BISON CONNECT

**Powelson, Katherine <katherine_powelson@fws.gov>**

# Peer Review Request from USFWS

20 messages

**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Mar 11, 2019 at 4:42 PM
To: maholyoak@ucdavis.edu

Dear Dr. Marcel Holyoak,

The U.S. Fish and Wildlife Service (Service) is soliciting independent scientific reviews for the "Draft Revised Recovery Plan for Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*)". Draft and final recovery plan revisions are publicly available through our Environmental Conservation Online System (ECOS, https://ecos.fws.gov); this draft revision is also attached.

We are seeking your expert review on the following:

- Have we assembled and considered the best available scientific and commercial information relevant to this species?
- Is our analysis of this information correct?
- Are our scientific conclusions reasonable in light of this information?

This request is provided in accordance with our July 1, 1994, peer review policy (USFWS 1994, p. 34270) and our current internal guidance. This request also satisfies the peer review requirements of the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review." Our updated peer review guidelines also require that all peer reviewers fill out a conflict of interest form (**see attached**). We will carefully assess any potential conflict of interest or bias using applicable standards issued by the Office of Government Ethics and the prevailing practices of the National Academy of Sciences (http://www.nationalacademies.org/coi/index.html). Divulging a conflict does not invalidate the comments of the reviewer; however, it will allow for transparency to the public regarding the reviewer's possible biases or associations. You may return the completed conflict of interest form either prior to or with your peer review.

We ask that you please provide your comments no later than **April 15, 2019**. Please provide your written response to us by email or by letter. Please be aware that your completed review of the draft recovery plan revision, including your name and affiliation, will be included in the administrative record and will be available to interested parties upon request.

Please let me know if you have any questions.

Thank you for your consideration

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916) 278-9448 office**
**3020 State University Drive East**
**Modoc Hall, Suite 2007**
**Sacramento CA 95819**

**2 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**Conflict of Interest Disclosure Form.pdf**
63K

**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Mar 11, 2019 at 4:44 PM

To: tstalley@ucsd.edu

Dear Dr. Theresa Talley ,
[Quoted text hidden]

**2 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**Conflict of Interest Disclosure Form.pdf**
63K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Mar 11, 2019 at 4:45 PM
To: "Silveira, Joe" <joe_silveira@fws.gov>

Dear Joe Silveira,
[Quoted text hidden]

**2 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**Conflict of Interest Disclosure Form.pdf**
63K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Mar 11, 2019 at 4:46 PM
To: bugdctr@comcast.net

Dear Dr. Richard Arnold,
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**2 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**Conflict of Interest Disclosure Form.pdf**
63K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Tue, Mar 12, 2019 at 9:32 AM
To: sharon.collinge@colorado.edu

Dear Dr. Sharon Collinge,
[Quoted text hidden]

**2 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**Conflict of Interest Disclosure Form.pdf**
63K

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**Theresa Talley** <tstalley@ucsd.edu> Mon, Apr 1, 2019 at 2:27 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Hi Kat,
Attached is the draft recovery plan with my comments in track changes and the comments function; and my COI form.

Attached are also two documents that i reference that were not included in the bibliography.

Please don't hesitate to contact me if you need more information or have questions about my comments.
Happy to help.
Best wishes, theresa
858-200-6975

Theresa Sinicrope Talley, PhD
**Coastal Specialist**

CALIFORNIA SEA GRANT
Scripps Institution of Oceanography, UC San Diego
Phone: **858-200-6975**
Web: **caseagrant.ucsd.edu**

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**10 attachments**

**CSGCLogo_blk.png**
9K

**ATT00001**
8K

**FremierTalley2009_Wetlands.pdf**
702K

**ATT00002**
1K

**Conflict of Interest Disclosure Form.pdf**
69K

**ATT00003**
1K

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3158K

**ATT00004**
1K

**klasson_etal_2005.doc**
496K

**ATT00005**
1K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Apr 1, 2019 at 2:38 PM
To: Theresa Talley <tstalley@ucsd.edu>

Thank you for your help!

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916) 278-9448 office**
**3020 State University Drive East**
**Modoc Hall, Suite 2007**
**Sacramento CA 95819**

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**Marcel Holyoak** <maholyoak@ucdavis.edu> Sun, Apr 14, 2019 at 4:11 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Dear Kat

Please find attached my review of the draft recovery plan for the VELB.

Best wishes, Marcel

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Dr. Marcel Holyoak, Professor and Chair

Department of Environmental Science and Policy http://desp.ucdavis.edu/

University of California, 1 Shields Ave., Davis, CA 95616, U.S.A.

Office location 2130 Wickson Hall (inside 2132 Wickson)

Cellphone +1 (530) 867-3391

Fax +1 (530) 752-3350

Email: maholyoak@ucdavis.edu

Webpage: http://www.des.ucdavis.edu/faculty/holyoak/

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**MH comments on revised recovery plan 20190410.docx**
17K

**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Apr 15, 2019 at 8:08 AM
To: Marcel Holyoak <maholyoak@ucdavis.edu>

Thanks Marcel!

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916) 278-9448 office**
**3020 State University Drive East**
**Modoc Hall, Suite 2007**
**Sacramento CA 95819**

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**Silveira, Joe** <joe_silveira@fws.gov> Tue, Apr 16, 2019 at 12:53 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Hi Katherine,

I have only a single edit on the cover photo, a question on the Subregion boundaries, a two comments (with supporting documents attached).

Let me know if you have any questions.

Thank you for the opportunity.

Joe
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Joseph Silveira
Wildlife Refuge Manager
U.S. Fish & Wildlife Service
Sacramento River National Wildlife Refuge
North Central Valley Wildlife Management Area – Llano Seco Unit
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(530) 934-7814 fax
joe_silveira@fws.gov

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**7 attachments**

**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx**
3146K

**VELBS SURVEY Report 0223 04.pdf**
1112K

**VELB Meghan Gilbart CSUC Thesis 2009.pdf**
497K

**TNC_Afton1_2018_VELB_FINAL_w_JS_ALL.pdf**
1309K

**Wildlife Response to Riparian Restoration -Golet et al- SF Estuary & Watershed Science 2008.pdf**
1914K

**Ecosytem Restoration Middle Sacramento River-Golet et al- SF Estuary & Watershed Science 2013.pdf**
1008K

**Ecosytem Restoration Middle Sacramento River APPENDIX A-Golet et al- SF Estuary & Watershed Science 2013.PDF**
1823K

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**Silveira, Joe** <joe_silveira@fws.gov> Tue, Apr 16, 2019 at 12:55 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

... this is the DRAFT with my comments...........

~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~

Joseph Silveira
Wildlife Refuge Manager
U.S. Fish & Wildlife Service
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North Central Valley Wildlife Management Area – Llano Seco Unit
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**Draft APG revision Valley Elderberry Longhorn Beetle_v3.docx JS comment**
3151K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Tue, Apr 16, 2019 at 1:14 PM
To: "Silveira, Joe" <joe_silveira@fws.gov>

Thanks you! Could you send me your conflict of interest form as well?

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916 o) 278-9448 office**
**3020 State University Drive East**
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**Sacramento CA 95819**

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**Sharon Collinge** <Sharon.Collinge@colorado.edu> Tue, Apr 16, 2019 at 1:02 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Katherine,

Just wanted to write and tell you that the deadline for this review (yesterday) slipped past me, but I should be able to complete it by tomorrow or Thursday. Does that still work for your timeline?

Apologies!

Sharon

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Sharon K. Collinge

Professor, Environmental Studies Program

Faculty Director, Center for Sustainable Landscapes and Communities

University of Colorado-Boulder

UCB 397, 4001 Discovery Drive

Boulder, CO 80309-0397

(303) 735-3242

sharon.collinge@colorado.edu

@CollingeS

@CUBoulderCSLC

**From:** "Powelson, Katherine" <katherine_powelson@fws.gov>
**Date:** Tuesday, March 12, 2019 at 10:34 AM
**To:** Sharon Collinge <Sharon.Collinge@colorado.edu>
**Subject:** Peer Review Request from USFWS

Dear Dr. Sharon Collinge,

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**Powelson, Katherine** <katherine_powelson@fws.gov> Tue, Apr 16, 2019 at 1:18 PM
To: Sharon Collinge <Sharon.Collinge@colorado.edu>

Yes the end of the week would be great. Thank you for taking the time to review.

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916) 278-9448 office**
**3020 State University Drive East**
**Modoc Hall, Suite 2007**
**Sacramento CA 95819**

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**Silveira, Joe** <joe_silveira@fws.gov> Tue, Apr 16, 2019 at 1:30 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Hi Katherine,

I'll sign, scan and send later today-- headed into staff/ safety meeting now.

Joe
~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~

Joseph Silveira
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joe_silveira@fws.gov

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**2 attachments**

**Conflict of Interest Disclosure Form Joe Silveira.pdf**
72K

**SacRiverNWR Location Map 2017.pdf**
1146K

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**Katherine Powelson** <katherine_powelson@fws.gov> Tue, Apr 16, 2019 at 1:37 PM
To: "Silveira, Joe" <joe_silveira@fws.gov>

Thanks it's not urgent

Sent from my iPhone
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<Conflict of Interest Disclosure Form Joe Silveira.pdf>

<SacRiverNWR Location Map 2017.pdf>

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**Sharon Collinge** <Sharon.Collinge@colorado.edu> Tue, Apr 16, 2019 at 1:26 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Great, thanks so much for your patience!

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**Silveira, Joe** <joe_silveira@fws.gov> Wed, Apr 17, 2019 at 1:21 PM
To: Katherine Powelson <katherine_powelson@fws.gov>

Hi Katherine,

I feel I did not provide much input for the Draft Recovery Plan-- just making sure you were aware of some the VELB work and other riparian habitat work occurring at Sacramento River NWR. It's a very big improvement from the original recovery plan. I am not sure what I should include in the Conflict of Interest Disclosure Form, given the current administration. Below, I list my associations with the USFWS and E&T Species, and groups which work on monitoring these species or documenting habitat use or improving habitat which these species use.

Concerning Conflict of Interest:
I am employed by U.S. Fish & Wildlife Service at San Luis NWR Complex (1990-1992) and Sacramento NWR Complex (1992 to present)

**I reviewed the VELB Recovery Plan at the request of the USDOI Solicitor, Washington DC (2000); AND**

**I was contacted and interviewed by phone by a USDOI Solicitor form San Diego/ Carlsbad (?) concerning my opinion why the VELB should be withdrawn from consideration for delisting ( about 2015)- I did not take notes, and I do not recall the Solicitor's name, location, or date, but I'm sure it's somewhere in the record.**

I currently serve on:
USFWS Vernal Pool Ecosystem Recovery Implementation Team (this team has inactive)
Central Valley Joint Venture Riparian Songbird Monitoring & Evaluation Working Group
Bank Swallow Technical Advisory Committee Monitoring & Research Subcommittee
California State University Chico, Department of Biological Sciences Academic Advisory Board (see below VELB graduate thesis work)

I have served on:
California Central Valley Landscape Conservation Cooperative, Central Valley LC Project Development Team (Deserts & Grasslands SubTeam)
USFWS Vernal Pool Ecosystem Recovery Implementation Team Butte County (NE VP Region/ NW VP Region) SubGroup
USFWS Vernal Pool Ecosystem Recovery Team (Technical Member)
Bank Swallow Technical Advisory Committee Organization Subcommittee

**I have served as graduate thesis committee member providing research direction & logical support for:**
**Valley Elderberry Longhorn Beetle (Gilbart 2009 California State University Chico (CSUC), this project also received funding from USFWS CNO (R8);**
Other Fed/State E&T Species (some **collaborated with and/ or were funded by USFWS or USBOR CVPIA**)--
Cordylanthus palmatus (Cloropyron palmatum) (Wright 2000 CSUC; Wingo 2009 CSUC); Yellow-billed Cuckoo-Western DPS (Hammond 2011 CSUC); Tuctoria greenei & Neostapfia colusana (Gottschalk Fisher 2013 CSUC); Bank Swallow (Garcia 2009 CSUC); Greater Sandhill Crane (Shaskey 2012 Sonoma State U)

**I have provided access to various units of Sacramento River NWR for others to conduct VELB surveys/ research, including:**
**Theresa Talley & Marcel Holyoak- Argentine ant recon (mid to late 1990s)**
**Dick Arnold & Robert Jensen- VELB pheromone dosage response study (2012-14)**

While employed by the USFWS, I have given declarations, served as expert witness, and given expert technical review for USDOI Solicitor for:
Federal listing of vernal pool Branchiopods (Building Industry Assoc of Superior Ca... v Bruce Babbitt, Sec Int) - declaration (1996);
Cut & fill destruction of vernal pools at East Grasslands Wildlife Management Area, Snobird Ranch, Merced Co (Toth v USA) - expert witness (1997);
Fill of vernal pools in Sacramento Co (Borden Ranch Partnership... v USACE) - expert witness (1999);
Seismic exploration damage to vernal pools at San Luis NWR, Merced Co (Emeral Trail LLC et al v Gale Norton, Sec Int) - expert technical adviser (2003);
Destruction of riparian habitat (cutting down trees) at Sacramento River NWR Rio Vista Unit, Tehama Co (USA v Lundie) - expert witness (2011)

Please let me know which of the above "associations" and actions are considered a conflict of interest.

Thank you,
Joe
~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~^~

Joseph Silveira
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joe_silveira@fws.gov

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**Sharon Collinge** <Sharon.Collinge@colorado.edu> Mon, Apr 22, 2019 at 3:23 PM
To: "Powelson, Katherine" <katherine_powelson@fws.gov>

Kat,

I've attached here my review of the draft VELB recovery plan and the completed COI form. Please let me know if you have any questions.

Thanks!

Sharon

Sharon K. Collinge

Professor, Environmental Studies Program

Faculty Director, Center for Sustainable Landscapes and Communities

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@CUBoulderCSLC

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**From:** "Powelson, Katherine" <katherine_powelson@fws.gov>
**Date:** Tuesday, March 12, 2019 at 10:34 AM
**To:** Sharon Collinge <Sharon.Collinge@colorado.edu>
**Subject:** Peer Review Request from USFWS

Dear Dr. Sharon Collinge,

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**2 attachments**

**COLLINGE Conflict of Interest Disclosure Form.pdf**
76K

**VELB review, April 2019.pdf**
45K

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**Powelson, Katherine** <katherine_powelson@fws.gov> Mon, Apr 22, 2019 at 3:31 PM
To: Sharon Collinge <Sharon.Collinge@colorado.edu>

Thank you!

**Kat Powelson**
**Science Support Coordinator, Science Applications**
**U.S. Fish & Wildlife Service, Pacific Southwest Region**
**(916) 278-9448 office**
**3020 State University Drive East**
**Modoc Hall, Suite 2007**
**Sacramento CA 95819**

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U.S. Fish & Wildlife Service

# Draft Revised Recovery Plan for

Valley Elderberry Longhorn Beetle
(*Desmocerus californicus dimorphus*)

Photo courtesy of Joe Silviera/USFWS

# Draft Revised Recovery Plan for Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*)

**Region 8**
**U.S. Fish and Wildlife Service**
**Sacramento, California**

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Regional Director, Pacific Southwest Region, Region 8,
U.S. Fish and Wildlife Service

Date: XXXXXXXXXXXXXXXXXX

## Disclaimer

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the U.S. Fish and Wildlife Service (Service), sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the view, official positions or approval of any individuals or agencies involved in the plan formulation, other than the Service. They represent the official position of the Service only after they have been signed by the Regional Director. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new finding, changes in species status, and the completion of recovery actions.

**Literature Citation Should Read as Follows:**

U.S. Fish and Wildlife Service. ~~2018~~2019. Draft Revised Recovery Plan for Valley Elderberry Longhorn Beetle. U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California. iii + 18 pp.

An electronic copy of this draft recovery plan is available at:
https://www.fws.gov/endangered/species/recovery-plans.html

## Acknowledgements

The recovery planning process has benefitted from the advice and assistance of many individuals, agencies, and organizations. We thank the following individuals for their assistance and apologize to anyone whose name was omitted inadvertently from this list:

**Lead Authors:**

Timothy Ludwick, Sacramento Fish and Wildlife Office

**Other Contributors:**

Amber Aguilera, Sacramento Fish and Wildlife Office
Jana Affonso, Bay-Delta Fish and Wildlife Office
John DiGregoria, Bay-Delta Fish and Wildlife Office

## DRAFT REVISED RECOVERY PLAN FOR VALLEY ELDERBERRY LONGHORN BEETLE (*DESMOCERUS CALIFORNICUS DIMORPHUS*)

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## Introduction

This document presents the U.S. Fish and Wildlife Service's (Service) plan for the conservation and recovery of the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). Pursuant to section 4(f) of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.*) (Act), a recovery plan must, to the maximum extent practicable, include (1) a description of site-specific management actions as may be necessary to achieve the plan's goals for the conservation and survival of the species; (2) objective, measurable criteria which, when met, would support a determination under section 4(a)(1) that the species should be removed from the List of Endangered and Threatened Species; and (3) estimates of the time and costs required to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal. This draft revised recovery plan is based on scientific information presented in the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) and the *Proposed Rule; Removal of the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (77 FR 60238, October 2, 2012), which describe the life history and biology of the species, the current status of the species, and the threats that impact the species. Both of these documents are available at https://ecos.fws.gov.

The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) was federally-listed as threatened under the Act on August 8, 1980, and has a recovery priority number of 9, indicating the taxon is a subspecies that is under moderate threat with a high recovery potential (45 FR 52803). The Service designated critical habitat for the species on August 8, 1980.

When listed, the valley elderberry longhorn beetle was known from only 10 records in 3 locations (Merced County, Yolo County, and Sacramento County). Subsequent surveys throughout the Central Valley discovered more locations and the current presumed historical range is now believed to extend from Shasta County to Madera County below 500 feet in elevation (152.4 meters) (79 FR 55874). Although different ranges for the beetle have been proposed in the past, the current presumed range relies only on verifiable sightings or specimens of adult male valley elderberry longhorn beetles (79 FR 55874). Previous iterations of the presumed range used both female sightings and exit holes to determine valley elderberry longhorn beetle presence. Both of these metrics are unreliable as female California elderberry longhorn beetle (*Desmocerus californicus californicus*) and valley elderberry longhorn beetles are indistinguishable in the field and exit holes cannot be accurately assigned to either species (Talley 2005).

Elderberry (*Sambucus* sp.) is the obligate larval host plant for the valley elderberry longhorn beetle. After hatching, the larva creates a feeding gallery (set of tunnels) in the pith at the stem center (Burke 1921, Barr 1991). While only one larva is found in each feeding gallery, multiple larvae can occur in one stem if the stem is large enough to accommodate multiple galleries (Talley et al. 2006). Though rarely observed, adults have been described as feeding on the nectar, flowers, and leaves of the elderberry plant (Arnold 1984, Collinge et al. 2001), or flying between trees (Service 1984).

Previous studies of the beetle (both subspecies) estimated that the larval development period inside the plant is 2 years (Burke 1921, Linsley and Chemsak 1972), but laboratory observations have indicated that the beetle may develop into an adult in a 1-year cycle (Halstead and Oldham 1990). Arnold (1984) reported that females lay eggs singly on elderberry leaves and at the junction of leaf stalks and main stems, with all eggs laid on new growth at the outer tips of elderberry branches.

Because elderberry is the host plant for the beetle, environmental and habitat conditions that favor a robust elderberry community also benefit the beetle. Elderberry is an important component of riparian ecosystems in California (Vaghti et al. 2009). It can be found as an overstory plant or understory plant within these communities. Elderberry also occurs in upland communities such as oak woodland. Occupancy of elderberry by the valley elderberry longhorn beetle is generally low but tends to be highest in riparian communities (Barr 1991, Collinge et al. 2001, Talley et al. 2007).

The valley elderberry longhorn beetle is distributed throughout available habitat in a widely dispersed metapopulation (Collinge et al. 2001, Talley et al. 2006). Metapopulations are defined as a system of discrete subpopulations that may exchange individuals through dispersal, migration, or human-mediated movement (Breininger et al. 2002; Nagelkerke et al. 2002). At local scales, the valley elderberry longhorn beetle occupies elderberry plants in clumps with the largest distance between occupied plants (or clumps of plants) being around 1,968.5-2,624.7 feet (600-800 meters) (Talley et al. 2006). Defining the population at landscape scales is more challenging, but the data suggest that the occupancy status of a particular area of suitable habitat (occupied or unoccupied) is spatially correlated across distances of 6.2-12.4 miles (10-20 kilometers) within the same drainage (Collinge et al 2001). That is, a patch of habitat is more likely to be occupied if there is other occupied habitat within 6.2-12.4 miles (10-20 kilometers). At landscape scales of 6.2 miles (10 kilometers) or less, occupancy appears random (Collinge et al. 2001).

## Recovery Strategy

The known historical range of the valley elderberry longhorn beetle is closely linked to the Great Valley ecosystem (79 FR 55874) of the Sacramento Valley and northern San Joaquin Valley. Research suggests that the valley elderberry longhorn beetle is further constrained by being naturally rare within its habitat. The main cause of the decline of the species has been the loss and degradation of its habitat; therefore, the recovery strategy focuses upon this threat. There has been a significant loss and degradation of riparian and other natural habitats in the presumed historical range of the valley elderberry longhorn beetle, much of which occurred prior to the listing of the species. Katibah (1984) estimated approximately 102,000 acres (41,300 hectares) of riparian forest remained in the Central Valley in 1984, a reduction of about 89 percent from an estimated total of 921,600 acres (373,100 hectares) of pre-settlement riparian forest area. Much of this loss has been driven by agricultural and urban development, and flood control activities throughout the Central Valley. Present day losses of valley elderberry longhorn beetle habitat are much more limited in extent and are often associated with urban development of agricultural areas and the maintenance of levees and other flood control structures. As noted in the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014), ongoing and future maintenance of these levees and other flood control structures may result in additional losses of riparian vegetation and elderberry shrubs. Long-term impacts of levee vegetation management actions may be offset with implementation of mitigation and conservation measures (e.g., establishment of preserves or restrictions on pruning). Although the data are not available to accurately determine the extent of the loss of occupied habitat, the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) summarized the extent of current elderberry habitat (based on 2009 imagery) mapped within the Central Valley, and assessed how these mapped areas conform to the metapopulation structure of the valley elderberry longhorn beetle as defined by species' experts. This preliminary assessment indicated that elderberry habitat remains limited in extent within the Central Valley and may not currently support the spatial requirements of sustainable metapopulations for the valley elderberry longhorn beetle.

Invasive Argentine ants have been confirmed at several locations occupied by the valley elderberry longhorn beetle (Holyoak and Graves 2010). Projections from climate change modeling indicate suitable conditions will occur for Argentine ants to continue to spread in California during the next several decades (Roura-Pascual et al. 2004; Hartley et al. 2006; Roura-Pascual et al. 2011). Studies show that Argentine ants will attack and consume exposed insect larvae and eggs, including those of the valley elderberry longhorn beetle larvae and may even interfere with adult behavior (Way et al 1992; Talley 2014, pers. comm.).

The predation threat from Argentine ants is likely to increase in the Central Valley as colonies further expand into the species' range unless additional methods of successful control within natural settings become available (Choe et al. 2014). Although additional studies are needed to better characterize the level of predation threat to the valley elderberry longhorn beetle from Argentine ants, the best available data indicate that this invasive species is a predation threat to the valley elderberry longhorn beetle, and it is likely to expand to additional areas within the range of the valley elderberry longhorn beetle.

Additional threats such as pesticide use, climate change, and invasive plants may also threaten the valley elderberry longhorn beetle. Most of these additional threats cannot be quantified because there is not enough information known about the ecology of the beetle or the effect the threat may have on the beetle. The *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) provides the most comprehensive summary of all the potential threats to the valley elderberry longhorn beetle. Many of the threats do not act on the beetle in isolation. For example, effects from habitat loss are compounded by potential pesticide effects that may result from having smaller habitat patches immediately adjacent to active agriculture. The recovery strategy focuses on what the Service believes are the largest threats and those actions that have the most ability to provide a concrete path to recovery.

The recovery strategy includes: 1) the establishment of sufficiently large populations throughout the species' range to ensure each population has the resiliency to withstand stochastic events; 2) maintaining the species' current level of representation (genetic and ecological diversity) so it potentially has the capacity to adapt to future environmental changes; and 3) increasing the species' current level of redundancy through the establishment of a sufficiently large number of local- and meta-populations widely distributed throughout the species' range to allow the species to withstand catastrophic events.

We developed the recovery criteria using the concepts described in the species status assessment (SSA) framework (Service 2016). The SSA framework provides a pathway for the Service to consider what the valley elderberry longhorn beetle and elderberry needs to maintain viability by

**Commented [TT1]:** Huxel, G.R. 2000. The effect of the Argentine ant on the threatened valley elderberry longhorn beetle. Biological Invasions 2: 81–85, 2000.

**Commented [TT2]:** It may be worth noting that we don't really know what "sufficiently large" means (make clear that there is uncertainty surrounding this species)

**Commented [TT3]:** With a lack of genetic information on this species, we don't know for sure that current genetic diversity can allow this (but it's all we've got) characterizing the status of the species in terms of its resiliency, representation, and redundancy. Using the concepts of resiliency, representation, and redundancy, we also describe the recovery vision for the species.

Resiliency

Resiliency describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, birth versus death rates and population size. Highly resilient populations are better able to withstand disturbances such as random fluctuations in reproductive rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

For the valley elderberry longhorn beetle to maintain viability, the populations found throughout the Central Valley must be resilient. Stochastic events that have the potential to affect valley elderberry longhorn beetle habitats and, in turn, their populations include drought, flooding, fire, vandalism, and other natural or human-caused disasters. A number of factors influence the resiliency of populations, including survival, dispersal, abundance, and reproduction. Influencing those factors are elements of valley elderberry longhorn beetle habitat that determine the number of individuals a population can support and whether those populations can increase reproductive success and their distribution, thereby increasing the resiliency of the population. These demographic factors and habitat elements are defined below and are shown in Figure 1.

Demographic factors:

Survival – individuals need to survive to a reproductive stage

Dispersal – because of their population structure and the patchy nature of the habitat, individuals need to disperse to find suitable elderberry shrubs to feed, find mates, and deposit eggs

Recruitment – predation and other stressors (e.g., pesticides, road dust) must be low enough and survival rates sufficiently high enough to allow eggs to hatch and larva to enter host plant; and host plant stressors (e.g., water stress, fire) to be low enough to allow larvae to develop into adults

Habitat elements:

~~Elderberry plants~~Elderberry quantity and quality – the valley elderberry longhorn beetle only occurs on elderberry plants. Elderberry density tends to increase ~~with~~ in moist, riparian ecosystems (Talley et al. 2007, Fremier et al. 2009)~~-~~; shrub must be suitable size (≥2 cm diameter stems), and suitable quality (e.g., pith nitrogen concentation; Talley 2007), but details of what constitutes a high quality host plants and patches are still largely uncertain ~~community health~~.

