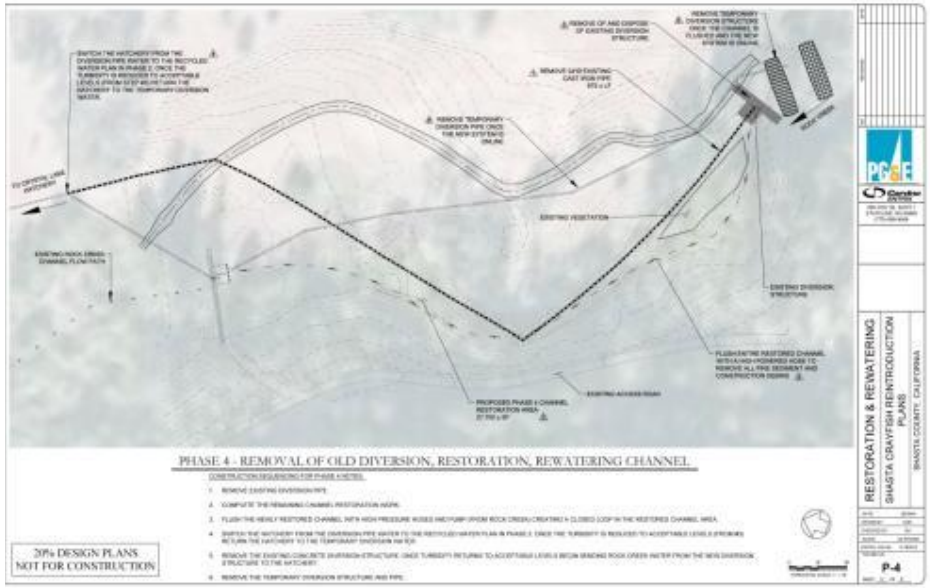


Rock Creek Meadow Restoration Construction Phasing









RESEARCH

- Observations on the range, distribution, natural history, and behavior of crayfish in the Fall River, Hat Creek, and Pit River Drainages
- Document species interactions in the field: Cage Experiments
- Potential mechanisms of competition and predation between species and age/size classes: Lab Experiments
- Observations on the species composition of branchiobdellidans on *P. fortis* and *P. leniusculus* in allopatric and sympatric crayfish populations
- Document species interactions between the non-native and native branchiobdellidans using *P. leniusculus* as the host in the laboratory