Connectivity – because valley elderberry longhorn beetles have limited dispersal ability, many elderberry plants in reasonably sized ~~-~~patches (10-50-m diameter patches; Talley 2007) that are in close proximity (200-300 m apart; Talley 2007), and without dangerous barriers (e.g.,



**Commented [TT4]:** It's not just density but elderberry suitability, which is largely still uncertain. We don't know what it is about the elderberry that the VELB cue into or what traits provide the best habitat for the VELB so we need to also maintain genetic and environmental diversity of elderberry. "Sufficiently large" elderberry populations or patches, and 'sufficiently large" numbers of suitable habitat patches throughout the range of the beetle… and maintenance of current levels of genetic and environmental representation, are all crucial to overall persistence of a beetle metapopultion, even if unoccupied. (I see that Representation is the next section so maybe put elderberry representation considerations in that section) highways or pesticide use between the patches) -are necessary to support a resilient population of the valley elderberry longhorn beetle

Representation

Representation describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and correlates with the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the higher the likelihood  more capable it is of to adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the number of distinct metapopoulations (e.g., regional populations associated with distinct drainages; Collinge et al. 2001), and the extent and variability of habitat characteristics across the species' geographical range.

**Commented [TT5]:** Or "based on the presence of many"

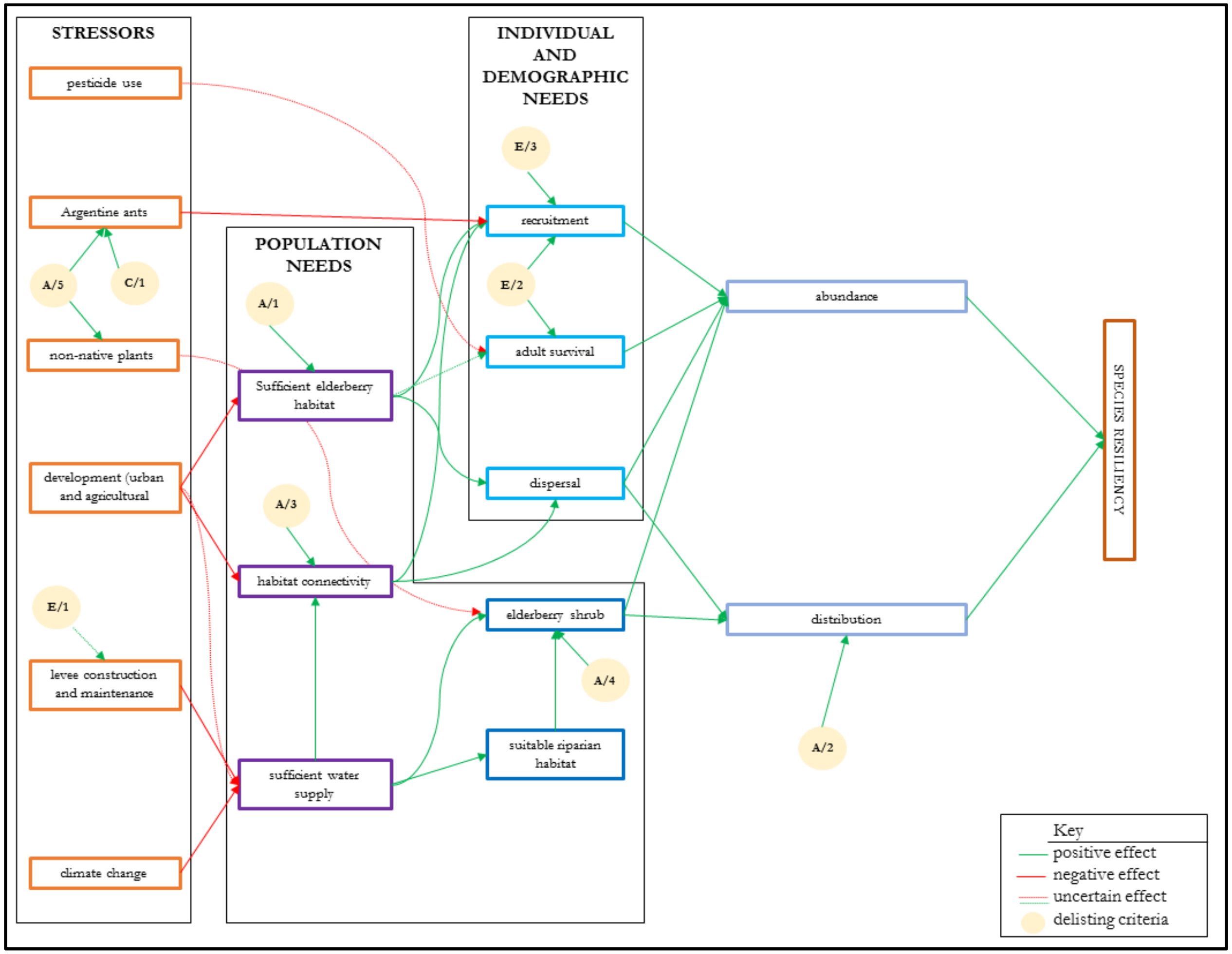

STRESSORS
pesticide use
Argentine ants
A/5
C/1
non-native plants
development (urban and agricultural
E/1
levee construction and maintenance
climate change
POPULATION NEEDS
A/1
Sufficient elderberry habitat
A/3
habitat connectivity
sufficient water supply
INDIVIDUAL AND DEMOGRAPHIC NEEDS
E/3
recruitment
E/2
adult survival
dispersal
elderberry shrub
A/4
suitable riparian habitat
abundance
distribution
A/2
SPECIES RESILIENCY
Key
positive effect
negative effect
uncertain effect
delisting criteria

Figure 1. Conceptual model of the stressors and needs influencing the resilience of the valley elderberry longhorn beetle. Add highways or roadways to stressors because they can inhibit connectivity and eb along roads were more water stressed and had lower nitrogen than those not next to roads (Klasson et al. 2005) Under individual and demographic needs: adult survival should say "Survival to adulthood" because pesticides and many threats may affect larvae as much if not more than adults. Under "Population Needs"; "Sufficient Elderberry Habitat" makes it sound like it's habitat for elderberry. Consider changing to "Elderberry host plant spatial arrangement, quantity and quality."

~~specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the species' geographical range.~~

The level of genetic diversity within and among populations of the valley elderberry longhorn beetle is unknown. Because the valley elderberry longhorn beetle is only found on elderberry, it has likely always been limited to areas of suitable elderberry habitat. Individual shrub occupancy is likely highly stochastic, but the highest quality valley elderberry longhorn beetle habitat (based on occupancy rates) appears to be riparian habitat in the lower alluvial plain (Talley et al. 2007). Valley elderberry longhorn beetle exit holes are generally found on stems that are greater than one inch in diameter, with stems between 0.7 and 4.7 inches accounting for most of the exit hole observations (Talley et al. 2007). Based on these data, habitat restoration, acquisition, and enhancement should focus on riparian communities with a mix of young and mature elderberry shrubs. The habitat should also show signs of natural elderberry recruitment in the form of new saplings or young shoots from established elderberry shrubs. Although the valley elderberry longhorn beetle is found in elderberries in both riparian and non-riparian areas, the selection mechanisms or larger habitat preferences are unknown. Occupancy rates of elderberry in riparian areas are higher, but surveys done in support of several research projects found that most seemingly suitable habitat is not occupied (Barr 1991, Collinge et al. 2001, Talley et al. 2007). It is believed that the valley elderberry longhorn beetle has always been rare with a patchy distribution within its preferred habitat.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of metapopulations across the range of the species, and number of local populations across the range of each metapopulation, as well as each population's resiliency, distribution, and connectivity, redundancy gauges the probability that the species has a margin of safety to withstand, or the ability to bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations).

Current data suggest that the valley elderberry longhorn beetle has populations distributed throughout the entire historical range of the species. However, given the amount of habitat lost historically, it is likely that many populations along river systems have been extirpated. A study completed in 2001 (Collinge et al. 2001) found 6.5% of the sites that were surveyed 6 years earlier showed no continued evidence of valley elderberry longhorn beetle presence. However, current scientific studies have not been conducted with enough consistency to ascertain population trends. Based on the information available, it is presumed that the species has a moderate level of redundancy due to broad range but locally rare occurrence.

Recovery Vision

Long-term viability for the valley elderberry longhorn beetle is envisioned as a high level of resiliency, redundancy, and representation through protection of healthy valley elderberry longhorn beetle populations throughout the suitable habitat found in the Central Valley. These populations are conserved in sufficient number and distribution to shield the species from complete loss from catastrophic events such as widespread, prolonged drought, catastrophic fire, extensive flooding, disease or pest outbreaks, and other natural or human-caused disasters. Additionally, populations are adequately protected from recreational activities and the invasion of non-native plant and insect species.

To delist the species, the valley elderberry longhorn beetle's status will require maintaining at least several self-sustaining metapopulations throughout the historical range in the Central Valley in areas with appropriate habitat. A stable metapopulation is essential to protect the species against local extirpation. It will be challenging to remove or ameliorate all threats to the species (many of the threats, particularly climate change and alteration of hydrologic regimes are difficult to reduce or control). The threat of ongoing loss of habitat in the Central Valley and limited areas for restoration in the southern portion of the range may constrain the populations in that area.

Management Units

Management units are a type of geographic area that can be designated, either with or without recovery units. The management units help organize recovery criteria throughout the range of the species and provide a spatial framework for targeting management actions to specific regions. For the valley elderberry longhorn beetle, three management units have been identified based on watersheds (Map 1). Precipitation varies within each watershed which may influence specific vegetation communities. Each management unit also shows variation in the historical and current development and in the threats to the valley elderberry longhorn beetle.

The management units are:

A. Sacramento River Management Unit
B. San Joaquin River Management Unit
C. Putah Creek Management Unit

Within each management unit, the major river systems correspond to the hydrologic unit code (HUC) 8 subbasin mapping units developed by the United States Geological Survey.

## Recovery Goal

The ultimate goal of this draft revised recovery plan is to outline specific actions that, when implemented, will sufficiently and permanently protect self-sustaining populations throughout the ecological, geographic, and genetic range of the species and reduce the threats to the valley elderberry longhorn beetle to allow for its eventual removal from the Act's protections.

## Recovery Objectives

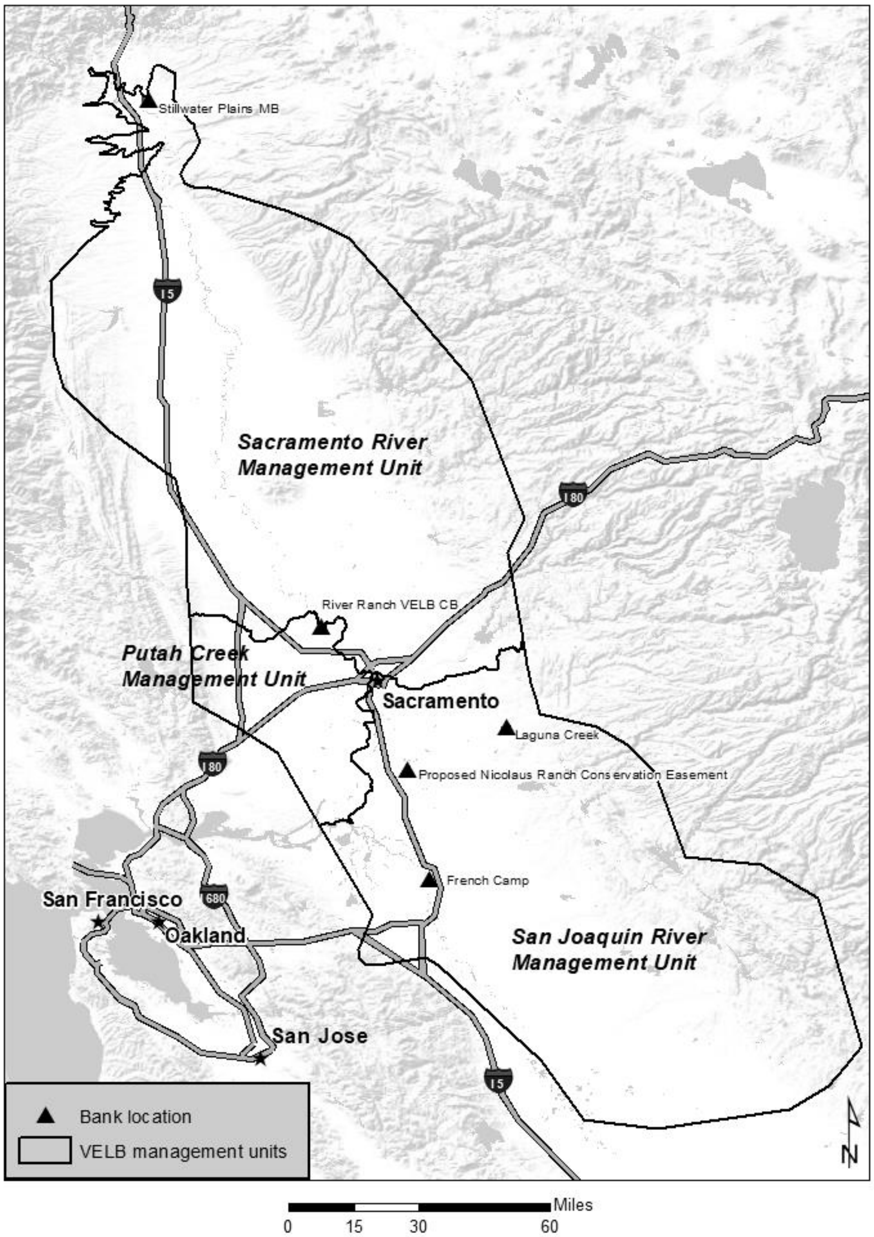
To meet the recovery goal, the following objectives have been identified:

- Maintain resilient populations of valley elderberry longhorn beetle in at least 80% of the HUC8 subbasins within each management unit (Map 1) across the historical range of the species. Because some of the HUC8 subbasins are either small or have limited opportunities for restoration, 80% was deemed an appropriate number that will provide resiliency for the species.

- Protect and manage a system of connected habitat patches along each river or major drainage within each HUC8 subbasin.

**Commented [TT6]:** 80% of the total management area? Or existing or historic riparian corridor area?

**Commented [TT7]:** Would be really good to support this '80%' with some sort of biological/ecological justification.




Map 1. Management units, HUC8 subbasins, and existing conservation banks for the valley elderberry longhorn beetle.

**Commented [TT8]:** Tough to see where or what the HUC8 subbasins are from this map. Please make sure it's clear.

## Recovery Criteria

A threatened species is defined in the Act as a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. When we evaluate whether or not a species warrants downlisting or delisting, we consider whether the species meets either of these definitions. A recovered species is one that no longer meets the Act's definitions of threatened or endangered due to amelioration of threats. Determining whether a species should be downlisted or delisted requires consideration of the same five factors that were considered when the species was listed and which are specified in section 4(a)(1) of the Act.

Recovery criteria are conditions that, when met, indicate that a species may warrant downlisting or delisting. Thus, recovery criteria are mileposts that measure progress toward recovery. Because the appropriateness of delisting is assessed by evaluating the five factors identified in the Act, the recovery criteria below pertain to and are organized by these factors. These recovery criteria are our best assessment at this time of what needs to be completed so that the species may be removed from the Act. Because we cannot envision the exact course that recovery may take and because our understanding of the vulnerability of a species to threats is likely to change as more is learned about the species and the threats, it is possible that a status review may indicate that delisting is warranted although not all recovery criteria are met. Conversely, it is possible that the recovery criteria could be met and a status review may indicate that delisting is not warranted. For example, a new threat may emerge that is not addressed by the current recovery criteria.

### Delisting Criteria

**Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range**

To delist the valley elderberry longhorn beetle, threats to the species habitat must be reduced. This reduction will be accomplished when the following have occurred:

**A/1** Sufficient suitable habitat patches[1] within each management unit (Table 1) should be protected (i.e., voluntary land acquisitions, conservation easements, or other similar mechanisms). Each HUC8 subbasin within the management unit should contain at least 5, 1,640.4-2,624.7 foot (500-800 meter) patches of quality habitat (see A/4). HUC8 subbasins that are small[2] or where only a small portion of the subbasin is in the management area should contain at least 1, 1,640.4-2,624.7 foot (500-800 meter) patch of quality habitat that meets the criteria in A/3.

[1]Suitable habitat for the valley elderberry longhorn beetle is a riparian community with a mix of young and mature elderberry shrubs as well as signs of natural elderberry recruitment in the form of new saplings or young shoots from established elderberry shrubs.

[2]Small subbasins are those that cover less than 100,000 acres within the management unit. There are 9 subbasins that meet this definition.

Table 1. Current Status of the Valley Elderberry Longhorn Beetle and Its Habitat within the Management Units.

| Management Unit | HUC8 Subbasin | # of protected suitable habitat patches (needed/current) | # of occurrences (CNDDB 2018) |
|---|---|---|---|
| Putah Creek | Lower Sacramento | 5/1[1, 2] | 28 |
| | Lower Cache | 1-5/0 | 3 |
| Sacramento River | Sacramento-Lower Cow-Lower Clear | 5/1[1] | 7 |
| | Upper Cow-Battle | 1-5/0 | 0 |
| | Lower Cottonwood | 1-5/0 | 2 |
| | Mill-Big Chico | 5/0 | 0 |
| | Sacramento-Lower Thomes | 5/0[2] | 31 |
| | Upper Stony | 5/0 | 0 |
| | Upper Butte | 5/0 | 0 |
| | North Fork Feather | 1-5/0 | 1 |
| | Middle Fork Feather | 5/0 | 0 |
| | Honcut Headwaters | 5/0 | 0 |
| | Lower Feather | 5/0 | 25 |
| | Lower Butte[2] | 5/0[2] | 10 |
| | Sacramento-Stone Corral[2] | 5/0[2] | 23 |
| | Upper Bear | 5/0 | 0 |
| | Lower Bear | 1-5/0 | 5 |
| | Upper Coon-Upper Auburn | 1-5/0 | 0 |
| | Lower American | 5/0[2] | 35 |
| | North Fork American | 1-5/0 | 5 |
| | South Fork American | 5/0 | 1 |
| San Joaquin River | Upper Cosumnes | 1-5/0 | 0 |
| | Lower Cosumnes-Lower Mokelumne | 5/2[1] | 13 |
| | Upper Mokelumne | 1-5/0 | 1 |
| | Upper Calaveras | 5/0 | 0 |
| | Lower Calaveras-Mormon Slough | 5/0 | 6 |
| | San Joaquin Delta | 5/1[1] | 3 |
| | Upper Stanislaus | 5/0 | 3 |
| | Upper Tuolumne | 5/0 | 1 |
| | Middle San Joaquin-Lower Merced-Lower Stanislaus | 5/0 | 14 |
| | Upper Merced | 5/0 | 0 |
| | Upper Chowchilla-Upper Fresno | 5/0 | 2 |
| | Middle San Joaquin-Lower Chowchilla | 5/0 | 1 |

[1]A conservation bank exists that has been established for the valley elderberry longhorn beetle (Map 1)

[2]This unit contains protected habitat either on a National Wildlife Refuge, mitigation property, or other protected area, but the extent, condition, or management of the habitat is unknown.

**A/2** Valley elderberry longhorn beetles should be present in at least 3 locations within each HUC8 subbasin. Currently 45% of the HUC8 subbasins meet this criterion (Table 1).

Because valley elderberry longhorn beetle populations can show a pattern of short-term colonization and extinction (Collinge et al. 2001), this number ensures that redundant populations of beetles are present in each watershed.

**Commented [TT9]:** Is a location a patch of habitat? Or a particular region within the subbasin. I cant tell how big or where subbasins are other than the list from the table so cant help advise. And maybe explain why 3 was chosen? Even if not totally scientifically based.

**A/3** Protected, clusters of suitable habitat patches within HUC8 subbasins (see A/1) should be no more than 12.4 mi (20 km) from the nearest adjacent protected suitable habitat patch.

**Commented [TT10]:** Make clear the spatial hierarchy. You don't want someone to interpret this as each shrub can be 12 miles apart. Individual shrubs should be 25-50 within reach of each other, these patches can be 200-300 m apart (see Talley 2007) across a landscape area (subbasin??) that then should be no more than 12 miles/20 km( is this what this means?) Does the 12 miles come from Collinge et al? I think she showed very little exchange over those distances (esp if those distances were the distance between 2 different drainages. ) And again, maybe explain where 12 mile/20 km came from.

**A/4** Within the areas of protected suitable habitat, there should be a diversity of elderberry life stages and signs of natural recruitment.

**A/5** All areas of protected suitable habitat need to have comprehensive management plans that maintain habitat values for the valley elderberry longhorn beetle and address potential threats such as Argentine ants, ~~and~~ invasive plants, pesticide and herbicide use, as well as provide for habitat maintenance and enhancement.

Implementation of habitat management plans is expected to also ameliorate threats described such as altered fire regime, vandalism and changes in environmental conditions resulting from climate change.

**Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes**

The overutilization for commercial, recreational, scientific, or educational purposes is not known to threaten the valley elderberry longhorn beetle at this time. Therefore, no recovery criteria have been developed for this factor.

**Factor C: Disease or Predation**

It is believed that Argentine ants may predate valley elderberry longhorn beetle eggs (Huxel 2000). To delist the beetle, Argentine ants should be eliminated or controlled at sites specifically designated for recovery of the valley elderberry longhorn beetle.

**Commented [TT11]:** Betty had a copy of my field and lab notebooks where predation by Argies on the little velb larvae was well documented. I have photos too if you need 'em.

**C/1** A control or eradication program for ~~argentine~~ Argentine ants should be implemented at each bank or other conservation area that has been established to support recovery of the valley elderberry beetle.

Control is considered achieved when the population of Argentine ants on a site is not appreciably affecting valley elderberry longhorn beetle recruitment.

**Factor D: Inadequacy of Existing Regulatory Mechanisms**

The inadequacy of existing regulatory mechanisms is not known to threaten the valley elderberry longhorn beetle at this time. Therefore, no recovery criteria have been developed for this factor.

Agencies continue to consult with the Service under the Act. To date, consultations under the Act have resulted in many protected habitat sites for the valley elderberry longhorn beetle.

**<u>Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence</u>**

Other natural or manmade factors believed to affect the continued existence of the valley elderberry longhorn beetle: changes in hydrology from water management, changes in environmental conditions resulting from climate change, trampling and vandalism of the host plant, road construction, pesticide and herbicide overspray from adjacent agriculture (79 FR 55874). To delist the valley elderberry longhorn beetle, these threats must be reduced. This reduction will have been accomplished when the following have occurred:

Commented [TT12]: I should've noted this above. Elderberry is very sensitive to glyphosate (RoundUp)

**E/1** Water flows are sufficient to promote healthy elderberry and riparian habitats at all sites identified in A/1. Healthy habitats are those that have a diverse native plant community and show recruitment and multiple age classes of elderberry shrubs.

**E/2** At least 2 of the locations in A/2 show long-term population viability. For the purpose of recovery, long-term is defined as at least 10 years.

The 10 year time frame is long enough to account for short-term colonization and extinction (Collinge et al. 2001) and encompasses years with average, above-average, and below-average rainfall conditions. The populations must demonstrate the ability to survive both precipitation extremes.

**E/3** In order to maintain resiliency, the populations identified in A/2 should have 2-3 recent exit holes/1,076.4ft$^2$ (100m$^2$) of elderberry habitat.

Density information is based on Talley (2005) from areas along Putah Creek and the American River with known long-term persistent populations.

## Recovery Actions

The actions identified in Table 2 below are those that, based on the best available science, the Service believes are necessary to move towards the recovery and delisting of the valley elderberry longhorn beetle.

Priority numbers are defined per Service policy (Service 1983) as:

Priority 1: An action that must be taken to prevent extinction or to prevent a species from declining irreversibly.

Priority 2: An action that must be taken to prevent a significant decline of the species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery of the species.

**Table 2.** Recovery actions and estimated costs.

| Recovery Action | Criteria Addressed | Priority Number | Estimated Cost |
|---|---|---|---|
| 1. Acquire, enhance, restore, and protect suitable habitat for the valley elderberry longhorn beetle. This action involves land acquisition, habitat management, and site improvements. | A/2, A/4, A/5 | 1 | $100,000/HUC8 Subbasin[1]<br>Total: $3,300,000[2] |
| 2. Develop management and monitoring plans for protected riparian areas that consider the threats and needs of the valley elderberry longhorn beetle. Plans should include status and demographic monitoring, non-native predator control, habitat enhancement, and other needed activities that may increase the resilience of the valley elderberry longhorn beetle. | A/1, A/2, A/3, A/4 | 1 | $30,000/HUC8 Subbasin[1]<br>Total:$990,000[3] |
| 3. Include valley elderberry longhorn beetle conservation as a component of state and local programs to protect riparian habitat. | A/1, A/2, A/3, A/5, E/1 | 3 | --- |
| 4. Complete studies that focus on: habitat patch size, elderberry density, and connectivity that influence the viability of individual valley elderberry beetle populations; influences on demography and reproductive rates of the valley elderberry longhorn beetle; and factors that influence or limit adult dispersal. | E/2 | 3 | $50,000 |
| 5. Conduct surveys for the valley elderberry longhorn beetle in each HUC8 subbasin to monitor and assess the health of known populations and to locate new populations. | A/2, E/3 | 2 | $100,000 |
| **Total Estimated Cost** | | | **$4,400,000** |

[1]There are 33 HUC8 subbasins within the range of the valley elderberry longhorn beetle.
[2]The total cost assumes that acquisition of 5 habitat patches in each subbasin is not required because there are already existing habitat patches that are suitable for the valley elderberry longhorn beetle that the Service is unaware of or that only need adequate management plans.
[3]The total cost assumes that many existing management plans require only minor updates to address valley elderberry longhorn beetle conservation.

## Estimated Time and Cost of Recovery Actions

The estimated cost of completing the recovery actions such that the criteria have been met and the species may be considered for delisting is $4,400,000. We estimate that these actions could be accomplished by 2050, assuming that only limited areas of suitable habitat have adequate protection. Several factors contribute to the long estimated time to reach the delisting threshold. Although, many presumed extant populations of the valley elderberry longhorn beetle are known from throughout the range, none have been monitored with enough frequency to determine long-term viability. Additionally, although several areas along the Central Valley river systems are under varying levels of protection, not all of them have adequate considerations for the valley elderberry longhorn beetle. Recovery actions place an emphasis on acquiring, maintaining, and protecting suitable, connected habitat for the valley elderberry longhorn beetle. In addition to specific preserves managed for the protection of the valley elderberry beetle, riparian restoration is occurring throughout the Central Valley that may contain suitable habitat for the valley elderberry longhorn beetle. Partnerships between federal, State, and non-governmental partners may significantly decrease the time needed to achieve the delisting criteria.

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# SCALING RIPARIAN CONSERVATION WITH RIVER HYDROLOGY: LESSONS FROM BLUE ELDERBERRY ALONG FOUR CALIFORNIA RIVERS

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*Abstract:* Conservation frequently requires the preservation or restoration of ecosystems in human-altered landscapes. Understanding these ecosystems requires matching patterns with processes at appropriate scales. On floodplains this necessitates coupling plant distributions with fine- and broad-scale hydrologic patterns. This is particularly important when target species are of conservation concern, such as the blue elderberry (*Sambucus mexicana*). Blue elderberry is the sole host plant for the federally threatened Valley elderberry longhorn beetle, yet controls on the shrub's distribution have largely been untested. We used nested hierarchical analyses to test hypotheses about the role of broad- and fine-scale variables structuring the distribution of elderberry in one undammed and three dammed rivers in California's Central Valley (USA). Elderberry presence across the floodplains was primarily driven by broad-scale hydrologic regime, as represented by the relative elevation, floodplain width, and lateral distance of shrubs from the stream, and secondarily by sediment texture and topography. The patchy spatial distributions of elderberry were similar among the rivers, but habitat quality characteristics (i.e., controls on abundance and size) were driven by divergent variables with high stochasticity. We can improve our understanding of species distributions and outcomes of recovery efforts by scaling floodplain conservation efforts to broad-scale hydrologic patterns and by detecting crucial variables using a multi-scale methodology. Within these relatively large, self-defined landscape units, certain precautions and the application of an adaptive management approach could be employed to address the local-scale uncertainty in large-scale conservation efforts.

*Key Words:* Central Valley, floodplain restoration, hydrology gradients, patch hierarchy, riparian, species recovery, Valley elderberry longhorn beetle

## INTRODUCTION

In systems with strong physical controls, the disturbance processes that influence species distributions are confounded by spatial scale (Ricklefs 1987) and alterations of historically natural conditions (Poff et al. 1997, Didham et al. 2005). In particular, the timing and magnitude of peak flow events on rivers around the world have been altered by dam construction and floodplain constriction (Dynesius and Nilsson 1994, Poff et al. 1997). Modified flow regimes have, in turn, changed adjacent riparian systems (Nilsson et al 1997), thereby complicating the management and conservation of these areas. Much riparian vegetation research focuses on lower riparian species, such as cottonwood and willow, which are more obviously constrained by gradients in flood magnitude, duration and frequency – with anoxia/scour setting lower limits in relative elevation and water availability (including ground water) setting upper limits (Mahoney and Rood 1998). In upper riparian areas the effects of hydrology on vegetation may be less obvious and therefore more uncertain (Tabacchi et al. 1998).

In an effort to elucidate hydrology-upper floodplain relationships, we tested the influences on blue elderberry (*Sambucus mexicana*, hereafter ''elderberry'') distributions along four rivers in California's Central Valley (U.S.A.), where it is a facultative riparian shrub. Elderberry is of particular importance in this region because it is a major component of ongoing restoration and mitigation, and may be experiencing regional declines in recruitment associated with damming (Vaghti et al. 2009) Elderberry provides habitat for a diversity of bird and insect species (Martin et al. 1951), including serving as the sole host for the federally threatened *Desmocerus californicus dimorphus* (Valley elderberry longhorn beetle) (USFWS 1980, 1999). Previous studies

Table 1. Variables used to assess the effects of landscape abiotic, local abiotic, and biotic variables on elderberry presence, abundance, and condition. All abiotic variables were calculated using ArcGIS 9.

| Variable | Definition |
|---|---|
| Landscape abiotic | |
| 1) Elevation | Elevation above mean sea level (m) |
| 2) Relative elevation | Vertical height (m) from each GIS grid cell to the low-flow water surface level (negative values indicate standing water). The water surface elevation was interpolated over each entire study reach using the inverse distance weighted (IDW) method. |
| 3) Lateral distance from channel | Euclidean distance (m) from each grid cell to the river channel edge. |
| 4) Floodplain width | Euclidean distance (m) between the levees on both sides of the river. Levees were visually determined from the DOQQs. |
| 5) Soil particle size | Percent of particles retained on a 72 μm mesh sieve, the cut off between fine sand (and coarser particles) and very fine sand (and silt and clay) (SSURGO). |
| Local abiotic | |
| 6) Heat Index | The heat index of each grid cell based on local aspect, slope and latitude (McCune and Keon 2002). |
| Landscape biotic | |
| 7) Vegetation architecture | Using the GIS vegetation data layer, three canopy cover classes were delineated: 1 = open (< 10% cover), 2 = sparsely wooded (10–49% cover), 3 = wooded (50–100% cover). |
| Local biotic | |
| 8) Canopy cover | The percent of elderberry shrub canopy covered by overstory visually estimated as 0, 1–25, > 25–50, > 50–75, > 75–100%. |
| 9) Shrub cover | The percent of elderberry shrub canopy and stems intertwined with other freestanding plants visually estimated as 0, 1–25, > 25–50, > 50–75, > 75–100%. |

revealed that the size or maturity, density, and connectivity of elderberry shrubs strongly affect the beetle's presence (Collinge et al. 2001, Talley et al. 2007). As with many plants that are targets of restoration (Zedler et al. 2003), elderberry has highly variable survival rates when seeded or planted (Holyoak et al., unpublished data), illustrating our lack of understanding about its habitat requirements. Since reference sites are not required for mitigation, little information exists on the controls of elderberry in remnant natural areas in this region, especially processes acting over between-site scales.

On alluvial river floodplains, as in other physically structured systems, broad-scale abiotic gradients are thought to coarsely control species distributions, while patches of finer-scale biotic and abiotic processes structure local occurrences (Keddy 1991, van Coller et al. 2000, Dixon et al. 2002). Variables traditionally associated with gradients and patches may, however, behave unexpectedly (Talley 2007). We therefore used both gradient (Whittaker 1975, Keddy 1991) and patch hierarchy (Wu and Loucks 1995) frameworks to resolve controls on elderberry distributions in four typical alluvial floodplains in California's Central Valley. Gradient analysis tested the effects that river-influenced variables (relative elevation, soil texture) had on elderberry presence across the riparian corridors (Keddy 1991). Hierarchical patch analysis determined both the spatial distribution patterns of elderberry within the riparian corridors, and the variables correlated with those patterns (O'Neill et al. 1989, Wu and Loucks 1995, Talley 2007).

We examined whether the same environmental variables were key to elderberry distributions along each river, which differed in land use history, geology, flow regulation (including one largely unimpounded river), and floodplain hydrologic regimes (inferred from average floodplain width, lateral distance from channel, and relative elevation, which are all often-used, proximate variables for sub-surface and ground-surface hydrology – Table 1) (Turner et al. 2004). We tested three hypotheses about mechanisms controlling the presence, abundance, and size, or age, of blue elderberry in the four alluvial floodplains. 1) We expected elderberry distribution would be predominantly affected by water limitation (Nilsson et al. 1993) and competition for light with tree species (Crane 1989 a,b, Nilsson et al. 1989) due to the fact that upper floodplains have lower inundation frequency, magnitude, and duration than lower floodplains (Blom and Voesensk 1996). We used cover of associated woody species to test for competition,

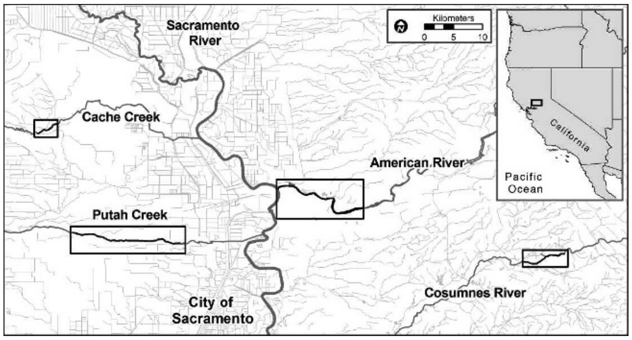


Figure 1. Site map of the riparian study sites in California's Central Valley. Each study reach is a low gradient, alluvial river. Each floodplain has levees setback from the river channel.

and relative elevation to reflect flood inundation frequency and magnitude, and access to ground water. Relative elevation is often used to express hydrologic gradients since it reflects the frequency, duration, and magnitude (depth) of flooding, and correlates with depth to the water table (Turner et al. 2004, Greco et al. 2008). 2) Upon observing the predominant effect of hydrology on elderberry presence, we then predicted that within the relative elevation gradient of all rivers, the presence of elderberry is influenced by light availability (vegetation canopy cover) and local abiotic factors (sediment type, topography). 3) Finally, we predicted that elderberry shrub distribution patterns are dispersed (i.e., not aggregated), with shrub abundance and age controlled by similar local biotic and abiotic variables (canopy cover, topography, and sediments) across rivers.

## METHODS

### Study Sites

We selected river reaches in four lowland rivers in California's Central Valley to encompass variability in conditions, and conducted surveys of all elderberry shrubs in the spring and summer 2002–2004 (Figure 1). We sampled 12 km and 1622 shrubs on the American River Parkway, 13 km and 1350 shrubs on Putah Creek, 2 km and 136 shrubs on Cache Creek, and 3 km and 189 shrubs on the Cosumnes River. The flows on three of the four streams are regulated, while the Cosumnes River is the largest river on the west slope of the Sierra Nevada without a major dam. We selected the study reaches because they were publicly accessible and because they have vegetation assemblages and surrounding land use types that are typical of riparian corridors in this region.

### Field Data Collection

Geographic coordinates (~ 1 m accuracy), maximum basal diameter (MBD), and local biotic variables – percent cover of associated vegetation growing above (canopy) and within (other shrub) the elderberry canopy (Table 1) – were recorded at all encountered shrubs within each reach (Table 1). The basal diameter of the largest main stem of the shrub (cm) reflected shrub age (unpublished data). Shrub abundance was calculated as the number of shrubs within each elderberry aggregation (see patch delineation section).

### Digital Data Calculations

Landscape abiotic variables include relative elevation, lateral distance from the channel, floodplain and channel widths, and soil texture (Table 1) and were defined as such because they vary over $\geq 30$ m$^2$ scales. Most landscape variables were estimated by sampling U.S. Geological Survey 30 m digital elevation models (DEM) and visual interpretation of orthophoto quarter-quadrangles (DOQQ) provided by California Spatial Information Library (CaSIL 2005). Channel width was measured from the 1997 DOQQ at base flow (reach average). Soil particle size was obtained from the Natural Resource Conservation Service database (NRCS 2006) and was expressed as the percent of soil retained in 72 µm mesh, which is the cutoff between very fine sand and fine sand (Table 1). The NRCS dataset provided a general representation of soil character at a coarse resolution (1:24,000 scale) from which we calculated the majority sediment type at a 30 m resolution. The local abiotic variable was heat index (a composite calculation using slope, aspect, and latitude; McCune and Keon 2002) and was calculated for each 30 m cell from the DEM (Table 1).

The landscape biotic variable, vegetation architecture (1 = open; 2 = sparsely wooded cover, such as savannah or live oak woodland; 3 = wooded cover or forested; Table 1), was available only for the American River and Putah Creek from geographic information system (GIS) layers provided by local sources (Sacramento County Parks and Talley unpublished data). All calculated variables were spatially joined to each shrub occurrence using the nearest neighbor method. We completed all spatial analyses in ArcGIS version 9.0 (Table 1) (ESRI 2004).

### Environmental Gradient Controls on Elderberry Presence

We tested for differences in environmental variables across rivers and between the elderberry-occupied and unoccupied cells within rivers using principal components analysis (PCORD – McCune and Mefford 1999). Co-linearity was relatively high between the variables, which are inherently related to river hydrology and geomorphology, even after treatment to remove dependence. PCA transforms variables into components, or new, uncorrelated variables, so it was useful for these analyses (Quinn and Keough 2002). Each sample point represented a $30 \times 30$ m cell of floodplain (presence and absence). We took a random subset of the absence data from the American River cells to reduce the size of the data matrix. The data matrix was relativized by the maximum and power transformed to normalize the data structure and homogenize the variances. The resultant scores on the first three principal components were recorded for elderberry presence and absence along each river. These scores were averaged and the standard deviations calculated for display.

Since the suite of variables reflecting floodplain hydrology (relative elevation, floodplain width, and lateral distance from river) was important in explaining elderberry presence/absence in most (but not all) of the comparisons, we tested the extent to which these variables influenced elderberry frequency across the floodplain. We plotted a frequency distribution of the proportion of 30 m grid cells within each 1 m relative elevation class that contained elderberry shrubs. The likelihood that the curves were significantly different than those obtained by chance were tested with G-tests calculated in Microsoft Excel.

Since important processes change along gradients (Menge 1976), we tested whether the other variables were acting along this hydrologic gradient (gradient inferred from relative elevation). The continuous 1 m relative elevation values were classified into three relative elevation ranges that corresponded with lower and upper distributional limits and the middle distributional range of elderberry to determine controls on the distributions of elderberry along the relative elevation gradient. Because elevation values varied with each river, relationships between elderberry presence/absence and the environmental variables within each relative elevation range were tested for each floodplain using a forward stepwise multiple logistic regression.

Regressions were performed using JMP (SAS 2004), with criteria of $p \leq 0.25$ to enter the model and both $p > 0.05$ and $R^2 < 0.05$ to be removed. Before analysis, all environmental variables were $\log_{10}$ transformed to normalize data and ensure homogeneity of variance. Colinearity between predictor variables was analyzed using simple regressions ($p < 0.05$). If two variables co-varied, the effect of the stronger variable or the one that made the most ecological sense (X) was removed from the other (Y) by regressing them against each other and using the residuals in the multiple regression analyses (Graham 2003). Linearity of relationships between elderberry presence/absence and the transformed environmental variables (Table 1) also was confirmed before analysis using simple regressions in JMP. Post-hoc power analyses were performed using G-Power 2.1.2 (Erdfelder et al. 1996) to test the statistical power of comparisons, or the probability that non-significant results were real and not due to a lack of sufficient replication. The effect size, or the magnitude of the differences detected by the power analysis, was defined as "large", "medium" or "small," with a medium effect size defined as the average size of observed effects in various fields (*sensu* Cohen 1992). All tests examining relationships between environmental variables and elderberry presence/absence were able to detect small to medium effects ($\beta \geq 0.96$), except for Cache Creek's $> 5$ m relative elevation class, which had too few replicates to even detect large effects.

### Elderberry Spatial Distribution and Patch Delineation

Elderberry spatial autocorrelation, or the spatial scales over which elderberry shrubs aggregated, were identified using Moran's I test for spatial autocorrelation in ArcGIS calculated across the range of distance intervals, from 10 to 10,000 m in progressively large intervals (25, 100, 200 m). Moran's I statistic ranges from about $-1$ to $+1$ (although values may exceed this range), where values approaching $+1$ indicate positive spatial autocorrelation (clustering), those approaching $-1$ indicate an evenly spaced distribution, and those around 0 indicate no distributional patterns. A peak of autocorrelation was considered an 'aggregation' at Moran's I $\geq 0.5$ with a $p \leq 0.05$. These aggregations, or patches, were used as the ecological units (Jax et al. 1998) in analyses to reduce effects of shrub spatial autocorrelation (Fortin et al. 1989). Patches of each significant scale were created in ArcGIS by drawing Thiessen polygons around the centroid of each group of elderberry shrubs that occurred at the significant distances away from each other (ESRI 2004). Within these polygons, environmental variables were either averaged or summed.

### Patch Hierarchy Analysis of Elderberry Abundance and Size

The environmental variables used to explain elderberry abundance and size/age included the

Table 2. Landscape and local variable statistics for 30 m grid cells that were occupied by elderberry shrubs across the entire floodplain of each river (See map in Figure 1). Data were collected during spring and summer 2002–2004. Shrub frequency = # 30 m grid cells occupied by elderberry shrubs / total # grid cells. MSL = mean sea level.

| | American River | | Cache Creek | | Cosumnes River | | Putah Creek | |
|---|---|---|---|---|---|---|---|---|
| Elderberry Shrub Frequency | 15% | | 10% | | 10% | | 6% | |
| | Avg | ± 1SD | Avg | ± 1SD | Avg | ± 1SD | Avg | ± 1SD |
| Elderberry shrub density (# of 30 m cells) | 3.0 | 2.3 | 2.1 | 1.4 | 1.7 | 1.1 | 1.4 | 4.6 |
| Landscape abiotic | | | | | | | | |
| 1) Elevation (m) | 40 | 13 | 108 | 6 | 134 | 6 | 49 | 10 |
| 2) Relative elevation (m) | 3 | 2 | 4 | 2 | 4 | 2 | 9 | 3 |
| 3) Lateral distance (m) | 225 | 169 | 80 | 71 | 116 | 50 | 58 | 40 |
| 4) Floodplain width (m) | 645 | 236 | 515 | 104 | 346 | 105 | 184 | 54 |
| Local abiotic | | | | | | | | |
| 5) Slope (degrees) | 1.2 | 1.4 | 1.3 | 2.0 | 1.1 | 1.3 | 3.4 | 2.0 |
| 6) Aspect (degrees) | 194 | 114 | 157 | 76 | 213 | 71 | 149 | 129 |
| 7) Soil part. size (% ≥72 μm) | 68 | 9 | 40 | 26 | 69 | 9 | 47 | 29 |
| Landscape biotic | | | | | | | | |
| 8) Vegetation architecture | 1.03 | 0.95 | n/a | n/a | n/a | n/a | 0.90 | 0.90 |
| n (grid cells / river) | 12, 971 | | 1,064 | | 1,073 | | 2,139 | |

landscape and local abiotic variables, and the local biotic variables (Table 1). These variables were $\log_{10}$ transformed, treated for co-linearity and tested for linearity as described above for the variables predicting elderberry presence. Relationships between the environmental variables and both the abundance of elderberry in and average maximum basal diameter of each patch were explored using forward, stepwise multiple regressions as described above. These analyses were carried out for each elderberry patch level within each river. Power analysis (Erdfelder et al. 1996) revealed that tests between these elderberry variables and environmental variables were able to detect medium sized effects on within patch scales and medium to large effects on between patch scales ($\beta \geq 0.96$).

## RESULTS

### Drainage-wide Patterns of Elderberry Distribution

Elderberry occupied ~ 15% of all cells on the American River floodplain, 10% on the Cosumnes River and Cache Creek floodplains, and 6% on the Putah Creek floodplain (Table 2). The highest-occupancy floodplain, the American River, differed from the other floodplains in variables reflecting a wide floodplain hydrology. The lowest occupancy habitat, Putah Creek, differed from the other rivers by having finer soil textures (Figure 2). When the four rivers were organized by the measured environmental variables in multivariate space, the first three principle component axes aligned with the following variables: Axis 1) floodplain hydrology, inferred from floodplain width, lateral distance, and relative elevation (PCA Axis 1, eigenvector r = 0.54, 0.60, 0.53, respectively), Axis 2) soil grain size (r = 0.82), and Axis 3) heat index (not shown, r = −0.91) (Table 3). The cumulative variance among sites accounted for by the first three axes was 40.4, 23.7, and 18.8%, respectively (82.9% total).

PCA performed on individual rivers showed that variables reflecting a wide-floodplain hydrology, coarser soil textures, and heat index correlated with elderberry presence along all rivers (i.e., variables correlated with Axes 1 and 2, explaining 62–71% of

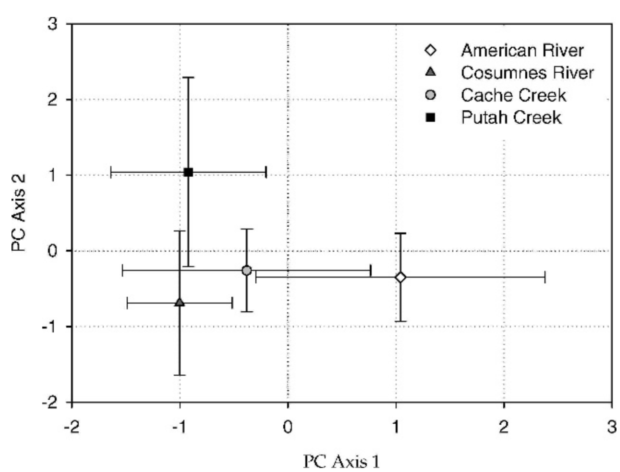


Figure 2. The mean coordinate scores for the first two principal components representing environmental conditions of each river plotted with standard deviations. The first axis corresponds best to variables that reflect floodplain hydrology and second to soil particle texture and heat index.

Table 3. Results of principal components analysis (PCA) showing environmental variables influencing elderberry presence vs. absence within each of four floodplains. Values are eigenvector r values for each of the first three axes and percent of variance between elderberry-occupied and uninhabited 30 m cells explained by variables.

| | American River | | | Cache Creek | | | Cosumnes River | | | Putah Creek | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC1 | PC2 | PC3 | PC1 | PC2 | PC3 | PC1 | PC2 | PC3 |
| Lateral distance | **0.55** | 0.15 | −0.27 | 0.13 | −0.01 | 0.18 | 0.13 | **−0.62** | **−0.71** | **0.61** | −0.20 | 0.02 |
| Floodplain width | **0.50** | −0.07 | 0.33 | **0.52** | 0.26 | **0.59** | **0.52** | 0.39 | 0.06 | 0.24 | **−0.69** | **−0.57** |
| Relative elevation | **0.50** | −0.15 | **−0.65** | **0.61** | −0.11 | −0.35 | **0.61** | −0.20 | 0.07 | **0.57** | 0.17 | 0.27 |
| Soil texture | **0.47** | −0.02 | **0.63** | **0.55** | **−0.65** | −0.37 | **0.55** | −0.24 | 0.29 | **0.48** | 0.25 | 0.13 |
| Heat index | 0.04 | **0.98** | −0.02 | 0.21 | **0.71** | **−0.61** | 0.21 | **0.61** | **−0.63** | 0.12 | **0.62** | **−0.76** |
| % variance explained | 42 | 20 | 15 | 47 | 24 | 14 | 39 | 26 | 17 | 42 | 22 | 18 |

variance in elderberry presence/absence; Table 3). Environmental differences between elderberry occupied and unoccupied areas on the two smaller rivers (Cache and Putah Creeks- Axis 2, Table 3), however, were likely not significant (Figure 3).

Elderberry shrub frequency (vs. presence/absence) was influenced by variables reflecting floodplain hydrology, in particular relative elevation. Elderberry shrubs were more frequent at intermediate than lower or higher relative elevations (Figure 4A). The

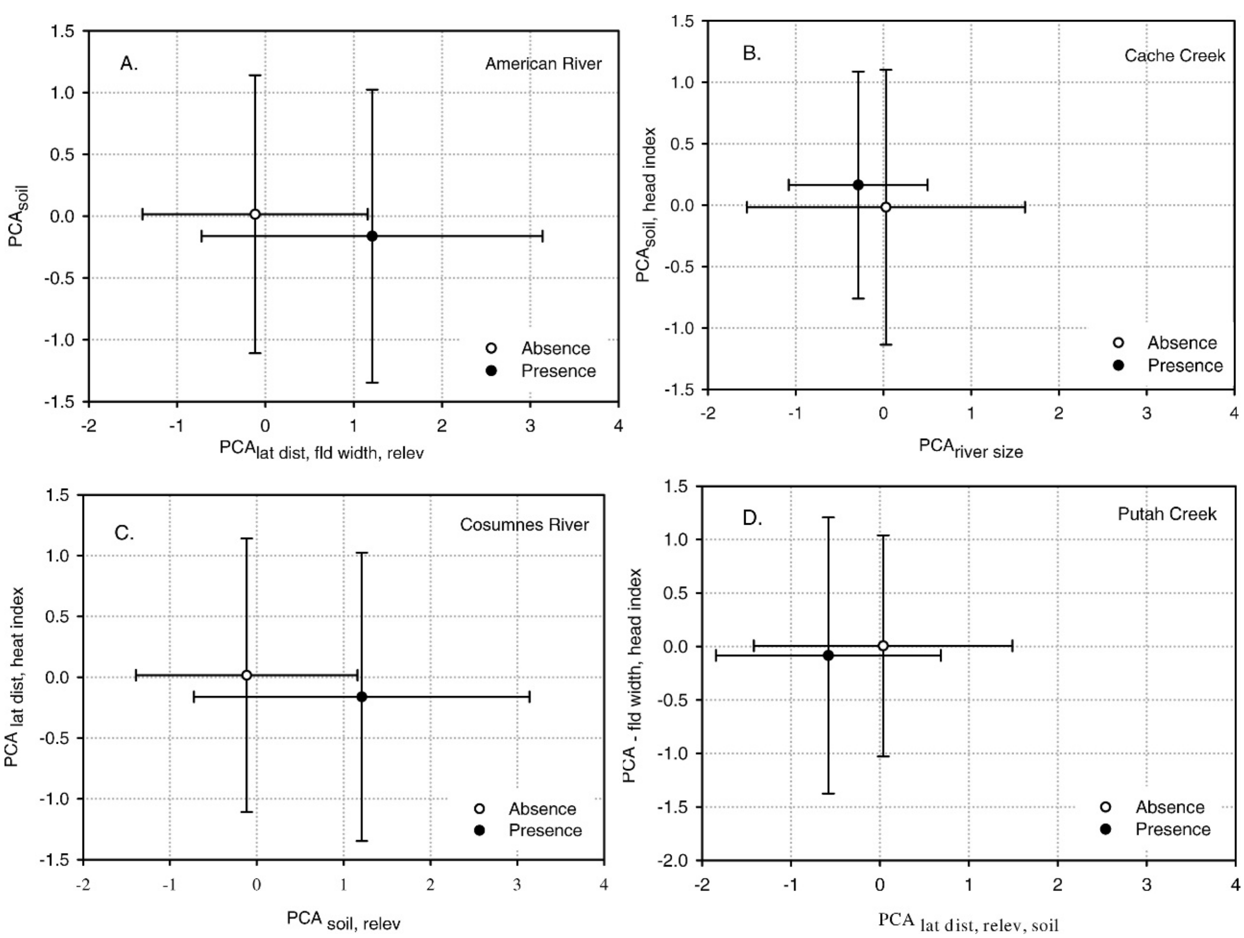


Figure 3. The mean coordinate scores for the first two principal components representing environmental conditions of elderberry-occupied and uninhabited areas along the A) American River, B) Cache Creek, C) Cosumnes River, and D) Putah Creek. Black symbols indicate presence, and hollow symbols absence. The first axes generally correspond best to variables that reflect floodplain hydrology and the second axes generally correspond best to soil coarseness and heat index although there is overlap (see Table 3 for variables and eigenvectors).

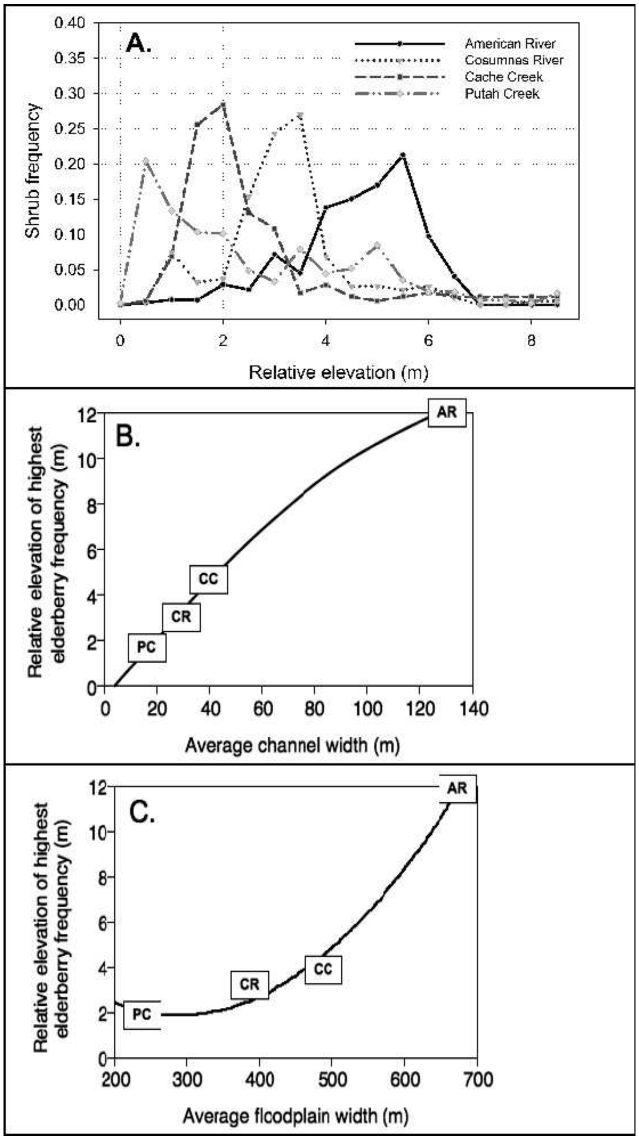


Figure 4. A) The relationship between relative elevation and elderberry shrub frequency (proportion of 30 m grid cells that contain elderberry within each 1 m relative elevation class) for four rivers. N= 14,937 grid cells for the American River (AR), 1,166 for Cache Creek (CC), 2,274 for Putah Creek (PC) and 1,183 for Cosumnes River (CR). B) The relationship between average river channel width and the relative elevation of the peak frequency of elderberry. The best fit curve represents the potential relationship ($Y = 4.00\times10^{-4} X^2 + 0.11 X + 0.40$, $p = 0.030$, $R^2 = 0.99$). C) The relationship between average floodplain width and the relative elevation of the peak frequency of elderberry. ($Y = 6.96\times10^{-5} X^2 + 0.02 X - 6.06$, $p = 0.080$, $R^2 = 0.99$).

relative elevation at which the peak frequency of elderberry was found in each of these rivers increased with river size, as reflected by average channel width (Figure 4B). This unimodal relationship may account for the weak relationships between floodplain hydrologic variables and elderberry presence/absence observed with the PCA, which assumes linear relationships. In addition, these frequency peaks correlated with floodplain width (although only significant at $p = 0.08$; Figure 4C) – most likely due to lower channel slopes along wider floodplains and, therefore, increased inundation frequency and duration. The non-significant relationship may be because floodplain width is not necessarily a good indication of inundation since the floodplain is often anthropogenically modified.

### Elderberry Distribution along Relative Elevation Gradients

In areas with the lowest and intermediate relative elevations, which generally tended to be closer to the channel, the likelihood of elderberry shrub presence still generally increased with variables reflecting wide-floodplain hydrology (wider floodplains and further lateral distances from the channel; Table 4). These relationships were especially strong along the unrestricted Cosumnes River (Table 4). In the high relative elevation areas, neither the biological nor abiotic variables significantly affected elderberry presence (the non-significant relationship in Cache Creek was likely due in part to low shrub number; Table 4). The exception was along the highly incised Putah Creek where shrubs were more likely on wider and/or flatter areas and at shorter lateral distances from the creek in all relative elevation classes (i.e., variables reflecting water limitation). Except for the Cosumnes River, relatively little variance in elderberry shrub presence was explained ($\leq$ 17%). In addition, relationships between elderberry presence and environmental variables were often weaker within the intermediate, preferred relative elevation classes than in the non-optimal floodplain elevations.

### Local Patches of Elderberry

*Elderberry Spatial Autocorrelation Patterns.* Elder-Elderberry density distributions were spatially autocorrelated within floodplains requiring that we use "naturally defined" patches as ecological units in our subsequent analyses to meet statistical assumption of independent replicates (Fortin et al. 1989, Jax et al. 1998). These elderberry patches had similar spatial structure over all floodplains, with areal extents of 25–50 m in three of the four floodplains and 50–75 m in one floodplain (Cache Creek) (Figure 5; see Fortin et al. 1989 for interpretation of correlograms). The distances between patches somewhat varied with patches located 300–400 m

Table 4. Results of forward, stepwise, ordinal, multiple regressions revealing the variables influencing elderberry presence across the relative elevation gradient within each floodplain. Relative elevation classes were determined by natural breaks in elderberry frequency (see Figure 2). ± = direction of relationships in terms of increased or decreased chance of presence, N.S. = not significant at sequential Bonferroni adjusted alpha values of ≤ 0.05, n = number of 30 m grid cells, n/a = not applicable.

| | | | |
|---|---|---|---|
| **American River** | | | |
| Relative elevation class: | ≤ 3.5 m | 3.5–10.5 m | > 10.5 m |
| Whole model | | | |
| $R^2$, | 0.14, | | |
| p-value | < 0.0001 | N.S. | N.S. |
| Chi Square | 31 | | |
| df (n) | 2 (2,398) | (12,033) | (506) |
| Explanatory variables | $R^2$ (+/−) | $R^2$ (+/−) | $R^2$ (+/−) |
| Distance from channel | 0.08 (+) | N.S. | N.S |
| Floodplain width | 0.06 (+) | N.S. | N.S. |
| **Cache Creek** | | | |
| Relative elevation class: | ≤2 m | 2–5 m | >5 m |
| Whole model | | | |
| $R^2$, | 0.07, | 0.17, | |
| p-value | < 0.0001 | < 0.0001 | N.S. |
| Chi Square | 44 | 221 | |
| df (n) | 1 (1,025) | 2 (124) | (17) |
| Explanatory variables | $R^2$ (+/−) | $R^2$ (+/−) | $R^2$ (+/−) |
| Soil grain size | 0.07 (+) | N.S. | N.S. |
| Distance from channel | N.S. | 0.08(+) | N.S |
| Floodplain width | N.S. | 0.09(+). | N.S. |
| **Cosumnes River** | | | |
| Relative elevation class: | ≤ 1.5 m | 1.5–3.5 m | > 3.5 m |
| Whole model | | | |
| $R^2$, | 0.40, | 0.12, | |
| p-value | < 0.0001 | < 0.0001 | N.S. |
| Chi Square | 29 | 22 | |
| df (n) | 2 (277) | 2 (232) | (674) |
| Explanatory variables | $R^2$ (+/−) | $R^2$ (+/−) | $R^2$ (+/−) |
| Distance from channel | 0.26 (+) | 0.06 (+) | N.S. |
| Floodplain width | 0.14 (+) | 0.06 (+) | N.S. |
| **Putah Creek** | | | |
| Relative elevation class: | ≤ 1.5 m | 1.5–5 m | > 5 m |
| Whole model | | | |
| $R^2$, | 0.11, | 0.10, | 0.11, |
| p-value | < 0.0001 | < 0.0001 | < 0.0001 |
| Chi Square | 44 | 38 | 30 |
| df (n) | 2 (734) | 1 (982) | 2 (652) |
| Explanatory variables | $R^2$ (+/−) | $R^2$ (+/−) | $R^2$ (+/−) |
| Distance from channel | 0.06 (−) | N.S. | 0.05 (−) |
| Floodplain width | 0.05(+) | 0.10 (+) | N.S. |
| Slope | N.S. | N.S. | 0.06 (−) |

apart along the American River, 200–300 m apart along Putah Creek, and 75–100 m apart along the Cosumnes River (Figure 5). Elderberry patches along Cache Creek were scattered with no significant spatial patterning (although replication was relatively low, with ≤ 21 grid cells, at intervals 100–200 m and above).

*Elderberry Abundance Within and Between Patches.* Controls on elderberry density were similar over within-patch and between-patch scales, and differed among rivers (Table 5A). Along Cache Creek shrubs tended to be denser closer to the river (Table 5A). Fine soil grain size was associated with higher elderberry density along the American River, while the opposite was true along the Cosumnes River (Table 5A), even though average soil grain size was similar between both rivers (68–69% of particles ≥ 72 μm diameter). Soils on these two rivers were on average 40–50% coarser than those found on Cache and Putah Creeks (Table 2). Elderberry density along Putah Creek was not affected by any of the variables tested (Table 5A). Despite sufficient replication, ≤ 21% of variation in elderberry density along the rivers was explained leaving more variance unexplained than explained, especially over within-patch scales (≤ 12% of variance explained).

*Elderberry Sizes Within and Between Patches.* Controls on the average maximum basal diameter of elderberry shrubs (indicative of shrub age) were generally similar over within- and between-patch scales, and differed among rivers (Table 5B). Shrub size (age) was unrelated to the environmental variables along the American River. Older shrubs were more likely to occur on coarser soils along Cache Creek, and at farther lateral distances from the Cosumnes River (Table 5B). Older shrubs along Putah Creek were found closer to the creek (between patch scales) and in canopy gaps (within-patch scales) (Table 5B). Again, little of the variance (≤ 20%) in elderberry age was explained, especially over the smallest within-patch scales (≤ 9%).

## DISCUSSION

### Influences on Drainage-wide Elderberry Distributions

The primary controls on the distribution of elderberry, in both the dammed and undammed river systems, were variables reflecting large-floodplain hydrology, such as intermediate relative elevation, wider floodplain reaches, and increased lateral distances from the channel. Influences of soil

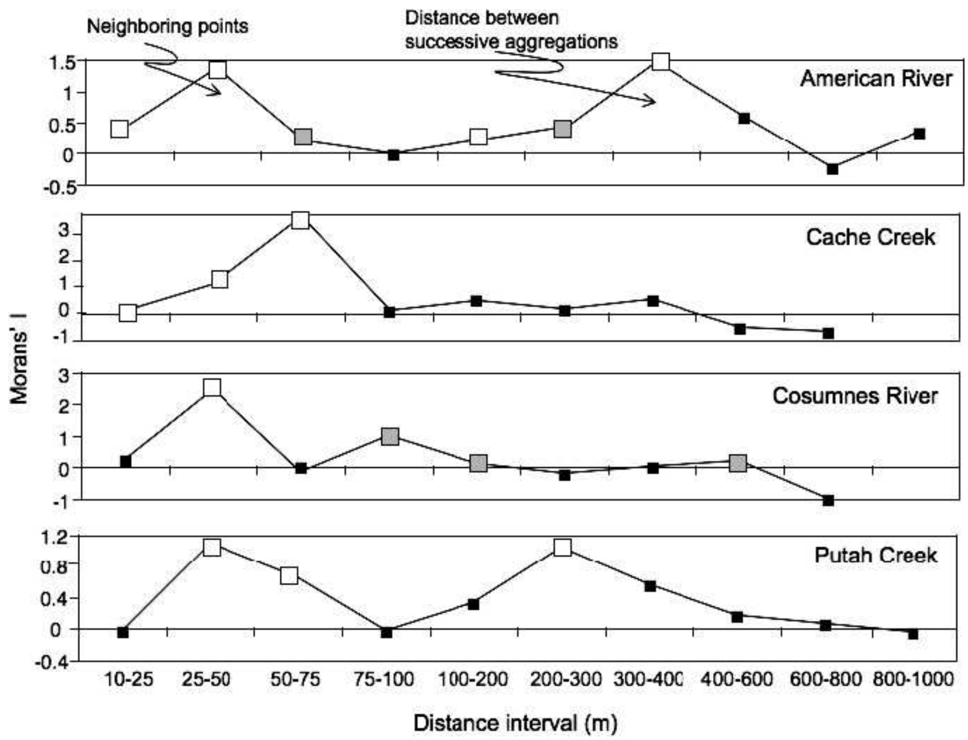


Figure 5. Correlograms showing the hierarchical levels of spatial clustering of elderberry shrubs. Significance values of the aggregations are $p \leq 0.05$. n = 701 local – and 51 between-patch aggregations for the American River, 45 local – and 21 between-patch aggregations for Cache Creek, 87 local – and 37 between patch aggregations for Cosumnes River, and 259 local – and 66 between-patch aggregations for Putah Creek.

texture and heat index on elderberry presence across rivers were likely indirect effects of hydrology and topography, with the wider floodplains containing coarser soils and more uniform irradiance than narrow, partially shaded floodplains.

## Influences on Elderberry Distribution Across the Relative Elevation Gradient

As with other systems influenced by strong physical gradients (e.g., intertidal; Menge 1976), variables important to elderberry distribution differed across the presumed hydrology gradient. The data are consistent with physical processes, such as anoxia and scour, determining lower distributional limits, since most of the variance was explained by greater distances from the channel, and elderberry has relatively inefficient adaptations to flood inundation compared with many obligate riparian plants (e.g., willows). Relationships between elderberry and the environment were weakest at intermediate elevations where peak frequencies occurred, illustrating a relatively optimal environment as compared with the edges of distribution where shrubs may face physiological limits and so be more influenced by the environment. The upper distributional limit of elderberry shrubs was generally not significantly correlated with any of the environmental variables possibly signifying the artificial (developed) upper boundaries of most of the corridors, the role of stochasticity in determining distributions, or the influence of variables acting over finer scales than were tested in this study (< 30 m).

## Influences Within and Between Elderberry Patches

Habitat quality characteristics for elderberry (i.e., controls on abundance) generally differed from those determining presence. Soil texture generally had the strongest influence on elderberry shrub density, although relationship direction differed with river likely due to differing hydrologic conditions. For example, coarser sediments may be more important in areas that flood more frequently, such as the undammed Cosumnes River, since elderberry favors moist but well drained soils (Crane 1989a,b). Similar spatial patterns, as we observed with elderberry patch distributions, are often attributed to similar processes; however, the variation in important environmental attributes across rivers revealed that different processes may contribute to habitat quality in each river. Additionally, the environmental variables used in this study often explained relatively little of the variance in elderber-

Table 5. Results of the regressions showing relationships between the fine- and broad-scale abiotic and biotic environmental variables, and (A) shrub density, and (B) shrub lateral size. Results for both within- and between (btwn) – patch scales are shown for each of the four rivers, where applicable. ± = direction of relationship, N.S. = not significant at a sequential Bonferroni-adjusted alpha calculated for tests within each river. Note: There was no uniform between–patch distance along Cache Creek.

| A. Shrub Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| | American River | | Cache Creek | Cosumnes River | | Putah Creek | |
| Patch Scale: | within | btwn | within | within | btwn | within | btwn |
| $R^2$ | 0.05 | 0.16 | 0.12 | N.S. | 0.21 | N.S. | N.S. |
| p | < 0.001 | 0.004 | 0.02 | | 0.005 | | |
| F | 31.3 | 9.4 | 5.8 | | 9.0 | | |
| n | 700 | 50 | 45 | 87 | 36 | 254 | 61 |
| Variables | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ |
| Lateral distance | N.S | N.S | 0.12(−) | N.S. | N.S. | N.S. | N.S. |
| Soil grain size | 0.05(−) | 0.16(−) | N.S | N.S. | 0.21(+) | N.S. | N.S. |

| B. Max Shrub Diameter | | | | | | | |
|---|---|---|---|---|---|---|---|
| | American River | | Cache Creek | Cosumnes River | | Putah Creek | |
| Patch Scale: | within | btwn | within | within | btwn | within | btwn |
| $R^2$ | N.S. | N.S. | 0.09 | 0.06 | 0.17 | 0.08 | 0.20 |
| p | | | 0.05 | 0.02 | 0.01 | < 0.001 | < 0.001 |
| F | | | 4.0 | 5.6 | 7.2 | 21.6 | 15.9 |
| n | 688 | 50 | 45 | 87 | 36 | 257 | 66 |
| Variables | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ |
| Soil grain size | N.S. | N.S. | 0.09(+) | N.S. | N.S. | N.S. | N.S. |
| Lateral distance | N.S. | N.S. | N.S. | 0.06(+) | 0.17(+) | N.S. | 0.20(−) |
| Canopy cover | N.S. | N.S. | N.S. | N.S. | N.S. | 0.08(−) | N.S. |

ry, presence, density, and size (≤ 20%) indicating a role of one or more complicating factors.

## Uncertainty, Environmental Stochasticity, and Data Resolution

We attribute much of the unexplained variance in elderberry distributions to natural stochasticity and potential data resolution issues. Stochasticity was likely a result of seed dispersal patterns and high rates of seedling mortality. Elderberry seeds are dispersed by vertebrates, especially birds, resulting in haphazard local patch distributions that correspond with seed deposition (Ozinga et al. 2005). Additionally, the herbaceous, shallow-rooted elderberry seedlings have high rates of mortality, which have been quantified in mitigation sites (Holyoak et al., unpublished data) but not in natural systems despite being quite evident (Talley et al., unpublished data).

Other causes of unexplained variance require further investigation. First, variability in relief, topography and sediment texture occurring over scales smaller than examined in this study undoubtedly underestimated their local effects on elderberry (Baker 1989). Due to resource limitations, we calculated these variables from 30 m resolution models to reveal controls on elderberry distributions over broad scales (whole floodplains). Our weak but significant relationships between elderberry variables and both soil texture and topography support observations that fine-scale variations in these variables may be important to elderberry distributions (Morzaria-Luna et al. 2004, Koch-Munz and Holyoak 2008) and warrant further exploration. Second, elderberry distributions may still be responding to the post-dam hydrology changes. Limited elderberry growth data revealed, however, that most of the shrubs encountered in this study were likely much younger (≤ 10 yrs old) than time since initiation of river regulation (30–60 yrs) (Holyoak and Talley unpublished data). Further, few if any relationships were observed between elderberry size, or age, and distance from current channels, which would be expected if restricted flows were affecting distributions patterns (Foster et al. 2003). Third, our selected explanatory variables were based on natural history of elderberry and those found to be important in the literature (van Coller et al. 2000, Turner et al. 2004). Given the large number and broad range of variables chosen, even if we missed an important variable (e.g., scour or stream energy), a covariate was likely included (e.g., relative elevation).

### Implications for Elderberry's Rare Inhabitant

Conservation priorities for the Valley elderberry longhorn beetle, and other rare species that depend upon a relatively common host, may benefit from host distribution models such as presented here since measures of habitat loss and compensation are often expressed in terms of host plants (USFWS 1999). Predicting elderberry presence, abundance, and size/maturity, or predicting where there will be uncertainty, will contribute to the recovery of the beetle since these host characteristics all influence beetle occupancy (Collinge et al. 2001, Talley et al. 2007). Generally weak relationships between the beetle and other environmental variables were attributed to stochasticity in occupancy patterns (Talley 2007, Talley et al. 2007). This study reveals that weak relationships may have also been the result of variables indirectly acting on the beetle through elderberry, such as relative elevation and stochasticity in elderberry abundance and size patterns. The double layer of stochasticity – both in beetle occupancy and host abundance patterns – indicates that metapopulation models often used to manage rare species (Hanski and Ovaskainen 2000) such as this one should include two species and environmental stochasticity that acts on habitat host patches and the rare species itself (Bonsall and Hastings 2004).

### The Importance of Spatial Scale in Determining Species Controls

The importance of approaching restoration using multiple scales is heuristically shown here by a comparison of potential conclusions gleaned from using either a broad or fine scale approach. Landscape gradients are often examined to determine the controls on species distributions (Whittaker 1975), especially in rivers (Hupp and Osterkamp 1996, van Coller et al. 2000, Dixon et al. 2002). If only a large-scale gradient approach was used in our system, we may have correctly concluded that variables reflecting floodplain hydrology primarily constrain broad elderberry distributions; however, we may have erroneously assumed that the same variables act across all scales, from individual shrubs to landscapes. The spatial autocorrelation of shrubs may have gone unnoticed, making relationships appear stronger than they actually were (Legendre 1993). Such incomplete conclusions can easily be translated into ineffective (or detrimental) management decisions, such as the suboptimal placement of elderberry plantings within seemingly desirable floodplains.

Conversely, the conclusions from a fine scale (within-site) approach may have focused on local abiotic variables (soil texture and moisture) and stochastic events, with little information on the optimal extent or location of elderberry community restoration relative to floodplain hydrology. We may have even concluded that the upper riparian system was largely decoupled from the river. These conclusions would further perpetuate a fine-scale conservation approach (Harris 1999, Morrison et al. 2003), such as little recognition of the value of riparian relative to non-riparian areas, or the use of localized management methods (e.g., irrigation, soil amendment) that potentially could be accomplished naturally with proper placement along the river or hydrologic gradients.

### Scaling Conservation to New Flood Regimes

Systems largely structured by a broad-scale physical process, such as riparian ecosystems worldwide, may be the most difficult to restore if the process is muted or extinct (Didham et al. 2005, Nilsson et al. 1997). Managing for plant communities that were created and maintained under extinct historic conditions, while not taking advantage of the impacted process (i.e., within site approaches), will lead to unexpected and often undesirable outcomes (Zedler 2005). For example, planting historic and declining riparian species is desirable, but the lack of historic flood and disturbance regimes may result in concurrent changes to community structure that inhibit recruitment or survival of these focal species (Vaghti et al. 2009).

Variables reflecting floodplain hydrology can and should, therefore, be used to delineate the extent of upper-riparian conservation areas (Ligon et al. 1995, Trush et al. 2000). For example, river size (channel and floodplain width) can be used to predict the floodplain position for elderberry community conservation and restoration in the Central Valley. Furthermore, a multivariate, multiscale approach revealed the distribution patterns of elderberry and their controls along the presumed hydrologic gradient. This type of information reveals where management efforts, such as planting or irrigation, might be necessary and when adaptive management should be applied to address local stochasticity or uncertainty (Zedler and Callaway 2003). This information also allows predictions about future shrub distributions given changes in land use. For example, increases in river flows associated with large dam releases may decrease the frequency of elderberry at its lower distributional limit and cause upland distribution shifts (i.e., opposite of effects observed in response to dam regulation; Foster et al. 2003). Finally, we strongly recommend the use of within-catchment reference sites for setting goals and assessing progress of restoration since it is likely that processes influencing elderberry (and its threatened beetle; Talley 2007, Talley et al. 2007) vary among drainages. Remnant natural sites, as studied here, have been underutilized in elderberry community restoration yet reveal general patterns and contingencies – information necessary to improve the predictability and efficiency of restoration outcomes.

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**National Fish and Wildlife Foundation**
**Final Project Evaluation Form**

**Project Name and Number:** Valley Elderberry Longhorn Beetle Management-II

2003-0244-000

**Recipient:** Sacramento County Department of Regional Parks, Recreation and Open Space

**Project Location:** Sacramento County

## 1) Were the specific objectives as outlined in your application and grant agreement successfully implemented and accomplished? Explain.

Phase II/year 2 contributed to development of a Valley Elderberry Longhorn Beetle ("VELB", *Desmocerus californicus dimorphus*) management plan and species recovery by assessing (1) commonly used landscape management practices; (2) VELB's natural enemies; (3) factors that promote VELB occupancy and abundance; and (4) existing guidelines, policies and activities.

For activity (1) assessments of road dust was completed, and pruning underwent its second year of data collection and analysis. A manuscript about the effects of dust on elderberry and the VELB was submitted to *Environmental Management*, and a quantitative estimate of the impacts of pruning has been made but the experiment is ongoing. A second pruning experiment was initiated to investigate the effects of "topping" that occurs beneath power lines. For (2), spatial analyses of VELB and predatory Argentine ant occurrence found no negative correlation between the ants and VELB occurrence. Conversely, a predation experiment found higher rates of predation of larval beetles (mealworms as a substitute for VELB) in areas with Argentine ants. This indicates that perhaps the negative effects of Argentine ants on VELB are variable and/or they take a long time to become evident at the level of whole VELB populations. For (3), VELB occupancy was identified as mainly being positively influenced by the density (or clump size or number of stems) of elderberry bushes, and distance from the river; however predictive ability of these relationships were low. For activity (4) mitigation procedures were evaluated using reports available from FWS. This led to figures on the efficiency of mitigation reporting and the relative value of planted seedlings versus transplanted shrubs in establishing VELB populations. The project led to submission of one manuscript to an ecological management journal, three scientific presentations at national ecological meetings, six meetings to management or conservation organizations, and eight mini-workshops on VELB ecology and field survey techniques for government and private biologists. Other results are still being written up or are a part of planned longer term investigations.

## 2) Please assess project accomplishments as quantitatively as possible

**(1) Assessing commonly used landscape management practices.**

**(i) Effects of road dust on elderberry and VELB.**

***Introduction/Methods***
A "natural" experiment was conducted along the American River Parkway during August 2003 to test the effects of dust from dirt roads relative to paved roads on elderberry characteristics. Along the Parkway, dirt roads are predominantly hiking and horseback riding trails, and paved roads consist mostly of bicycle trails and paved levees, all of which have limited motor vehicle traffic. In each of six sections of Parkway, replicate sites adjacent to a dirt road (n=6) and a nearby paved road (n=6) were established (Figure 1). Within each site, five elderberry shrubs were chosen at each of distances that were near (2-10 m) and far (25-40 m) from the edge of the roads. These distances were selected because there is a rapid decline in large dust particles (>50 µm) within the first 8 m from roads and a second decline of particles >20 µm after about 30 m (Everett 1980, as cited in Farmer 1993).

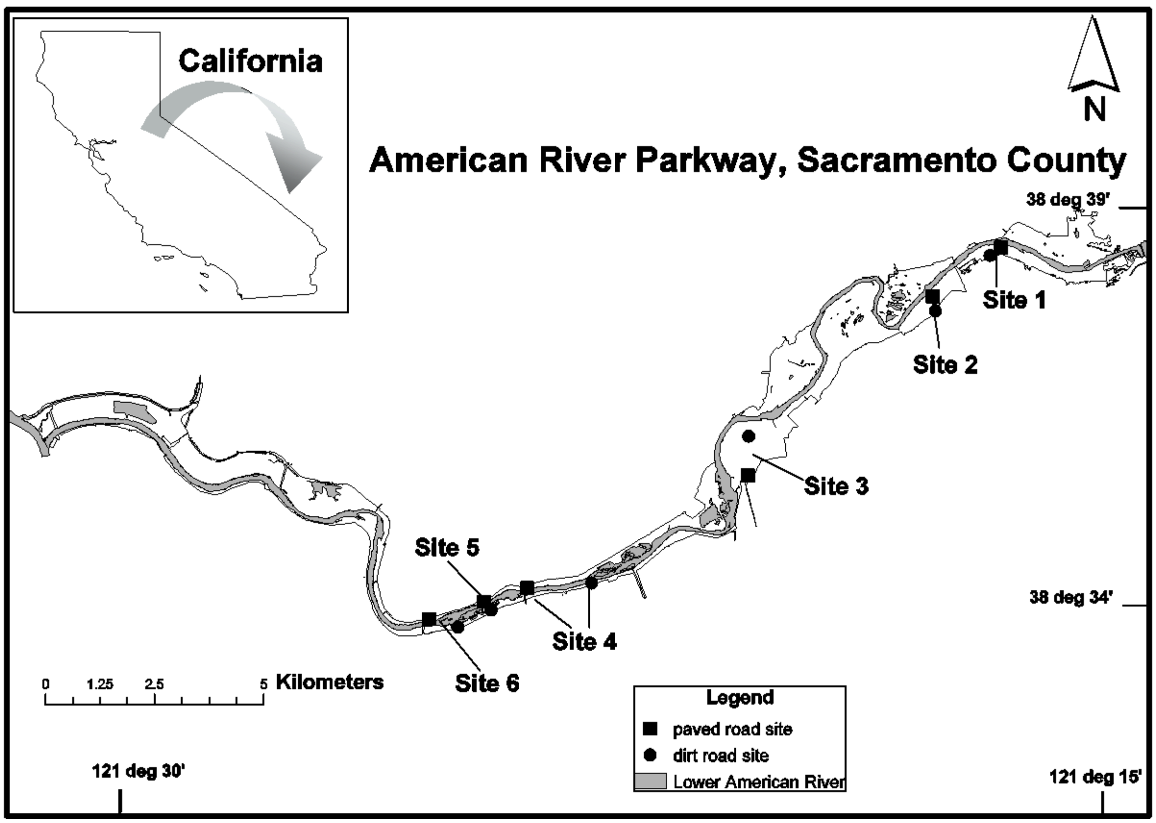



**Figure 1**. Location of the dust experiment and surveying of lower American River Parkway. The map shows the six paved and dirt road sites used for the dust experiment conducted during August 2003: Sites 1-6 with paved and dirt road areas paired within each site. Also shown is the extent of "mapped elderberry" that was surveyed between June 2002 and March 2003 for the valley elderberry longhorn beetle (VELB).

***Results***. The surface treatment showed that relative to paved roads, dirt roads were generally associated with elderberry that were "stressed" in that they were shorter, had lower % leaf water content, thicker leaves, more inflorescences per stem, higher % dead stems, and higher water stress (Table 1—*Tables and other figures are at the end of this document*; Figure 2A-F). Shrub cover tended to be higher and canopy cover of plant species other than elderberry lower along dirt roads relative to paved roads (Table 1; Figure 3A,B), supporting the result that water stress may be higher along dirt surfaces. Exotic annual grasses and thistles dominated the ground cover in all areas sampled. Proximity to roads (near vs. far) was associated with smaller leaf area and dry weight, larger maximum diameters, more inflorescences per stem, and higher water stress (Table 1, Figure 2D, F, G, H); these results were consistent with a higher canopy cover (more shading) of species other than elderberry at the farther distance from roads. Additionally, % cover of lichens on elderberry was highest close to roads, regardless of road surface type (Table 1, Figure 3C).

There were differences in elderberry characteristics between sites, with Site 6 generally being among the most stressed and Site 5 among the least stressed (e.g., least water stress and leaf thickness, highest % leaf water; results for means are not shown, ANOVA results are shown in Table 1). Elderberry variables differed in inconsistent ways between the other sites. Additionally, differences between sites resulted in most of the significant cross-variable interactions (Table 1). *Post-hoc* power analyses showed that the power of these analyses was reasonable for detecting large effects (power=0.62), but somewhat low for medium-sized effects (power=0.23). Hence we conclude that large effects are likely to be consistent with the significant findings above, but we refrain from drawing conclusions about smaller effects that were not statistically significant because of limited power.

Sediment accumulation on elderberry leaves did not differ with road surface or distance, but did differ with site (Site 3 leaves had less sediment than those from Sites 4, 5 or 6; Table 1). With data from all sites pooled, the amount of sediment per $cm^2$ of leaf was weakly but positively correlated only with the number of fruits per inflorescence ($r^2$=0.06, P=0.007, $F_{1,115}$=7.2, alpha=0.007) and not any other elderberry characteristics or vegetation cover (i.e., the variables listed in Table 1. The power for detecting medium sized effects was high (power = 0.96), indicating that it is likely that effects of dust deposition on elderberry would have been detected were they present.

Background sedimentation rates did not differ with road surface but were higher at near relative to mid and far distances from the road (Figure 4). Background sedimentation rates also tended to be highest in sites 4 and 5, intermediate in sites 6 and 3, and lowest in sites 1 and 2 (Tables 1 and 2). When data from all sites were pooled, sedimentation rate was weakly positively correlated with the amount of sediment accumulated on elderberry leaves ($r^2$=0.04, P=0.04, $F_{1,115}$=4.3, alpha=0.05), as well as with plant water stress ($r^2$=0.08, P=0.015, $F_{1,73}$=6.7, alpha=0.006), number of inflorescences per stem ($r^2$=0.05, P=0.013, $F_{1,118}$=6.3, alpha=0.007), and % dead stems on elderberry shrubs ($r^2$=0.06, P=0.010, $F_{1,115}$=6.9, alpha=0.006), although the elderberry characteristics are not significant at the sequential Bonferroni adjusted alpha. Sedimentation rate was weakly negatively correlated with average leaf dry weight ($r^2$=0.11, P=0.003, $F_{1,115}$=14.2) and, although not significant at adjusted alpha=0.010, average leaf area ($r^2$=0.05, P=0.021, $F_{1,115}$=5.5).

Distance from dirt roads was not correlated with elderberry shrub height or shrub density (number per 1963 $m^2$, which is a 25 m radius circle). While shrub height was also not correlated with distance from paved roads, elderberry density slightly increased with proximity to paved roads (Table 3); this relationship accounted for a very low proportion of the variance in elderberry density. Elderberry distance from paved roads was not correlated with other elderberry measures, but decreased distance from dirt roads was weakly associated with smaller maximum stem diameter and decreased proportion of dead stems on each shrub (Table 3). Statistical power was strong for these correlations revealing small effects (power=0.99).

Using the GIS data, there were no relationships between the presence of new or 1 year-old holes and the distance from either dirt or paved roads (power for detecting small effects was 0.99, i.e., very high). The chance of old holes being present, however, slightly increased with decreased distance to both dirt and paved roads (Table 3); the very low $r^2$-values indicate that these relationships have almost no predictive power and are consistent with more-or-less no effect. New and 1 year-old holes were most likely to occur in the presence of old holes (new: $P<0.0001$, $U=0.20$, $Chi_{1,2848}=215$; 1-yr: $P<0.0001$, $U=0.16$, $Chi_{1,2848}=316$). The low correlation coefficients suggest that there are variables other than the distance from roads that may better explain variation in VELB presence.

***Interpretation*.** Despite similar dust settlement rates and leaf dust accumulations along low-traffic dirt and paved roads, elderberry tended to be more stressed near the dirt than paved surfaces implying that factors other than dust influenced elderberry condition. For example, dirt roads generally experience less surface water runoff than paved roads resulting in less water availability for roadside plants. Additionally, unsurfaced areas along the American River Parkway where this study was conducted are generally farther from irrigation and the river (i.e., less sediment moisture) than most of the paved areas. Dust, however, does appear to contribute to elderberry stress. Variability in ambient dust levels for the Parkway (between sites) was greater than within sites. When all sites were pooled, increased sedimentation rate was weakly associated with shrub stress symptoms, such as water stress, smaller leaves, more dead stems, and more inflorescences per stem. This gives insight into how elderberry may respond to dust stress, but it is not clear whether the levels of plant stress encountered are capable of having any effects on the VELB.

The amount of stress associated with elderberry found near dirt roads does not appear to negatively affect elderberry population sizes since elderberry density was independent of the distance from dirt roads. The weak positive relationship between elderberry density and distance from paved roads suggested that low-traffic paved roads may slightly facilitate elderberry recruitment (0.2 shrubs per 100 $m^2$ more next to road vs. 600 m away), or that there are other factors correlated with paved road locations that influence elderberry density. It appears, therefore, that while dirt roads did not affect elderberry quantity, they did influence elderberry in ways that may relate to host plant quality, even if dust levels are similar to ambient. The question of how elderberry condition quantitatively influences VELB presence remains uncertain and under investigation.

This study indicates that suitable habitat for the VELB can occur adjacent to low-traffic dirt or paved roads. The selection of sites for conservation, mitigation and restoration of VELB, as well as the management of these areas should be guided by these results if sedimentation rates are similar to those found in this study (Table 2). As long as dust levels from dirt roads or construction remain at or below levels found here, no action need be taken. The rates of sedimentation that we recorded are probably applicable throughout the American River Parkway and other areas where traffic on roads is restricted 10 or less motor vehicles per day and consists mostly of non-motor vehicle use such as bicycles, horses and hikers. These road dust levels appear to be relatively innocuous; they have benign or no effects on elderberry or the VELB.

A manuscript was submitted to the journal *Environmental Management* in November 2004 and has been sent out for peer review by the editors of the journal.

**(ii) Effects of pruning on VELB and Elderberry**

To quantify the effects of tree trimming on elderberry growth and condition, as well as VELB occupancy and abundance, two types of experiments, pruning and topping, were established along the American River Parkway, Sacramento County, California, USA. The Parkway is a 37 km stretch of riparian habitat owned by Sacramento County Parks that borders both sides of the American River and contains one of two areas designated as Critical Habitat for the VELB (USFWS 1984). Among the maintenance activities that occur along this urban Parkway is the pruning of elderberry shrubs along access roads, and topping of shrubs growing beneath power lines. Both experiments were meant to mimic the type and extent of pruning that occurs with these routine maintenance procedures along the Parkway or other similar public areas. Hence, these forms of pruning are relevant to utilities such as WAPA, PGE , SMUD and the California Department of Transportation. Since the present task order is contributing to continuation of an ongoing experiment, the project structure is described below along with preliminary results.

***Methods for the experiments to date:*** The pruning experiment mimicked the trimming of shrubs that overhang roads or trails. Pruning involved the removal of 50% of all 2.5-cm or less diameter branches from each shrub. The experiment was established on 16 July 2002 over a 5.7 ha area of the Parkway. A total of 120 shrubs were selected; 60 of which contained recent VELB exit holes and 60 of which had been recently uninhabited. Half of each of the VELB-occupied and unoccupied shrubs were haphazardly assigned to be pruned. An attempt was also made to select shrubs of similar size and condition. Each shrub consisted of one large (12-20 cm basal diameter) to 3 smaller (2-7 cm diameter) main stems. Shrubs were sampled before pruning, 2 weeks after pruning, and then annually during the following two springs (15-16 June 2003, 13-14 May 2004). Follow-up measurements will be made during 2005 and 2006.

The topping experiment investigated the form of pruning that occurs beneath power lines, where “topping” removes the top 1 m of a shrub or clump of shrubs. Most branches at this height are 2.5 cm or less in diameter. On 23 July 2003, branches were cut from across the top 1 m of the shrubs. The experimental design was similar to the pruning experiment, however, 40 large shrubs were selected, with 10 shrubs per treatment combination of VELB-no VELB and topped-not topped. Shrub in this topping experiment varied from one to several large stems (30-40 cm) to a maximum of 47 smaller stems (20-cm or less diameter). The area covered by each shrub or clump ranged from 33 to 205 $m^2$. Shrubs were sampled before topping on 8-10 July 2003, one month after topping (19 August 2003) and during the following spring (20-21 May 2004). Field measures and collections, and the lab procedures were the same for both experiments.

At each sampling date, measures of elderberry size and condition were made, the presence and abundance of VELB holes was noted, and elderberry samples were collected for nutrient and defense chemical analyses. Procedures for this are described in the Phase 3 proposal.

In the lab, the effects of pruning on relative plant nutrition levels were estimated using carbon to nitrogen ratios (C:N) for leaves and proportion of N content for pith. Pith material is very low density and because of this it could only be analyzed for % N. The leaf C:N data included a break-down of % C and % N so that data could be compared across plant material type . Leaves were rinsed with distilled water, while the pith was extracted from the sections of collected stems. All plant material was dried at 60 degrees C until a constant weight was achieved (at least 24 hrs), finely ground into a powder, and submitted to the DANR Analytical Laboratory at UC-Davis for carbon and nitrogen content analysis.

The effects of pruning on the presence and amount of plant defense chemicals was tested using Fiegl-Anger test papers which turn blue in the presence of hydrogen cyanide gas such as would be emitted from plant material when cell damage occurs (Seigler 1991). The release of this toxic gas is thought to be an herbivore deterrent mechanism and is documented for other species of elderberry (*Sambucus racemosa, S. nigra*) (Buhrmester et al. 2000). Samples were tested in a standardized way following procedures described by Seigler (1991).

***Results to date*** Effects of shrub trimming on VELB: Neither pruning nor topping affected the colonization or loss of VELB from shrubs (Chi square tests, $p \geq 0.25$). There was one shrub which was occupied by VELB prior to the topping experiment and unoccupied after the experiment, and it occurred in an untopped (control treatment) shrub. In the pruning experiment, changes from VELB-occupied to unoccupied occurred in 15 of 33 and 13 of 24 pruned shrubs in the first and second years, respectively. These levels of change from occupied to unoccupied were statistically similar to those in control treatments that were not pruned. Of the colonizations by VELB that occurred, 5 of 7 were in topped shrubs, and 6 of 9 and 7 of 12 were in pruned shrubs in the first and second years. The length of time that a shrub was either occupied or unoccupied by VELB was also unaffected by pruning. Length of occupancy was related to the occupancy status at the start of the experiment, with occupied shrubs remaining occupied and those without holes remaining vacant (Chi square tests, $p \leq 0.0001$).

Effects of trimming on elderberry: Neither pruning nor topping had any detectable effects on elderberry nutrient content. Proportions of leaf nitrogen, leaf carbon, leaf C:N, and pith N did not differ initially in either experiment (2 Way ANOVA, $P \geq 0.12$) and remained similar one month ($P \geq 0.64$) and one year ($P \geq 0.53$) after topping, and 2 weeks ($P \geq 0.58$), one year ($P \geq 0.35$) and two years after pruning ($P \geq 0.85$). Similarly, hydrogen cyanide was at negligible levels at the start of both experiments (no test paper color change), and remained so in both experiments at all dates.

There were no short-term changes (2-4 wks) in shrub survival, growth or condition in response to pruning or topping. Shrub mortality occurred only in the pruning experiment but did not differ between VELB versus no-VELB or pruned and not-pruned shrubs for either year (2-way ANOVA; 2003 $P=0.87$; 2004 $P=0.78$). Pruning and the initial presence of VELB did not effect changes in the number of main stems per shrub, the maximum basal stem diameter or shrub height for either year (2 Way ANOVAs; 2003 $P \geq 0.24$; 2004 $P \geq 0.57$). Similarly, topping and the initial presence of VELB did not affect the number of stems per shrub or the maximum stem diameter (2 Way ANOVA; $P \geq 0.16$). The initial height of shrubs did not differ between VELB- no VELB shrubs or those soon to be topped (2 Way ANOVA; $P=0.28$). Topping removed 50-100 cm from the top of the shrubs but there was no difference in height among treatments the following spring (2 Way ANOVA; $P=0.28$) suggesting that the small cut stems grew quickly. Elderberry condition was not affected by pruning or topping.

The only negative effect of trimming elderberry observed was a temporary loss of habitat in the form of the cut stems. After one year, an average of 2.3 new branches emerged from each pruned shoot and 2.0 new branches from each topped shoot. The new branches, which were thin (≤1 cm diameter) and so not usable by the VELB, emerged from the first node beneath the cut.

After 2 years, there was an average of 1.8 new branches for each pruned branch suggesting some mortality of these new shoots. In this second year shoot diameters were 1.5 to 2 cm and had become fairly woody although they still appeared unsuitable for use by the VELB based on their size. If we assume a constant mortality rate with each year, which may be an over estimate because as the shoots get thicker mortality should decrease, there would be 1.5 new branches for each one pruned in year 3 and 1.0 new branches by year 4. From the observed growth rates, surviving branches are expected to reach 2.5 cm diameter in the 3rd year. These experiments suggest that, on average, each 2-2.5 cm diameter branch that is cut will be replaced in about 3 to 4 years. However, these are estimates and they need to be experimentally verified, which is one of the major aims of this proposal.

Since this study is ongoing it has not been published yet. Eventually we will publish a manuscript in a journal like *Environmental Management.*

**(2) Assessing VELB's natural enemies.**

The biggest threat to the VELB has been assumed to be the invasive Argentine ant (*Linepithema humile*). This ant is both an aggressive competitor and predator that is spreading throughout riparian habitats in California and displacing assemblages of native arthropods. A negative association between the ant and the VELB was observed along Putah Creek in 1997 (Huxel 2000). This study aimed to identify potential mechanisms behind this relationship, as well as the spatial extent of such relationships and the conditions under which negative relationships may arise. Additionally, this study identified the role of other potential natural enemies in VELB survival. Statistical analyses of natural enemy effects are still being completed but preliminary results are presented here.

***Methods.*** Ant species composition and relative abundances near elderberry were sampled using baited traps (Petri dishes with tuna oil and sugar water) during the summer of 2003 and 2004. Traps were set along previously mapped sections of the American River. Sets of three to five traps were placed within 50 m of each other, and sets were distributed throughout several areas of the Parkway on both sides of the river: Discovery Park, Woodlake, Cal Expo-Glen Hall Park, Howe- Watt Ave. Sets of traps were also placed in 15 mitigation sites throughout the American River valley. Other potential enemies present on elderberry were sampled during May 2004 using live mealworm beetle adults and larvae that were tethered to live elderberry stems. A piece of sticky tape was placed next to the tethered individual and 'traps' were left for 24 hrs. Use of live beetle larvae and adults will give an idea of enemies likely to interact with live VELB and leaving traps overnight allowed an opportunity to sample nocturnal enemies. The traps were placed in sets of five (each trap was 10-20 m from each other). Sets were placed in several areas along the Parkway; Discovery Park, Woodlake, CalExpo, and Glen Hall Park. Condition of the mealworm beetle was noted (live, dead, intact, partial, gone) and individuals stuck to the tape were identified and counted.

***Results to date.*** Analyses using ant trap data and mapping data revealed there were positive associations between the Argentine ant and the VELB across shrub-wide (~10m) distances (Rho=0.25, $p<0.02$). When numbers of VELB and Argentine ants were averaged over 25 m and 50 m scales, there was no relationship between the two species. When averaged over 100 m scales, the relationship was positive again (Rho=0.20, $p=0.02$). This suggests that there is often co-occurrence of the two species on site-wide (100 m) scales suggesting that the two species have similar environmental requirements (e.g., microclimate, moisture, canopy cover). The two species also tend to co-occur on elderberry shrubs (10 m scales). This makes sense since elderberry shrubs have something to offer for both species; VELB rely solely on elderberry for food and habitat, while the ant takes advantage of the diverse insect prey, nectar, and fruits, as well as habitat provided by abandoned holes in elderberry stems. The tethering experiment reveals, however, that given the opportunity, the ant will increase mortality (i.e. predation) of vulnerable beetle larvae. The presence of intact larvae decreased ($R^2$=0.54, p=0.037), and partially eaten larvae increased ($R^2$=0.25, p=0.020) with increased Argentine ant density. Previous observations of Argentine ants quickly attacking a VELB larva in the field support this. It is likely that there are threshold densities of the Argentine ant, under which the amount of predation does not significantly affect VELB populations, but above which predation rates may substantially decrease VELB population survival; we are analyzing the data to answer this question.

The Argentine ant was present in most mitigation sites surveyed (14 of 15) both because it is introduced with seedlings from nurseries and because irrigation encourages proliferation of Argentine ant populations. Mitigation sites with Argentine ants always had among the highest relative densities of the ant (density ranks of 4 or 5 out of 5) based on the ant traps. We suspect that these densities are above our hypothesized threshold density of the ant making mitigation sites inhospitable environments for the VELB in part because of Argentine ant predation.

The other common, potential natural enemies found along the Parkway were ground squirrels, Western fence lizards and European earwigs. These three species move freely up and down elderberry stems searching for food. While squirrels happily ate mealworm larvae, we are skeptical that squirrels would be searching for a prey item as tiny as a VELB larva and the aposematic coloration of the adults makes it unlikely prey for a vertebrate. The Western Fence lizard was an effective predator on the mealworm larvae and adults, and would be efficient at preying upon even smaller insect larvae like the VELB. Lizards were common in natural as well as in mitigation sites. In one restoration site along the Sacramento River, every single elderberry seedling out of ~1500 surveyed had a fence lizard on it. Again, we doubt that the lizard would prey on VELB adults although either squirrel or lizard activities could disrupt VELB adult activities of feeding and mating. Finally, the European earwig is a scavenger and omnivore that was often found feeding on the tethered mealworm larvae. The earwig is common in elderberry and often nests in abandoned holes in the stems. The earwig, like the Argentine ant, requires moisture and is often found associated with irrigation. We believe that earwig presence and densities tended to be highest in mitigation sites likely because of the irrigation, although this needs to be statistically tested. The presence of earwigs could contribute to unnaturally high predation rates in mitigation sites. Additionally, the high densities of Argentine ants and earwigs in mitigation sites, could be subsidizing higher abundances of lizards, and further increasing predation pressure on invertebrates in these areas. These ideas need to be tested further but our preliminary recommendations are to reduce the introductions of Argentine ants and earwigs into mitigation sites, water in such a way as not to encourage their population growth and populations of lizards will decline also relieving predation pressure on invertebrates in these sites.

**(3) Assessing factors that promote VELB occupancy and abundance.**

When the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*, “VELB”) was listed, there was a lack of biological information about the beetle. The recovery plan was written on the assumption that increasing abundance of its host plant, elderberry (*Sambucus mexicana*), would lead to more beetles but little else was known about the habitat requirements of this species. The regulation requirements associated with listing (in 1980) undoubtedly slowed or halted the decline of the beetle, but after 25 years, recovery, or an increase in extent or abundance, has not been achieved. Additionally, information from this study and previous studies show that only 25% or less of apparently suitable habitat are occupied by the VELB. This lack of recovery, despite numerous mitigation and restoration efforts, and a lack of saturation of elderberry by the VELB suggest that other factors may be controlling VELB presence and abundances. We are examining the role of local habitat characteristics, landscape characteristics, and spatial variables (e.g., isolation, distance from features), as well as elderberry size and density on VELB distributions and abundance.

***Methods.*** We are continuing with the mapping effort along the American River Parkway. To date, we have mapped every elderberry shrub in the Parkway from the confluence with the Sacramento River to the east, past Goethe Park (almost 2/3 of the Parkway). At each shrub we recorded geographic coordinates, measures of shrub size, shrub condition, the number of beetle exit holes, and the cover and species of any plants growing over or within the dripline of the shrub. Elderberry grows vegetatively and shrubs often have multiple main stems, or stems emerging from the ground. Elderberry size measures included the maximum basal stem diameter of the shrub, maximum height classified as a midpoint within one of six height classes (1-2, 2-4, 4-6, 6-8, 8-10, >10 m), and the number of main stems occurring with each of four diameter classes (2-7, 7.1-12, 12.1-20 and >20 cm). Area and perimeter of each shrub was measured by creating a polygon around the drip line of shrubs whose canopies were 5 m or more diameter. The area and perimeter of shrubs less than 5 m across was estimated using a formula resulting from a regression between total stem number per shrub and area/perimeter of the larger shrubs. A subsample of these estimates was field validated. Elderberry condition estimates included a classification of the amount of leaf damage (0-10, 10-25, 25-50, 50-75, 75-100%), amount of bark damage (none, partial, girdled) and the proportion of dead stems (0-25, 25-50, 50-75, 75-100%).

Beetle exit holes were recorded as being recent or old. Recent holes had crisp margins, minimal evidence of healing, light gray wood color, and, in some cases, frass (wood shavings and droppings). Older holes were characterized by faded margins, evidence of healing, and dark gray to black wood color. Additionally, the height off the ground and the stem diameter where the hole occurred were recorded for the Parkway.

**GIS calculations & analyses**: The effects of landscape and spatial properties on the beetle were explored by calculating these variables from GIS data provided by Sacramento County Parks. Variables included the distances from every elderberry shrub to the nearest road, the river and other surface water, the upland riparian edge, the next nearest elderberry shrub, and the nearest recent holes were computed using the Nearest Features script available for ArcView 3.2 (Jenness Enterprises, http://www.jennessent.com). ArcGIS 9 was used for all other calculations and analyses. Riparian width was calculated as the sum of the distances to the upland edge and the river. The land ownership and the general vegetation community (e.g., annual grassland, riparian scrub) on which each elderberry occurred were also determined.

Effects on the beetle of the amount of elderberry available over small spatial scales (≤100m scales) was explored by calculating the density of shrubs (points) and main stems, and the areal cover of elderberry over several areas. Shrub densities along the Parkway were estimated for 1963, 7854 and 31416 $m^2$ areas (25, 50 and 100 m radii). The number of main stems per shrub and shrub area were averaged over several areas (100, 625, 2500, 10,000 $m^2$) to standardize these values per unit area and to compare the effects on the beetle of shrub size against total available habitat (shrub) in a given area.

**Statistics:** Independence of predictor variables was explored with simple regressions using JMP Statistical Software. Predictor variables found to be strongly correlated with each other ($R^2 \geq 0.4$) were removed; leaving the one variable that made the most biological sense or that had the strongest correlations with the most other variables. If variables were significantly, but less strongly correlated with each other ($0.1 \leq R^2 < 0.4$) the effect of one variable on the other was removed by using the residuals resulting from a regression performed on the two. Multiple logistic regressions using R were used to explore the effects of predictor variables on the presence or absence of the VELB. Individual contributions of each variable were explored by sequentially removing and replacing each variable and recording changes in the overall $R^2$ value. The most important variables, those explaining 50% or more of the variability in the regression, were identified and used in further analyses. Hierarchical partitioning analysis in R was used to determine the independent contribution of each important variable and the contribution of each variable in concert with the others.

Correlations between the presence/absence of VELB in a particular shrub and VELB abundance averaged over a range of scales (10, 25, 50, 100 m) were run using logistic regressions in JMP. Similarly, correlations between elderberry stem and shrub density in one spot and densities averaged over the same range of scales were run using simple regressions in JMP. Averages of VELB and elderberry abundances over these areas, as well as nearest neighbor analyses, were calculated using ArcGIS 9.

***Results to date*** The presence of recent beetle exit holes was only weakly correlated with the environmental variables ($R^2$=0.12). The seven most important environmental variables to beetle presence (explaining a total 8% of the variance) were decreased width of the riparian corridor (2.1% variance explained), increased density of stems within a 25 m radius (1.8%), increased maximum height of the shrub (1.2%), increased latitude of the shrub (1.0%), decreased distance to the nearest road (0.7%), increased cover of *Robinia* (0.6%), increased proportions of larger stems on each shrub (≥12 cm diameter; 0.4%). The independent compared with the combined contribution of these seven variables to VELB presence reveals that the cover of *Robinia* and distance to the nearest road do not have independent contributions to VELB presence but are only important in terms of the other four variables. The independent and dependent contributions of the other four variables were fairly similar. This suggests that, despite the initial weeding out of covariates, the cover of *Robinia* and proximity to roads is related to other variables. The hierarchical partitioning analysis is useful, however, because it identities unintuitive relationships between variables and could indicate variables that are indirectly correlated with the VELB (e.g., *Robinia* cover may affect elderberry stress and nutrient levels, which in turn affect VELB presence).

The presence of VELB in a particular shrub was most correlated with the abundance of holes within a 25 m radius of the shrub ($r^2$=0.36, $p<0.0001$) suggesting that beetles aggregate over these distances. Aggregations could be due to attraction of adults or could be because the VELB is dispersal limited. There was also a strong correlation between previous and current occupancy of a shrub by the VELB ($r^2$=0.15, $p<0.0001$) supporting that aggregations are at least in part due to limited movement across years. Elderberry size and shrub density in one particular spot were also correlated with size and density in the surrounding 15- 25 m ($r^2$=0.30-0.32, $p<0.0001$), distances that correspond to VELB aggregations. The average (±1SE) distance between occupied shrubs was, however, 74±7 m (range 2.5 – 685 m) indicating that the VELB will migrate outside of its local aggregation or shrub to seek out other host plants and /or mates.

The consideration of all these variables, not only numbers of elderberry, can be integrated into improved management practices and conservation plans, including mitigation and restoration site design. Analysis of the relationships between VELB abundance and turnover and predictor variables, as well as spatial analyses to look at the spatial population structure of the VELB, are all still underway.

**(4) Evaluating existing guidelines, policies and activities.**

We (M. Holyoak, S. E. Wood and T. S. Talley) conducted an assessment of all mitigation reports available in the Sacramento USFWS office (89 reports from 45 mitigation sites from the beetle's entire range). Reports indicated a mean of 2.5 mitigation sites initiated per year. 64% of plantings were replantings that replaced dead plants, representing a substantial source of wasted effort and opportunity for improvement. Across all sites 2,379 elderberry seedlings were planted per year and 351 elderberry were transplanted per year. Mitigation efforts were disproportionately biased towards Sacramento and Placer Counties, which is where the ARP lies. Based on expectations from reporting guidelines only 20-60% of the expected reports were filed, indicating a substantial loss of valuable information on mitigation practices. Initial survival of planted seedlings (92%) was greater than that for transplanted elderberries (67%). However per bush seedling and transplant survival were equivalent by year 7, and this was the soonest that colonization of seedlings by VELB occurred. 48% of sites were colonized by VELB, but almost all of these sites received transplants containing VELB and colonization of seedlings by VELB is largely unknown—more than the current 10 years of monitoring is required. These preliminary findings help to identify how mitigation can be improved by resolving some data reporting problems, but they also show that mitigation has a low success rate in establishing VELB. The only scientific finding that comes from these analyses that can help to improve the mitigation process is that transplants are more valuable than seedlings (contrary to popular opinion). A manuscript is in preparation from this study, for submission to *Biological Conservation*.

**Presentations made**

(1) FWS-Sacramento Field Office. January 2003. Theresa Talley, Marcel Holyoak and Peter Buck all presented. Integrating management and science to conserve the threatened Valley Elderberry Longhorn Beetle. U.S. Fish and Wildlife Service Noon-time seminar series, 6 January 2004.
(2) Multiple outreach presentations to river groups. Talley, T.S. and M. Holyoak. 2003. Integrating conservation and management to conserve the threatened valley elderberry longhorn beetle. Presented at task force meetings for the Lower American River (10 Dec 2002), the Cosumnes River (13 May 2003) and Putah Creek (20 May 2003).
(3) Two progress report meetings at SAFCA to all of the funding partners involved in the project. These involved a presentation of the results and about 2 hours of discussion of these!

(4) Wood, S., T.S. Talley and M. Holyoak. 2003. Improving habitat mitigation practices for a threatened riparian beetle. Western Society of Naturalists Meeting, 9-12 November 2003, Long Beach, CA. (honorable mention, best student poster)
(5) Wood, S., T.S. Talley and M. Holyoak. 2004. Improving habitat mitigation practices for a threatened riparian beetle. Society for Conservation Biology, January 2004, Davis, CA

### 3) ASSESS THE NUMBER OF PEOPLE REACHED THROUGH YOUR WORK (E.G., LANDOWNERS, STUDENTS, ORGANIZATIONS, AGENCIES) DID OTHER LAND MANAGERS BENEFIT FROM THE PROJECT?

Numbers refer to the presentation's made in the previous section

USFWS (1): approximately 50 people in attendance, mainly FWS employees, but also 2 people from Wildlands mitigation banking and restoration practitioners.

Project supporters (2). About 20 individuals from a diverse array of private companies and public agencies.

Number of people that T.S. Talley and Dr. Holyoak advised about VELB management issues in connection with this project—about 30 per year total. Includes USFWS, State Parks, National Parks, BLM, Bureau of Reclamation, city officials from several cities, CalTrans, Federal Highways, Dept of Water Resources, Sacramento County Regional Sanitation District, River Partners, TNC, Biological Consulting Firms, California State University, Surface Water Resources, Army Corps of Engineers.

We cannot directly estimate numbers of people that viewed either Theresa Talley's or Dr. Holyoak's web sites in connection with this project, but this is also a substantial number of people. Two high school students contacted Dr. Holyoak about the VELB in response to information on this web site. T. Talley is contacted several times each month by consultants and government biologists asking about information on the website and asking for further information.

Estimated minimum total number of people = at least 1 per week

### 4) WERE ANY SURVEYS OR INTERVIEWS CONDUCTED WITH PARTNERS TO HELP GAUGE THE SUCCESS OF YOUR EFFORTS?

Not directly, but two 3-hour meetings were held with representatives of the thirteen public companies or agencies who are supporting this work in attendance, and the results of the findings were discussed at length. The research team at UC-Davis is also in frequent contact with FWS and other management groups who are seeking information on the VELB. There has been uniform enthusiasm for the gains in knowledge that the project brought.

### 5) HOW WILL THE PROJECT BE EVALUATED IN TERMS OF MONITORING OR ASSESSMENT OF CAUSE-AND-EFFECT RESPONSE? DESCRIBE THE EVALUATION TIMESCALE (E.G., ONE YEAR, FIVE YEARS, TEN YEARS). HOW WILL MONITORING RESULTS BE REPORTED?

The project includes a broad range of components that can be directly assessed. This includes:

1. Establish pilot projects to determine the effectiveness of proposed management guidelines. These are primarily further surveys along the American River Parkway, but also further surveys of mitigation sites (in work that is funded separately but follows from this project).
2. Complete and implement the VELB Habitat Management Plan (HMP) in the American River Parkway (ARP).
3. To publish, present and otherwise make available the findings to a broad audience of management agencies, conservation organizations, scientists and the public.
4. To parameterize a model to evaluate regional persistence, and to use it and other information to aid USFWS in revising the VELB Recovery Plan.

Rather than laboriously go through all of the ways of evaluating the project we have taken a quantitative approach to evaluating its effectiveness, which follows from the NFWF piloted evaluation process. This is based on considering particular outputs/outcomes of the project, the baseline value for measurements and what could be regarded as a successful outcome. Because only a very general Species Recovery Plan and mitigation guidelines exist for the VELB, the early stage of discovery means there are few baseline values in existence.

| **Output/Outcome** | **Baseline** | **Reference for success** |
|---|---|---|
| Improved identification of VELB habitat | % of variance in VELB abundance explained; baseline= ~20% to date | >20% |
| Improved mitigation | Number of detrimental or suboptimal practices identified (baseline is defined as zero) | Several practices |
| | % of mitigation sites colonized by beetles (48%, of which all but 2% are from transplanted elderberries) | Increases in values several years after the project ends |
| Estimate of VELB take through pruning | Number of VELB destroyed per pruning, or number of elderberry stems destroyed (baseline is currently all VELB per shrub) | A proportion of the number of VELB per shrub |
| Confirmation of whether VELB are harmed by irrigation (via ant introduction) | A correlation between VELB presence/abundance and irrigation or ant presence (no baseline) | Establishment of values |
| Understanding the value of mitigation practices | Survival rates of transplanted plants and seedlings (no baseline) | Establishment of values |
| | Correlations between the colonization of sites by beetles and site conditions (no baseline) | Establishment of positive or negative correlations |
| Improved monitoring of mitigation practices | Identifying inconsistencies in mitigation reporting (no baseline) | Establishment of nature of inconsistencies |
| Eased management of VELB through production of HMP | Cost per year (cost can be calculated) | Reduced cost per year and production of the HMP |
| Publication of articles, giving talks and providing signs | Number of such items produced (baseline is zero) | Number of citations per year, and column inches published |
| Estimation of number of local populations required for VELB | Unknown | To be established |

| Output/Outcome | Baseline | Reference for success |
|---|---|---|
| persistence | | |

The project led to one manuscript submitted to an ecological journal already and one more in preparation at this time. This is a broad dissemination of scientific findings and means that scientific findings are likely to be adopted by USFWS.

6) **DOES THIS PROJECT FIT INTO A LARGER PROGRAM, SPATIALLY OR TEMPORALLY? IF SO, HOW HAS THAT PROGRAM BENEFITED FROM YOUR WORK? (FOR EXAMPLE, AN EASEMENT OR ON-THE-GROUND WORK THAT CONNECTS OR BENEFITS OTHER PROTECTED PROPERTIES.)**

The project is part of a broader effort to improve the management status, recovery potential, and recovery plan for the VELB. Work is being conducted in four other watersheds. The larger project benefited enormously, in a variety of ways: (1) Data from the current efforts were available for comparison with that from other watersheds. (2) Funds from the project also helped to support an additional investigation of the effects of hydroelectric damming on elderberry and VELB. (3) Contacts made through pulling people together to provide matching funds have been an extremely useful network that has provided the project's scientists with information about the needs of management agencies and access to further funding opportunities through these agencies.

7) **DOES THE PROJECT INCORPORATE AN ADAPTIVE MANAGEMENT COMPONENT? IF SO, PLEASE EXPLAIN. ANY LESSONS LEARNED THAT WILL GUIDE FUTURE IMPLEMENTATION OF THIS, OR SIMILAR, PROJECTS?**

Yes, adaptive management is being exercised in a variety of ways, mostly at the level of improved procedures being used by USFWS in its management of the VELB, for example: (1) Investigations showed that VELB is more abundant in natural habitats with clumps of elderberry occurring together. This led to planting of a new mitigation site with elderberry in a clumped distribution. (2) The negative effects of Argentine ants on VELB have led to attempts to eliminate the ants from the pots of elderberry to be planted on mitigation sites. (3) The quantification of the effects of both dust and pruning on the VELB have been conveyed to USFWS and agency personnel are now able to more accurately calculate the amount of mitigation required in response to elevated dust (e.g., from construction) or from pruning. (4) The discovery of the value of transplanted shrubs in mitigation sites has led to an increased emphasis on transplants where they are possible.

8) **WAS THERE A LOCAL/REGIONAL/NATIONAL RESPONSE? ANY MEDIA/PRESS INVOLVEMENT?**

As detailed above, there has been substantial interaction with local/regional and national managers and companies. The results were also presented at a national meeting, the annual meeting of the Ecological Society of America where results were conveyed to conservation biologists nationwide. The answer to question 7) involves responses by USFWS to our scientific discoveries. No media involvement resulted from the project.

9) **TO WHAT DEGREE HAS THIS PROJECT CONTRIBUTED TO THE CONSERVATION COMMUNITY AS A WHOLE?**

The project has served as a focus for conservation efforts for the threatened VELB. It provided a mechanism for SAFCA staff to bring together numerous groups who were concerned with the management of the VELB. The project provided the only funding that was available for studies (remember NFWF is not supposed to fund research) about the VELB's management (nobody was conducting funded scientific studies on the VELB in 2002-3!), and since has fueled other funding through creating interactions between UC-Davis scientists, public agencies and companies. Having NFWF backing was key to providing legitimacy to the project so that it could attract further support and interest. The project has also created a sense of cooperative problem solving that has improved the relationship between several companies or agencies and USFWS.

**10) DID YOUR WORK BRING IN ADDITIONAL PARTNERS, MORE LANDOWNERS, ET CETERA, WHO WOULD BE INTERESTED IN DOING SIMILAR WORK ON THEIR LAND IN THE FUTURE? IF SO, PLEASE DESCRIBE.**

The project's funding partners grew from 3 to 8 during the project period, with new interest from the American River Flood Control District, Western Area Power Authority, Sacramento Municipal Utilities District, Pacific Gas & Electric and the Sacramento regional County Sanitation District. Additional statements of interest have been received for future involvement from the State of California Reclamation Board, City of Sacramento Departments of Utilities and Parks & Recreation, Federal Highways Administration and Cal Trans.

**11) DO YOU HAVE ANY SUGGESTIONS FOR NFWF TO GUIDE IMPROVEMENT OF OUR PROJECT ADMINISTRATION?**

The project was slowed by the delays in the granting process, with funding not being secured until well into the field season. In the end these delays were minimized by SAFCA's willingness to take financial risks to keep the project going, but care needs to be taken to avoid such delays.

**Table 1**. Effects of dust from dirt and paved roads on elderberry shrubs. Values are results of three-way ANOVA's testing the effects of three natural treatments (road surface type, site number and distance from the road) on elderberry characteristics, cover of associated vegetation and sediment accumulation. n=6 replicate sites of each treatment combination. Surf = road surface, dist = distance from road, - = P>0.05.

| Dependent variables | Overall | | | P values (only P≤0.05 are shown) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | P | F | df | Site | Surface | Distance | Site×dist | Surf×dist | Site×surf | Site×surf ×dist |
| **Elderberry characteristics** | | | | | | | | | | |
| water potential (bars) | 0.006 | 2.32 | 74 | 0.014 | 0.048 | 0.015 | - | - | - | - |
| average leaf area ($cm^2$) | 0.001 | 2.43 | 116 | - | - | 0.001 | 0.052 | - | 0.052 | - |
| leaf water content (%) | 0.002 | 2.66 | 74 | 0.005 | 0.001 | - | 0.018 | - | - | - |
| average leaf dry weight (g) | <0.001 | 3.44 | 115 | <0.001 | - | <0.001 | - | - | - | 0.021 |
| leaf thickness (g dw $cm^{-2}$) | <0.001 | 3.71 | 116 | <0.001 | 0.005 | - | 0.018 | - | <0.001 | 0.032 |
| shrub height | <0.001 | 3.10 | 114 | - | <0.001 | - | 0.050 | - | 0.003 | - |
| max stem diameter | <0.001 | 3.44 | 116 | 0.009 | - | <0.001 | 0.028 | - | 0.042 | - |
| inflorescences $stem^{-1}$ | <0.001 | 3.78 | 114 | - | <0.001 | 0.001 | 0.033 | - | 0.004 | - |
| fruits $inflorescence^{-1}$ | 0.002 | 2.34 | 116 | - | - | - | 0.004 | 0.035 | 0.046 | 0.017 |
| % dead stems $shrub^{-1}$ | <0.001 | 5.85 | 116 | <0.001 | <0.001 | - | 0.037 | - | <0.001 | 0.027 |
| **Associated vegetation** | | | | | | | | | | |
| % shrub cover | <0.001 | 5.33 | 116 | <0.001 | 0.003 | 0.052 | <0.001 | 0.012 | <0.001 | 0.013 |
| % canopy cover | <0.001 | 12.16 | 116 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| % lichen cover | <0.001 | 6.81 | 116 | <0.001 | - | <0.001 | 0.013 | 0.005 | <0.001 | - |
| **Sedimentation** | | | | | | | | | | |
| leaf sediment (g dw sed $cm^{-2}$) | 0.020 | 1.86 | 116 | 0.050 | - | - | - | - | - | 0.012 |
| background sedimentation rate (mg $cm^{-2}$ $day^{-1}$) | <0.001 | 3.40 | 66 | 0.005 | - | 0.001 | - | 0.027 | - | - |

Table 2. Summary statistics for sediment accumulated on elderberry shrub leaves and aluminum pans. The results are for accumulation of airborne dust within the American River Parkway. Data are from August 2003.

| | A. Leaf sediment (mg dw sediment $cm^{-2}$ leaf) | | | B. Sedimentation rate in pans (mg $m^{-2}$ $day^{-1}$) | |
|---|---|---|---|---|---|
| Range: | 0.012 to 0.042 | | | 13.4 to 605.3 | |
| Site | Mean | SE | | Mean | SE |
| 1 | 0.022 | 0.003 | | 95.5 | 44.2 |
| 2 | 0.021 | 0.003 | | 74.6 | 21.8 |
| 3 | 0.017 | 0.002 | | 168 | 71.8 |
| 4 | 0.025 | 0.003 | | 367.4 | 100.5 |
| 5 | 0.031 | 0.004 | | 257.3 | 78.2 |
| 6 | 0.029 | 0.003 | | 185.5 | 68.6 |

Table 3. Effects of distance from dirt/paved roads on elderberry shrubs and VELB. The table gives statistical results for the effects of the distance from dirt and paved roads on elderberry (*Sambucus mexicana*) characteristics, and the presence or absence of the valley elderberry longhorn beetle along the American River. Values are results of simple regressions (continuous explanatory variables), logistic regressions (beetle presence/absence) or 1-way ANOVA's (categorical class data). Data were collected between June 2002 and March 2003. n=2848 elderberry shrubs, except for max stem diameter where n=524 shrubs; - = P>0.05; blank=not applicable. Of the P values shown, only the overall P value for dead stem classes in paved sites was not significant at the sequential Bonferroni adjusted alpha.

| **Dependent variables** | **DIRT ROADS** | | | **PAVED ROADS** | | |
|---|---|---|---|---|---|---|
| | P | F or $X^2$ | $R^2$ or U | P | F or $X^2$ | $R^2$ or U |
| **Elderberry characteristics** | | | | | | |
| no. shrubs in 1963 $m^2$* | - | - | - | <0.001 | 47.00 | -0.02 |
| maximum stem diameter (cm) | <0.001 | 14.3 | + 0.03 | - | - | - |
| no. stems per shrub | - | - | - | - | - | - |
| height class** | - | - | | - | - | |
| dead stem class*** | <0.001 | 22.83 | | 0.015 | 3.49 | |
| **Beetle presence/absence** | | | | | | |
| new holes | - | - | - | - | - | - |
| 1 yr-old holes | - | - | - | - | - | - |
| old holes | 0.004 | 8.29 | -0.003 | 0.007 | 7.35 | -0.003 |

* 1963 $m^2$ = area of a 25 m-radius circle
** height classes: 2-4 m, 4-6 m, 6-8 m, 8-10 m, >10 m

*** dead stem classes: 0-25%, 25-50%, 50-75%, 75-99%

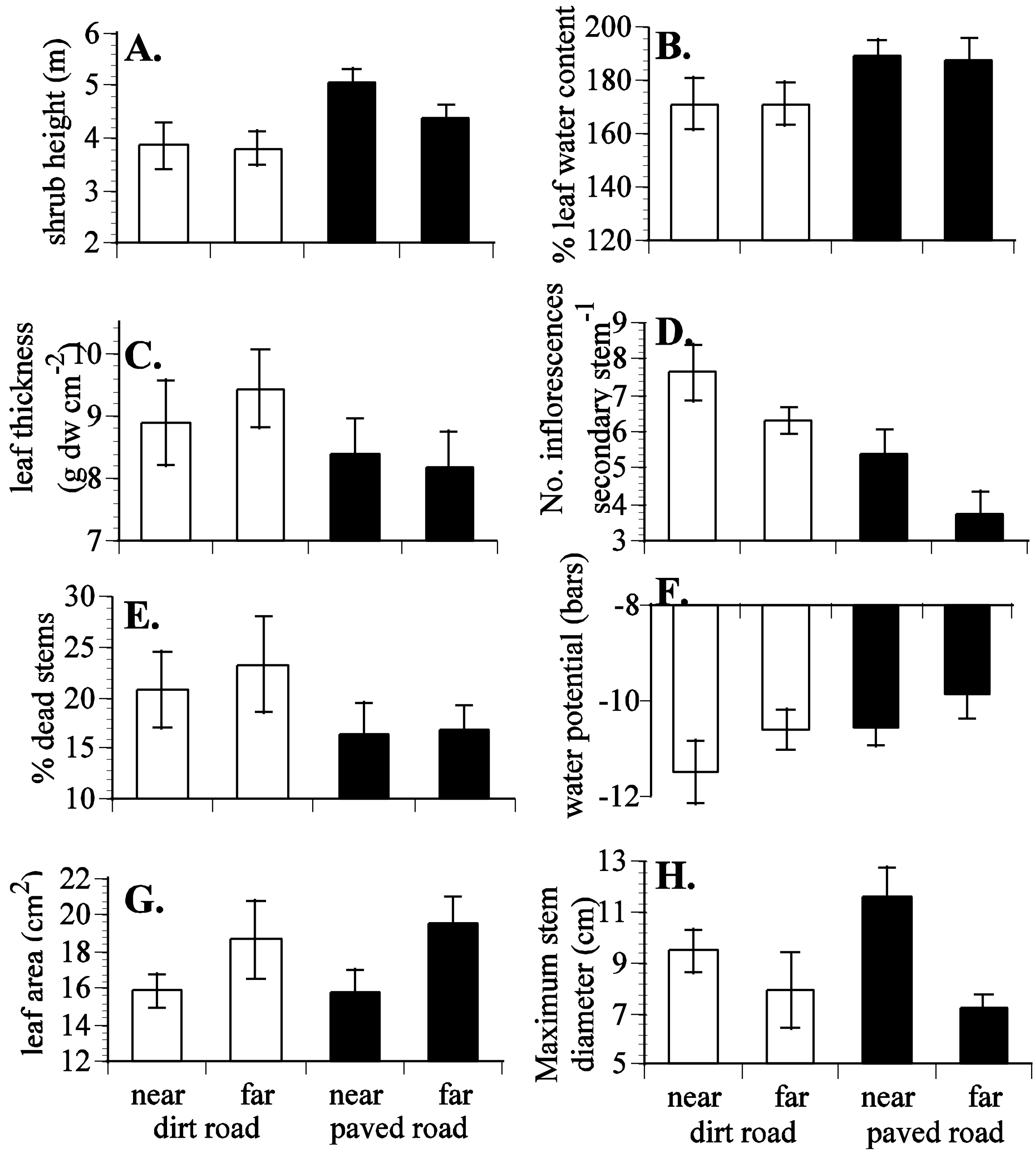



Figure 2. Elderberry characteristics at near and far distances from dirt and paved roads. Near = 2-10 m and Far = 25-40 m from the road edge. Elderberry characteristics were means (±1 standard error) for A. shrub height, B. leaf water content, C. leaf thickness, D. number of inflorescences per secondary stems, E. % dead stems per shrub, F. water stress of shrub, G. leaf area and H. the maximum stem diameter of the shrub. Data were collected during August 2003, n=3 to 5 shrubs for each distance and road surface type, data were pooled across sites for graphical presentation.

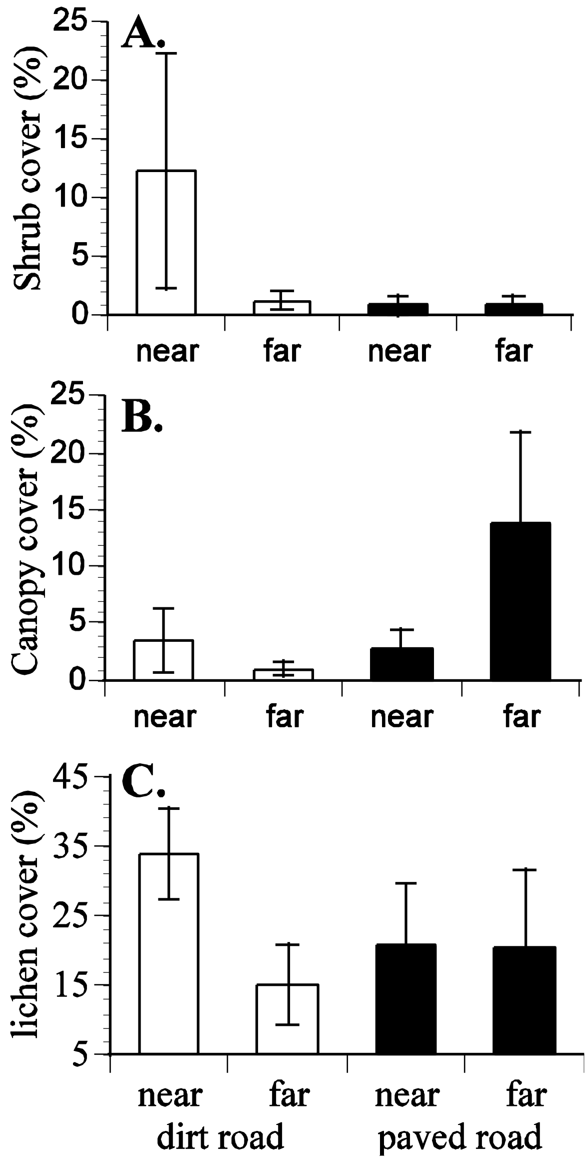



Figure 3. Effects of distance from dirt/paved roads on shrubs, canopy and lichens. (A.) % cover of shrubs, (B.) % canopy cover, and (C.) % cover of lichens associated with elderberry shrubs at near and far distances from both dirt and paved roads along the American River Parkway. Near = 2-10 m and Far = 25-40 m from the road edge. Shrubs and canopy vegetation were those growing over or into the elderberry canopy, while the lichens were covering elderberry stems. Data are means (±1 standard error) and were collected during August 2003, n=5 shrubs per each distance and road surface type, data were pooled across Sites for graphical presentation.

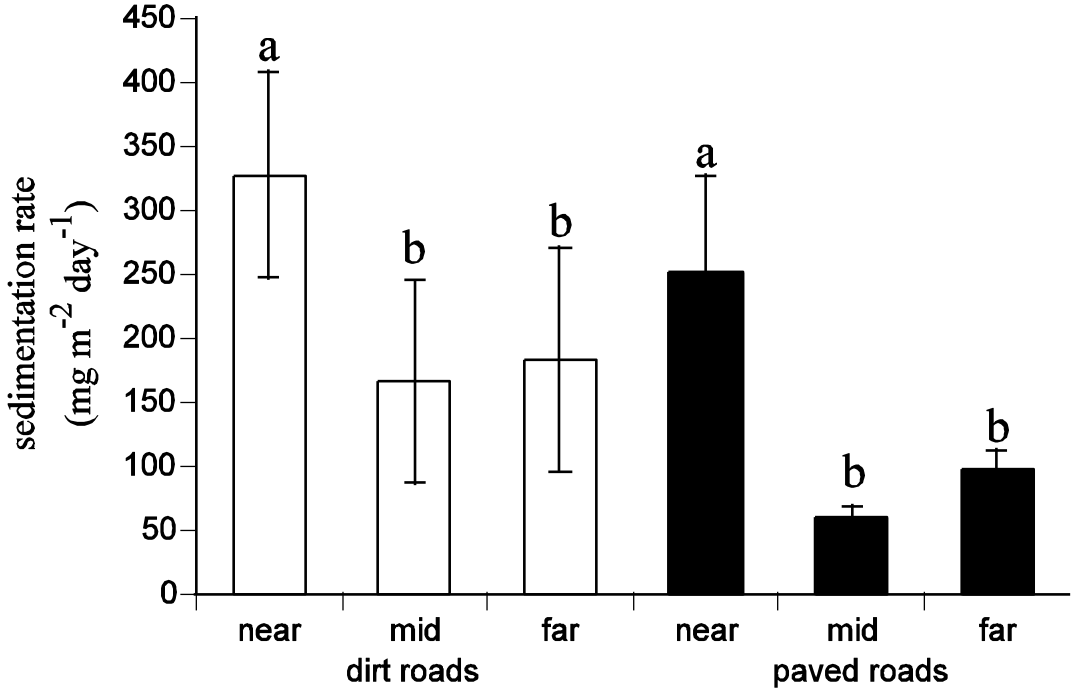



Figure 4. Sedimentation rates for near, mid and far distances from dirt/paved roads. Near = 2-10 m; Mid= 10-25 m; and Far = 25-40 m from the road edge. Data are means (±1 standard error) and were collected during August 2003. n=2 particle collectors per each distance and road surface type placed at ground level. Data were pooled across sites for graphical presentation. Different letters indicate significance at P=0.002.

**Review of VELB species recovery plan by Marcel Holyoak, University of California at Davis, 4/14/2019. Email maholyoak@ucdavis.edu or phone 530-867-3391.**

The draft VELB recovery plan has been prepared to a high standard. With the exception of the points and minor corrections listed below the FWS staff have used the best available scientific and commercial information relevant to this species, provided correct analyses, and reached reasonable and defensible scientific conclusions with the information at hand.

My points below start with the most substantial points of interpretation and end with grammar.

Page 2: The following is not what I would conclude from the cited literature: "with the largest distance between occupied plants (or clumps of plants) being around 1,968.5-2,624.7 feet (600-800 meters) (Talley et al. 2006)" The problem of interpretation also carries across to criterionA1 on the bottom of page 9 where the same distances are used. Talley et al. (2006) is better replaced by Talley (2007, in Ecology), which provides the original statistical analyses. Talley (2007) states about beetle distributions "Local aggregations covering 25–50 m scales occurred at distances of 200–300 m along the American River (Fig. 3) and 600–800 m apart along Putah Creek (Legendre and Fortin [1989] interpret the shapes of correlograms). The extent of each group of aggregations was 800 m along the American River (Fig. 3) and up to several kilometers along Putah Creek. Aggregations along the Cosumnes were more spread out (200–300 m) and were separated by 400–600 m distances, which was about the extent of the distribution in the area sampled." Differences among watersheds could easily just represent the size of areas of high elderberry density within the American River Parkway. It is also hard to give precise demographic meaning to the numbers because we don't know if the occupancy was correlated across the stated distance ("local aggregations" in Talley 2007) because physical or chemical conditions were similar, or because of some demographic process (colonization, extinction, reproduction, survival) was similar across this distance. Then the extent of group of aggregations is even less clear in meaning with respect to beetle demography and likely says more about elderberry distribution, which was highly variable between watersheds. Perhaps the most meaningful figure is that separate aggregations of beetles occurred over distances of 200-800 across the three watersheds that Talley (2007) studied. So less than these distances represented more distinct demographic units for the beetle. For A1 (page 9) perhaps change to say something like "at least five aggregations of elderberry (of up to 200 m extent) that are separated by at least 800 m." The original full sentence from A1 (page 9) "Each HUC8 subbasin within the management unit should contain at least 5, 1,640.4-2,624.7 foot (500-800 meter) patches of quality habitat (see A/4)" could be found in the American River Parkway but not the areas of the two other watersheds studied by Talley (2007): I state this to further clarify why the criterion is problematic.

Table 1. It is not clear what a habitat patch is in this table.

Table 2. The total dollar amount on the last row of the table does not correspond to the numbers above it in the table. The same number is also given in the last paragraph on page 14.

Page 6: "A study completed in 2001 (Collinge et al. 2001) found 6.5% of the sites that were surveyed 6 years earlier showed no continued evidence of valley elderberry longhorn beetle presence." This sentence is problematic in two ways. First, a more full version of what is in Collinge et al. (2001) is that while 6.5% of sites showed extinctions in the 6-year period, 12.9% of sites that were previously unoccupied were colonized during the 6-year period. Second, the 6-year period is from 1991 to 1997, although the paper was not published until 2001.

Page 2: defining a metapopulation as including "human-mediated movement" is strange. Humans could move organisms around or constrain their movement to create any kind of population or metapopulation structure, and since (meta)population types are intended to describe what is happening in nature it is a peculiar definition. Hanski's (e.g. 1997) definition as a series of populations that are connected through movement of some individuals is more general. On Page 2 the distinction between dispersal (a population-level process) and migration (an individual level process) is also unclear and I don't think it means much since migration is presumably just movement and not round-trip seasonal migration.
Hanski, I. A. (1997). Metapopulation dynamics: from concepts and observations to predictive models. In I. P. Hanski & M. E. Gilpin (Eds.), Metapopulation biology: ecology, genetics and evolution (pp. 69–91). San Diego, California: Academic Press.

Page 2. In the Recovery Strategy section this sentence could use a bit less definite wording "The main cause of the decline of the species has been". Perhaps reword to "The main known cause of the decline of the species is".

Page 1: "multiple larvae can occur in one stem if the stem is large enough to accommodate multiple galleries" is better stated as "multiple larvae can occur in one stem if the stem is long enough to accommodate multiple galleries".

A minor point: I believe the correct name is Valley elderberry longhorn beetle. Valley is capitalized because it refers to the Central Valley.

Criterion E/2 page 12: "The 10 year time frame" should be a compound adjective "The 10-year time frame".

U.S. Fish & Wildlife Service

# Draft Revised Recovery Plan for

## Valley Elderberry Longhorn Beetle
## (*Desmocerus californicus dimorphus*)

Photo courtesy of ~~Joe Silviera~~Jon Katz/USFWS

**Commented [SJ1]:** Volunteer photographer for Gilbart (2009).

# Draft Revised Recovery Plan for Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*)

**Region 8**
**U.S. Fish and Wildlife Service**
**Sacramento, California**

Approved: XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

Regional Director, Pacific Southwest Region, Region 8,
U.S. Fish and Wildlife Service

Date: XXXXXXXXXXXXXXXXXX

# Disclaimer

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the U.S. Fish and Wildlife Service (Service), sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the view, official positions or approval of any individuals or agencies involved in the plan formulation, other than the Service. They represent the official position of the Service only after they have been signed by the Regional Director. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new finding, changes in species status, and the completion of recovery actions.

**Literature Citation Should Read as Follows:**

U.S. Fish and Wildlife Service. 2018. Draft Revised Recovery Plan for Valley Elderberry Longhorn Beetle. U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, California. iii + 18 pp.

An electronic copy of this draft recovery plan is available at:
https://www.fws.gov/endangered/species/recovery-plans.html

## Acknowledgements

The recovery planning process has benefitted from the advice and assistance of many individuals, agencies, and organizations. We thank the following individuals for their assistance and apologize to anyone whose name was omitted inadvertently from this list:

**Lead Authors:**

Timothy Ludwick, Sacramento Fish and Wildlife Office

**Other Contributors:**

Amber Aguilera, Sacramento Fish and Wildlife Office
Jana Affonso, Bay-Delta Fish and Wildlife Office
John DiGregoria, Bay-Delta Fish and Wildlife Office

# DRAFT REVISED RECOVERY PLAN FOR VALLEY ELDERBERRY LONGHORN BEETLE (*DESMOCERUS CALIFORNICUS DIMORPHUS*)

## Introduction

This document presents the U.S. Fish and Wildlife Service's (Service) plan for the conservation and recovery of the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). Pursuant to section 4(f) of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.*) (Act), a recovery plan must, to the maximum extent practicable, include (1) a description of site-specific management actions as may be necessary to achieve the plan's goals for the conservation and survival of the species; (2) objective, measurable criteria which, when met, would support a determination under section 4(a)(1) that the species should be removed from the List of Endangered and Threatened Species; and (3) estimates of the time and costs required to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal. This draft revised recovery plan is based on scientific information presented in the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) and the *Proposed Rule; Removal of the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (77 FR 60238, October 2, 2012), which describe the life history and biology of the species, the current status of the species, and the threats that impact the species. Both of these documents are available at https://ecos.fws.gov.

The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) was federally-listed as threatened under the Act on August 8, 1980, and has a recovery priority number of 9, indicating the taxon is a subspecies that is under moderate threat with a high recovery potential (45 FR 52803). The Service designated critical habitat for the species on August 8, 1980.

When listed, the valley elderberry longhorn beetle was known from only 10 records in 3 locations (Merced County, Yolo County, and Sacramento County). Subsequent surveys throughout the Central Valley discovered more locations and the current presumed historical range is now believed to extend from Shasta County to Madera County below 500 feet in elevation (152.4 meters) (79 FR 55874). Although different ranges for the beetle have been proposed in the past, the current presumed range relies only on verifiable sightings or specimens of adult male valley elderberry longhorn beetles (79 FR 55874). Previous iterations of the presumed range used both female sightings and exit holes to determine valley elderberry longhorn beetle presence. Both of these metrics are unreliable as female California elderberry longhorn beetle (*Desmocerus californicus californicus*) and valley elderberry longhorn beetles are indistinguishable in the field and exit holes cannot be accurately assigned to either species (Talley 2005).

Elderberry (*Sambucus* sp.) is the obligate larval host plant for the valley elderberry longhorn beetle. After hatching, the larva creates a feeding gallery (set of tunnels) in the pith at the stem center (Burke 1921, Barr 1991). While only one larva is found in each feeding gallery, multiple larvae can occur in one stem if the stem is large enough to accommodate multiple galleries (Talley et al. 2006). Though rarely observed, adults have been described as feeding on the nectar, flowers, and leaves of the elderberry plant (Arnold 1984, Collinge et al. 2001), or flying between trees (Service 1984).

Previous studies of the beetle (both subspecies) estimated that the larval development period inside the plant is 2 years (Burke 1921, Linsley and Chemsak 1972), but laboratory observations have indicated that the beetle may develop into an adult in a 1-year cycle (Halstead and Oldham 1990). Arnold (1984) reported that females lay eggs singly on elderberry leaves and at the junction of leaf stalks and main stems, with all eggs laid on new growth at the outer tips of elderberry branches.

Because elderberry is the host plant for the beetle, environmental and habitat conditions that favor a robust elderberry community also benefit the beetle. Elderberry is an important component of riparian ecosystems in California (Vaghti et al. 2009). It can be found as an overstory plant or understory plant within these communities. Elderberry also occurs in upland communities such as oak woodland. Occupancy of elderberry by the valley elderberry longhorn beetle is generally low but tends to be highest in riparian communities (Barr 1991, Collinge et al. 2001, Talley et al. 2007).

The valley elderberry longhorn beetle is distributed throughout available habitat in a widely dispersed metapopulation (Collinge et al. 2001, Talley et al. 2006). Metapopulations are defined as a system of discrete subpopulations that may exchange individuals through dispersal, migration, or human-mediated movement (Breininger et al. 2002; Nagelkerke et al. 2002). At local scales, the valley elderberry longhorn beetle occupies elderberry plants in clumps with the largest distance between occupied plants (or clumps of plants) being around 1,968.5-2,624.7 feet (600-800 meters) (Talley et al. 2006). Defining the population at landscape scales is more challenging, but the data suggest that the occupancy status of a particular area of suitable habitat (occupied or unoccupied) is spatially correlated across distances of 6.2-12.4 miles (10-20 kilometers) within the same drainage (Collinge et al 2001). That is, a patch of habitat is more likely to be occupied if there is other occupied habitat within 6.2-12.4 miles (10-20 kilometers). At landscape scales of 6.2 miles (10 kilometers) or less, occupancy appears random (Collinge et al. 2001).

## Recovery Strategy

The known historical range of the valley elderberry longhorn beetle is closely linked to the Great Valley ecosystem (79 FR 55874) of the Sacramento Valley and northern San Joaquin Valley. Research suggests that the valley elderberry longhorn beetle is further constrained by being naturally rare within its habitat. The main cause of the decline of the species has been the loss and degradation of its habitat; therefore, the recovery strategy focuses upon this threat. There has been a significant loss and degradation of riparian and other natural habitats in the presumed historical range of the valley elderberry longhorn beetle, much of which occurred prior to the listing of the species. Katibah (1984) estimated approximately 102,000 acres (41,300 hectares) of riparian forest remained in the Central Valley in 1984, a reduction of about 89 percent from an estimated total of 921,600 acres (373,100 hectares) of pre-settlement riparian forest area. Much of this loss has been driven by agricultural and urban development, and flood control activities throughout the Central Valley. Present day losses of valley elderberry longhorn beetle habitat are much more limited in extent and are often associated with urban development of agricultural areas and the maintenance of levees and other flood control structures. As noted in the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014), ongoing and future maintenance of these levees and other flood control structures may result in additional losses of riparian vegetation and elderberry shrubs. Long-term impacts of levee vegetation management actions may be offset with implementation of mitigation and conservation measures (e.g., establishment of preserves or restrictions on pruning). Although the data are not available to accurately determine the extent of the loss of occupied habitat, the *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) summarized the extent of current elderberry habitat (based on 2009 imagery) mapped within the Central Valley, and assessed how these mapped areas conform to the metapopulation structure of the valley elderberry longhorn beetle as defined by species' experts. This preliminary assessment indicated that elderberry habitat remains limited in extent within the Central Valley and may not currently support the spatial requirements of sustainable metapopulations for the valley elderberry longhorn beetle.

Invasive Argentine ants have been confirmed at several locations occupied by the valley elderberry longhorn beetle (Holyoak and Graves 2010). Projections from climate change modeling indicate suitable conditions will occur for Argentine ants to continue to spread in California during the next several decades (Roura-Pascual et al. 2004; Hartley et al. 2006; Roura-Pascual et al. 2011). Studies show that Argentine ants will attack and consume exposed insect larvae and eggs, including those of the valley elderberry longhorn beetle larvae and may even interfere with adult behavior (Way et al 1992; Talley 2014, pers. comm.).

The predation threat from Argentine ants is likely to increase in the Central Valley as colonies further expand into the species' range unless additional methods of successful control within natural settings become available (Choe et al. 2014). Although additional studies are needed to better characterize the level of predation threat to the valley elderberry longhorn beetle from Argentine ants, the best available data indicate that this invasive species is a predation threat to the valley elderberry longhorn beetle, and it is likely to expand to additional areas within the range of the valley elderberry longhorn beetle.

Additional threats such as pesticide use, climate change, and invasive plants may also threaten the valley elderberry longhorn beetle. Most of these additional threats cannot be quantified because there is not enough information known about the ecology of the beetle or the effect the threat may have on the beetle. The *Withdrawal of the Proposed Rule To Remove the Valley Elderberry Longhorn Beetle From the Federal List of Endangered and Threatened Wildlife* (79 FR 55874, September 17, 2014) provides the most comprehensive summary of all the potential threats to the valley elderberry longhorn beetle. Many of the threats do not act on the beetle in isolation. For example, effects from habitat loss are compounded by potential pesticide effects that may result from having smaller habitat patches immediately adjacent to active agriculture. The recovery strategy focuses on what the Service believes are the largest threats and those actions that have the most ability to provide a concrete path to recovery.

The recovery strategy includes: 1) the establishment of sufficiently large populations throughout the species' range to ensure each population has the resiliency to withstand stochastic events; 2) maintaining the species' current level of representation (genetic and ecological diversity) so it has the capacity to adapt to future environmental changes; and 3) increasing the species' current level of redundancy through the establishment of a sufficiently large number of populations widely distributed throughout the species' range to allow the species to withstand catastrophic events.

We developed the recovery criteria using the concepts described in the species status assessment (SSA) framework (Service 2016). The SSA framework provides a pathway for the Service to consider what the valley elderberry longhorn beetle needs to maintain viability by characterizing the status of the species in terms of its resiliency, representation, and redundancy. Using the concepts of resiliency, representation, and redundancy, we also describe the recovery vision for the species.

Resiliency

Resiliency describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, birth versus death rates and population size. Highly resilient populations are better able to withstand disturbances such as random fluctuations in reproductive rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of anthropogenic activities.

For the valley elderberry longhorn beetle to maintain viability, the populations found throughout the Central Valley must be resilient. Stochastic events that have the potential to affect valley elderberry longhorn beetle habitats and, in turn, their populations include drought, flooding, fire, vandalism, and other natural or human-caused disasters. A number of factors influence the resiliency of populations, including survival, dispersal, abundance, and reproduction. Influencing those factors are elements of valley elderberry longhorn beetle habitat that determine the number of individuals a population can support and whether those populations can increase reproductive success and their distribution, thereby increasing the resiliency of the population. These demographic factors and habitat elements are defined below and are shown in Figure 1.

Demographic factors:

Survival – individuals need to survive to a reproductive stage

Dispersal – because of their population structure and the patchy nature of the habitat, individuals need to disperse to find suitable elderberry shrubs to feed, find mates, and deposit eggs

Recruitment – predation must be low enough and survival sufficient to allow eggs to hatch and larva to develop into adults

Habitat elements:

Elderberry plants – the valley elderberry longhorn beetle only occurs on elderberry plants. Elderberry density tends to increase with riparian community health.

Connectivity – because valley elderberry longhorn beetles have limited dispersal ability, many elderberry patches in close proximity are necessary to support a resilient population of the valley elderberry longhorn beetle

Representation

Representation describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and correlates with the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the more capable it is of adapting to changes (natural or human caused) in its environment. In the absence of species-

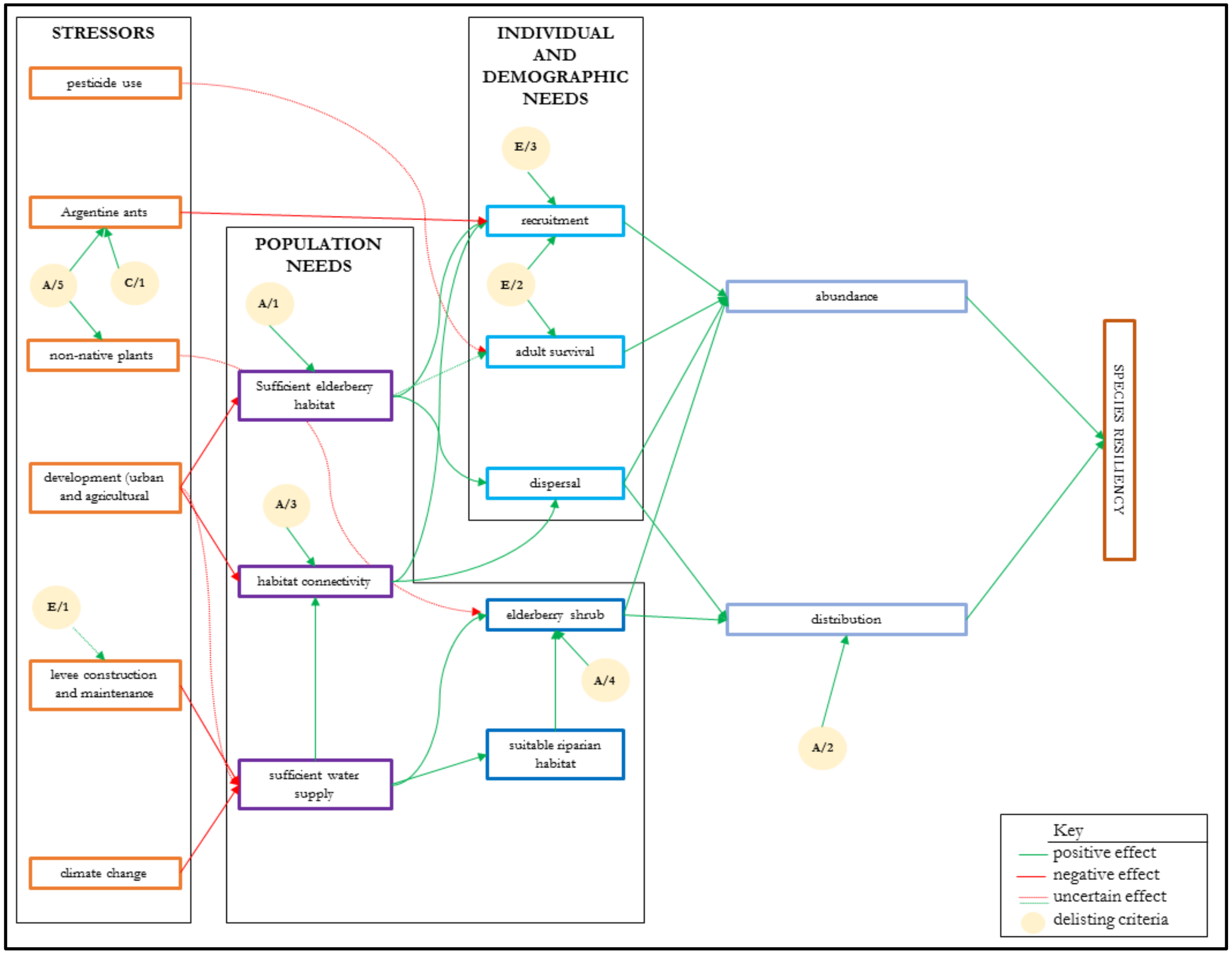



Figure 1. Conceptual model of the stressors and needs influencing the resilience of the valley elderberry longhorn beetle.

specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the species' geographical range.

The level of genetic diversity within and among populations of the valley elderberry longhorn beetle is unknown. Because the valley elderberry longhorn beetle is only found on elderberry, it has likely always been limited to areas of suitable elderberry habitat. Individual shrub occupancy is likely highly stochastic, but the highest quality valley elderberry longhorn beetle habitat (based on occupancy rates) appears to be riparian habitat in the lower alluvial plain (Talley et al. 2007). Valley elderberry longhorn beetle exit holes are generally found on stems that are greater than one inch in diameter, with stems between 0.7 and 4.7 inches accounting for most of the exit hole observations (Talley et al. 2007). Based on these data, habitat restoration, acquisition, and enhancement should focus on riparian communities with a mix of young and mature elderberry shrubs. The habitat should also show signs of natural elderberry recruitment in the form of new saplings or young shoots from established elderberry shrubs. Although the valley elderberry longhorn beetle is found in elderberries in both riparian and non-riparian areas, the selection mechanisms or larger habitat preferences are unknown. Occupancy rates of elderberry in riparian areas are higher, but surveys done in support of several research projects found that most seemingly suitable habitat is not occupied (Barr 1991, Collinge et al. 2001, Talley et al. 2007). It is believed that the valley elderberry longhorn beetle has always been rare with a patchy distribution within its preferred habitat.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations across the range of the species, as well as each population's resiliency, distribution, and connectivity, redundancy gauges the probability that the species has a margin of safety to withstand, or the ability to bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations).

Current data suggest that the valley elderberry longhorn beetle has populations distributed throughout the entire historical range of the species. However, given the amount of habitat lost historically, it is likely that many populations along river systems have been extirpated. A study completed in 2001 (Collinge et al. 2001) found 6.5% of the sites that were surveyed 6 years earlier showed no continued evidence of valley elderberry longhorn beetle presence. However, current scientific studies have not been conducted with enough consistency to ascertain population trends. Based on the information available, it is presumed that the species has a moderate level of redundancy due to broad range but locally rare occurrence.

Recovery Vision

Long-term viability for the valley elderberry longhorn beetle is envisioned as a high level of resiliency, redundancy, and representation through protection of healthy valley elderberry longhorn beetle populations throughout the suitable habitat found in the Central Valley. These populations are conserved in sufficient number and distribution to shield the species from complete loss from catastrophic events such as widespread, prolonged drought, catastrophic fire, extensive flooding, disease or pest outbreaks, and other natural or human-caused disasters. Additionally, populations are adequately protected from recreational activities and the invasion of non-native plant and insect species.

To delist the species, the valley elderberry longhorn beetle's status will require maintaining several self-sustaining metapopulations throughout the historical range in the Central Valley in areas with appropriate habitat. A stable metapopulation is essential to protect the species against local extirpation. It will be challenging to remove or ameliorate all threats to the species (many of the threats, particularly climate change and alteration of hydrologic regimes are difficult to reduce or control). The threat of ongoing loss of habitat in the Central Valley and limited areas for restoration in the southern portion of the range may constrain the populations in that area.

Management Units

Management units are a type of geographic area that can be designated, either with or without recovery units. The management units help organize recovery criteria throughout the range of the species and provide a spatial framework for targeting management actions to specific regions. For the valley elderberry longhorn beetle, three management units have been identified based on watersheds (Map 1). Precipitation varies within each watershed which may influence specific vegetation communities. Each management unit also shows variation in the historical and current development and in the threats to the valley elderberry longhorn beetle.

The management units are:

A. Sacramento River Management Unit
B. San Joaquin River Management Unit
C. Putah Creek Management Unit

Within each management unit, the major river systems correspond to the hydrologic unit code (HUC) 8 subbasin mapping units developed by the United States Geological Survey.

## Recovery Goal

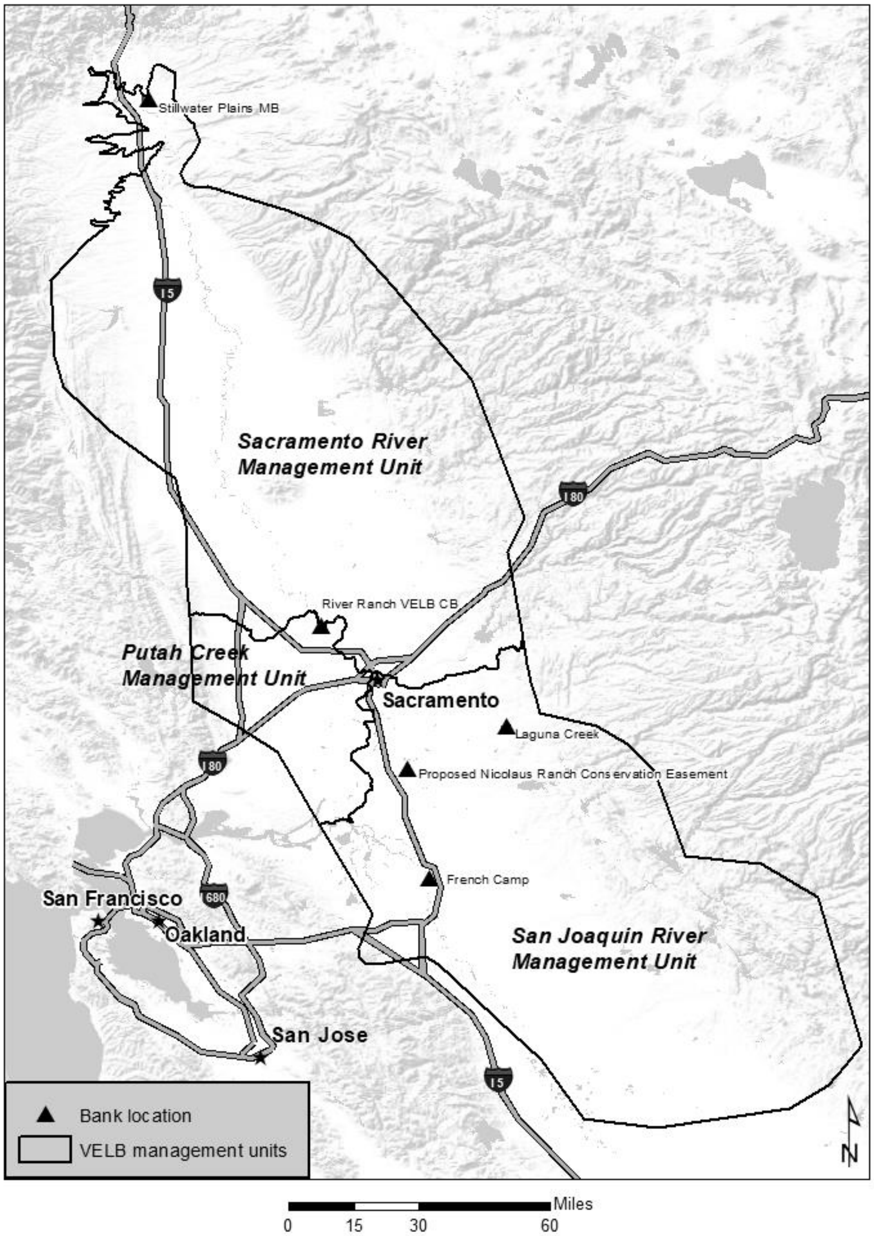
The ultimate goal of this draft revised recovery plan is to outline specific actions that, when implemented, will sufficiently and permanently protect self-sustaining populations throughout the ecological, geographic, and genetic range of the species and reduce the threats to the valley elderberry longhorn beetle to allow for its eventual removal from the Act's protections.

## Recovery Objectives

To meet the recovery goal, the following objectives have been identified:

- Maintain resilient populations of valley elderberry longhorn beetle in at least 80% of the HUC8 subbasins within each management unit (Map 1) across the historical range of the species. Because some of the HUC8 subbasins are either small or have limited opportunities for restoration, 80% was deemed an appropriate number that will provide resiliency for the species.

- Protect and manage a system of connected habitat patches within each HUC8 subbasin.




Map 1. Management units, HUC8 subbasins, and existing conservation banks for the valley elderberry longhorn beetle.

## Recovery Criteria

A threatened species is defined in the Act as a species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. When we evaluate whether or not a species warrants downlisting or delisting, we consider whether the species meets either of these definitions. A recovered species is one that no longer meets the Act's definitions of threatened or endangered due to amelioration of threats. Determining whether a species should be downlisted or delisted requires consideration of the same five factors that were considered when the species was listed and which are specified in section 4(a)(1) of the Act.

Recovery criteria are conditions that, when met, indicate that a species may warrant downlisting or delisting. Thus, recovery criteria are mileposts that measure progress toward recovery. Because the appropriateness of delisting is assessed by evaluating the five factors identified in the Act, the recovery criteria below pertain to and are organized by these factors. These recovery criteria are our best assessment at this time of what needs to be completed so that the species may be removed from the Act. Because we cannot envision the exact course that recovery may take and because our understanding of the vulnerability of a species to threats is likely to change as more is learned about the species and the threats, it is possible that a status review may indicate that delisting is warranted although not all recovery criteria are met. Conversely, it is possible that the recovery criteria could be met and a status review may indicate that delisting is not warranted. For example, a new threat may emerge that is not addressed by the current recovery criteria.

### Delisting Criteria

**<u>Factor A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range</u>**

To delist the valley elderberry longhorn beetle, threats to the species habitat must be reduced. This reduction will be accomplished when the following have occurred:

**A/1** Sufficient suitable habitat patches[1] within each management unit (Table 1) should be protected (i.e., voluntary land acquisitions, conservation easements, or other similar mechanisms). Each HUC8 subbasin within the management unit should contain at least 5, 1,640.4-2,624.7 foot (500-800 meter) patches of quality habitat (see A/4). HUC8 subbasins that are small[2] or where only a small portion of the subbasin is in the management area should contain at least 1, 1,640.4-2,624.7 foot (500-800 meter) patch of quality habitat that meets the criteria in A/3.

[1]Suitable habitat for the valley elderberry longhorn beetle is a riparian community with a mix of young and mature elderberry shrubs as well as signs of natural elderberry recruitment in the form of new saplings or young shoots from established elderberry shrubs.

[2]Small subbasins are those that cover less than 100,000 acres within the management unit. There are 9 subbasins that meet this definition.

Table 1. Current Status of the Valley Elderberry Longhorn Beetle and Its Habitat within the Management Units.

| Management Unit | HUC8 Subbasin | # of protected suitable habitat patches (needed/current) | # of occurrences (CNDDB 2018) |
|---|---|---|---|
| Putah Creek | Lower Sacramento | 5/1[1, 2] | 28 |
| | Lower Cache | 1-5/0 | 3 |
| Sacramento River | Sacramento-Lower Cow-Lower Clear | 5/1[1] | 7 |
| | Upper Cow-Battle | 1-5/0 | 0 |
| | Lower Cottonwood | 1-5/0 | 2 |
| | Mill-Big Chico | 5/0 | 0 |
| | Sacramento-Lower Thomes | 5/0[2] | 31 |
| | Upper Stony | 5/0 | 0 |
| | Upper Butte | 5/0 | 0 |
| | North Fork Feather | 1-5/0 | 1 |
| | Middle Fork Feather | 5/0 | 0 |
| | Honcut Headwaters | 5/0 | 0 |
| | Lower Feather | 5/0 | 25 |
| | Lower Butte[2] | 5/0[2] | 10 |
| | Sacramento-Stone Corral[2] | 5/0[2] | 23 |
| | Upper Bear | 5/0 | 0 |
| | Lower Bear | 1-5/0 | 5 |
| | Upper Coon-Upper Auburn | 1-5/0 | 0 |
| | Lower American | 5/0[2] | 35 |
| | North Fork American | 1-5/0 | 5 |
| | South Fork American | 5/0 | 1 |
| San Joaquin River | Upper Cosumnes | 1-5/0 | 0 |
| | Lower Cosumnes-Lower Mokelumne | 5/2[1] | 13 |
| | Upper Mokelumne | 1-5/0 | 1 |
| | Upper Calaveras | 5/0 | 0 |
| | Lower Calaveras-Mormon Slough | 5/0 | 6 |
| | San Joaquin Delta | 5/1[1] | 3 |
| | Upper Stanislaus | 5/0 | 3 |
| | Upper Tuolumne | 5/0 | 1 |
| | Middle San Joaquin-Lower Merced-Lower Stanislaus | 5/0 | 14 |
| | Upper Merced | 5/0 | 0 |
| | Upper Chowchilla-Upper Fresno | 5/0 | 2 |
| | Middle San Joaquin-Lower Chowchilla | 5/0 | 1 |

[1]A conservation bank exists that has been established for the valley elderberry longhorn beetle (Map 1)

[2]This unit contains protected habitat either on a National Wildlife Refuge, mitigation property, or other protected area, but the extent, condition, or management of the habitat is unknown.

**Commented [SJ2]:** I cannot identify which Subbasins are within the footprint of the Sacrament River NWR.

**A/2** Valley elderberry longhorn beetles should be present in at least 3 locations within each HUC8 subbasin. Currently 45% of the HUC8 subbasins meet this criterion (Table 1).

Because valley elderberry longhorn beetle populations can show a pattern of short-term colonization and extinction (Collinge et al. 2001), this number ensures that redundant populations of beetles are present in each watershed.

**A/3** Protected suitable habitat patches within HUC8 subbasins (see A/1) should be no more than 12.4 mi (20 km) from the nearest adjacent protected suitable habitat patch.

**A/4** Within the areas of protected suitable habitat, there should be a diversity of elderberry life stages and signs of natural recruitment.

**A/5** All areas of protected suitable habitat need to have comprehensive management plans that maintain habitat values for the valley elderberry longhorn beetle and address potential threats such as Argentine ants and invasive plants as well as provide for habitat maintenance and enhancement.

Implementation of habitat management plans is expected to also ameliorate threats described such as altered fire regime, vandalism and changes in environmental conditions resulting from climate change.

**Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes**

The overutilization for commercial, recreational, scientific, or educational purposes is not known to threaten the valley elderberry longhorn beetle at this time. Therefore, no recovery criteria have been developed for this factor.

**Factor C: Disease or Predation**

It is believed that Argentine ants may predate valley elderberry longhorn beetle eggs (Huxel 2000). To delist the beetle, Argentine ants should be eliminated or controlled at sites specifically designated for recovery of the valley elderberry longhorn beetle.

**C/1** A control or eradication program for argentine ants should be implemented at each bank or other conservation area that has been established to support recovery of the valley elderberry beetle.

Control is considered achieved when the population of Argentine ants on a site is not appreciably affecting valley elderberry longhorn beetle recruitment.

**Factor D: Inadequacy of Existing Regulatory Mechanisms**

The inadequacy of existing regulatory mechanisms is not known to threaten the valley elderberry longhorn beetle at this time. Therefore, no recovery criteria have been developed for this factor.

Agencies continue to consult with the Service under the Act. To date, consultations under the Act have resulted in many protected habitat sites for the valley elderberry longhorn beetle.

**Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence**

Other natural or manmade factors believed to affect the continued existence of the valley elderberry longhorn beetle: changes in hydrology from water management, changes in environmental conditions resulting from climate change, trampling and vandalism of the host plant, pesticide overspray from adjacent agriculture (79 FR 55874). To delist the valley elderberry longhorn beetle, these threats must be reduced. This reduction will have been accomplished when the following have occurred:

**E/1** Water flows are sufficient to promote healthy elderberry and riparian habitats at all sites identified in A/1. Healthy habitats are those that have a diverse native plant community and show recruitment and multiple age classes of elderberry shrubs.

**Commented [SJ3]:** I agree:
For the middle Sacramento River (Hwy 36/ Red Bluff to Hwy 20/ Colusa—100-river miles), the meandering portion of the river (an alluvial system), physical processes must be restored to create healthy riparian and floodplain habitats. These processes are hydrogeomorphic, characterized by overbank flows, lateral bank movement, scouring, sediment transport and deposition.

Background:
Sacramento River NWR consists of 10,355 acres on 31 units along 81 river miles within the 100-year floodplain (roughly, the recent 100-150 year meander zone). Approximately 5,360 acres have been restored through horticultural re-vegetation and 4,535 acres are remnant. Between 1990 and 2012, refuge restoration partners (The Nature Conservancy and River Partners) have planted about 114,420 elderberry shrubs (formerly, *Sambucus mexicana*) in a variety of floodplain habitats, including Valley Oak/ Elderberry Savanna, Valley Oak Riparian Forest, and Mixed Riparian Forest. VELB colonization is occurring at these restored floodplain habitats (River Partners 2004; Gilbart 2009; Kirk & Hunt 2018). However, continued periodic monitoring is needed to determine longterm population trends.

Note:
Horticultural restoration has benefited many riparian and floodplain taxa in the shortterm (Golet et al. 2008); however, river physical processes must be restored for longterm survival of various taxa (Golet et al 2013 and Appendix A). This is especially true for Sacramento River NWR, where irrigation wells and electricity are decommissioned and removed after horticultural restoration is completed.

**E/2** At least 2 of the locations in A/2 show long-term population viability. For the purpose of recovery, long-term is defined as at least 10 years.

The 10 year time frame is long enough to account for short-term colonization and extinction (Collinge et al. 2001) and encompasses years with average, above-average, and below-average rainfall conditions. The populations must demonstrate the ability to survive both precipitation extremes.

**E/3** In order to maintain resiliency, the populations identified in A/2 should have 2-3 recent exit holes/1,076.4$ft^2$ (100$m^2$) of elderberry habitat.

Density information is based on Talley (2005) from areas along Putah Creek and the American River with known long-term persistent populations.

## Recovery Actions

The actions identified in Table 2 below are those that, based on the best available science, the Service believes are necessary to move towards the recovery and delisting of the valley elderberry longhorn beetle.

Priority numbers are defined per Service policy (Service 1983) as:

Priority 1: An action that must be taken to prevent extinction or to prevent a species from declining irreversibly.

Priority 2: An action that must be taken to prevent a significant decline of the species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery of the species.

**Table 2.** Recovery actions and estimated costs.

| Recovery Action | Criteria Addressed | Priority Number | Estimated Cost |
|---|---|---|---|
| 1. Acquire, enhance, restore, and protect suitable habitat for the valley elderberry longhorn beetle. This action involves land acquisition, habitat management, and site improvements. | A/2, A/4, A/5 | 1 | $100,000/HUC8 Subbasin[1]<br>Total: $3,300,000[2] |
| 2. Develop management and monitoring plans for protected riparian areas that consider the threats and needs of the valley elderberry longhorn beetle. Plans should include status and demographic monitoring, non-native predator control, habitat enhancement, and other needed activities that may increase the resilience of the valley elderberry longhorn beetle. | A/1, A/2, A/3, A/4 | 1 | $30,000/HUC8 Subbasin[1]<br>Total:$990,000[3] |
| 3. Include valley elderberry longhorn beetle conservation as a component of state and local programs to protect riparian habitat. | A/1, A/2, A/3, A/5, E/1 | 3 | --- |
| 4. Complete studies that focus on: habitat patch size, elderberry density, and connectivity that influence the viability of individual valley elderberry beetle populations; influences on demography and reproductive rates of the valley elderberry longhorn beetle; and factors that influence or limit adult dispersal. | E/2 | 3 | $50,000 |
| 5. Conduct surveys for the valley elderberry longhorn beetle in each HUC8 subbasin to monitor and assess the health of known populations and to locate new populations. | A/2, E/3 | 2 | $100,000 |
| **Total Estimated Cost** | | | **$4,400,000** |

[1]There are 33 HUC8 subbasins within the range of the valley elderberry longhorn beetle.
[2]The total cost assumes that acquisition of 5 habitat patches in each subbasin is not required because there are already existing habitat patches that are suitable for the valley elderberry longhorn beetle that the Service is unaware of or that only need adequate management plans.
[3]The total cost assumes that many existing management plans require only minor updates to address valley elderberry longhorn beetle conservation.

**Commented [SJ4]:** I strongly agree that Recovery Actions 1 and 2 are necessary for the recovery VELB through land acquisition, habitat restoration and management, and monitoring and investigations. Monitoring and research would include: VELB colonization and occupancy with consideration for habitat/ vegetation variables; and elderberry bush seed dispersal (mechanisms—birds; floodplain soils conditions/ scour and/ or sedimentation) germination, growth, and survival.

## Estimated Time and Cost of Recovery Actions

The estimated cost of completing the recovery actions such that the criteria have been met and the species may be considered for delisting is $4,400,000. We estimate that these actions could be accomplished by 2050, assuming that only limited areas of suitable habitat have adequate protection. Several factors contribute to the long estimated time to reach the delisting threshold. Although, many presumed extant populations of the valley elderberry longhorn beetle are known from throughout the range, none have been monitored with enough frequency to determine long-term viability. Additionally, although several areas along the Central Valley river systems are under varying levels of protection, not all of them have adequate considerations for the valley elderberry longhorn beetle. Recovery actions place an emphasis on acquiring, maintaining, and protecting suitable, connected habitat for the valley elderberry longhorn beetle. In addition to specific preserves managed for the protection of the valley elderberry beetle, riparian restoration is occurring throughout the Central Valley that may contain suitable habitat for the valley elderberry longhorn beetle. Partnerships between federal, State, and non-governmental partners may significantly decrease the time needed to achieve the delisting criteria.

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# Appendix A. Detailed Information on Individual Ecological Indicators

## Table of Contents

## Forest Patch Core Size

*Definition:* Forest patch core size is a landscape pattern indicator that is a characterization (derived by FRAGSTATS, McGarigal and Marks 1994) of the size of the patches, minus the edge effect zone.

*Rationale:* Patch core size can help define the value of patches for particular taxa and ecological processes. For taxa that are edge sensitive, patch core size may be more meaningful than just total patch size (Hansen and di Castri 1992).

*Methods:* Vegetation landcover types (including forest) in the Sacramento River riparian zone (Red Bluff to Colusa) were mapped from visual interpretation of georectified aerial photographs taken in 1997 and 2007. Forest patch core size was calculated with FRAGSTATS (McGarigal and Marks 1994) for both years.

*Results:* Mean core area for forested patches increased dramatically from 1997 to 2007 (Table 1).

**Table 1.** Comparison of landscape pattern indicators for forest habitats on the Sacramento River. Values listed are area-weighted means with standard deviations provided in parentheses. Data from and Schott and Shilling.

| Indicator | Year | | Percentage change |
|---|---|---|---|
| | 1997 | 2007 | |
| Forest patch core size | 12.4 (4.1) | 88.1 (15.3) | +610% |
| Forest patch proximity | 15.6 (31.1) | 204.9 (588.9) | +1,215% |
| Forest edge contrast | 48.8 (23.1) | 72.0 (13.0) | +48% |

*Interpretation:* Mean core area for forested patches has increased dramatically; whether because of the creation of large patches of forest, or because of the augmentation of existing patches. Herbaceous, scrub, and wetland have all decreased in mean patch core area. Differences between 1997 and 2007 in gravel bar and wetland may be related to differences in height of inundation, as opposed to real changes in actual extent.

## Forest Patch Proximity

*Definition:* Forest patch proximity is a landscape pattern indicator that is a characterization of the proximity of a forest patch relative to other forest patches. Patch proximity is the corollary of a commonly used landscape metric called patch isolation.

*Rationale:* Forest patch proximity can help characterize the value of patches for particular taxa and ecological processes. Typically, the more isolated the patch, the less likely it will provide high habitat value. Highly fragmented landscapes tend to have more isolated, lower proximity, patches, and lower overall habitat value (Johannesen et al. 2000, Betzholtz et al. 2007).

*Methods:* Vegetation landcover types (including forest) in the Sacramento River riparian zone (Red Bluff to Colusa) were mapped from visual interpretation of georectified aerial photographs taken in 1997 and 2007. Forest patch proximity was calculated with FRAGSTATS (McGarigal and Marks 1994) for both years.

*Results:* Forested patches were dramatically improved in their proximity to other forested patches between 1997 and 2007 (Table 1).

*Interpretation:* This result suggests an improvement in habitat condition for area sensitive species (e.g., Yellow-billed Cuckoo, [*Coccyzus americanus*]).

**Forest Edge Contrast**

*Definition:* Forest edge contrast is a landscape pattern indicator that is a characterization of structural contrast between forest habitat and other habitat types along adjoining patch edges. For example, a high contrast edge is found between a row crop field and a remnant patch of mature riparian forest, while a low contrast edge is present between mature riparian forest and older restored riparian forest.

*Rationale:* This is a useful indicator because some forest-dwelling species are edge-sensitive, meaning that they are adversely impacted by various factors associated with high contrast edges. This indicator has been used previously in research of various taxa, including plants (Hernandez-Stefanoni 2006), insects (Debuse et al. 2007), birds (Zharikov et al. 2007), and mammals (Desrochers et al. 2003, Constible et al. 2006).

*Methods:* Vegetation landcover types (including forest) in the Sacramento River riparian zone (Red Bluff to Colusa) were mapped from visual interpretation of georectified aerial photographs taken in 1997 and 2007. Forest edge contrast was calculated with FRAGSTATS (McGarigal and Marks 1994) for both years.

*Results:* Between 1997 and 2007, edge contrast increased substantially for forested patches (Table 1).

*Interpretation:* Given that the total forest core area has increased 5 fold in extent in that time, it is likely that the increase in edge contrast is due to new forest establishment in areas that adjoin agriculture. For core-forest dependent species, an increase in edge contrast is expected to extend edge effects into the forest patch interior, however this impact is likely offset by increases in overall patch size.

**Percent of Historical Riparian Zone Currently in Conservation Ownership**

*Definition:* Percent of historical riparian zone currently in conservation ownership is defined as the subset of the area that was formerly in riparian habitat that is currently owned by a conservation entity.

*Rationale:* This is a valuable indicator because the amount of land that is managed for conservation influence the well being of ecological resources in the area.

*Methods:* Conservation entities may be state (e.g., DFG, DWR), federal (e.g., USFWS, BLM), or private (e.g., TNC, Northern California Regional Land Trust, River Partners). The historical riparian zone was defined by Greco (1999) from the Holmes et al. (1913) soil map of the Sacramento River Valley. To calculate this indicator, this zone was reduced to include only the main stem of the Sacramento River between Colusa Bridge and Red Bluff Diversion Dam. In total this is 73,437 hectares. The area is that is in conservation ownership is not currently all in habitat. Some is in agriculture that is slated for restoration.

*Results:* In 2007, 16.2% of the historical riparian zone was in conservation ownership. The corresponding value in 1999 is between 9.3% and 10.5%. This is reported as a range rather than an absolute number because some conservation ownership properties were purchased before 1999 but had more land added to them after 1999. Since the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999.

*Interpretation:* Conservation ownership increased by at least 35% (and up to 43%) from 1999 to 2007. The increase in conservation ownership is a result of ongoing acquisitions by conservation entities and state and federal agencies. Having more land in conservation ownership should result in improved habitat management for wildlife.

**Percent of Historical Riparian Zone Currently in Natural Habitat**

*Definition:* Percent of historical riparian zone currently in natural habitat is defined as a subset of former habitat area that is in natural habitat.

*Methods:* The location and extent of natural habitat was mapped from visual interpretation of georectified aerial photographs. Some of this land may be being used for grazing, but generally there is not active clearing of vegetation (with the exception of exotics control) on these sites. Restoration sites where active planting of native species has taken place are included. Mapping was done in 1999 and 2007 according to methods described in Nelson et al. (2008).

*Rationale:* This indicator is complementary from the previous one in that it accounts for habitat that is privately owned, and in that it omits lands in conservation ownership that have not yet been restored. The amount of habitat influences biodiversity health for area-sensitive species.

*Results:* In 2007, 17.7% of the historical riparian zone (within the mapped area) was in natural habitat. This value includes restored areas. If restored areas are excluded then the value is 14.9%. In 1999 the value was 16.0% including restoration sites.

*Interpretation:* This represents an 11% increase in habitat over 8 years. This is smaller than expected, given the substantial increase in land in conservation ownership over this same time period. There are several plausible explanations for the decrease being smaller than expected. One is that some of the sites that were acquired by conservation entities are still in agriculture and have not yet been restored with native species. Another is that the mapping done in 1999 may have be more comprehensive of small “stringers” of habitat that are small in and of themselves, but that collectively add up to a significant amount of habitat. Also it is conceivable that what was mapped as habitat differed between the two time periods. Finally, it is possible that the increase was in fact small, and that there has been some clearing of habitat in areas not in conservation ownership (e.g., around existing farms). Further examination of the data to understand the observed pattern is warranted.

This comparison demonstrates that restoration has increased the amount of riparian habitat in the historical riparian zone by ~19%. Note that this does not imply that riparian habitat has increased by this amount over the time period that restoration has been implemented (post 1989). That amount is calculated by another indicator comparison.

**Percent of Riparian Shoreline Bordered by >500 Meters of Natural Habitat**

*Definition:* This indicator is defined as the fraction of total shoreline that is bordered by >500 meters of natural habitat.

*Rationale:* Terrestrial habitats surrounding wetlands are critical to the management of natural resources. They are core habitats for many semi-aquatic species that depend on mesic ecotones to complete their life cycle. Having a riparian buffer provides benefits in terms of water quality (e.g., toxin sequestration), shaded riverine aquatic habitat, and connectivity for species that utilize both the aquatic and terrestrial realm. Proximity of aquatic to upland habitat is important for many species such as bats that forage over the river but roost in trees, and turtles that nest in upland sites but that otherwise reside in the aquatic realm. In a literature review by Semlitsch and Bodie (2003), core terrestrial habitat ranged from 159 to 290 m for amphibians and from 127 to 289 m for reptiles from the edge of the aquatic site.

*Methods:* This indicator is calculated by summing the total length of the river on both sides that has natural habitat >500 meters deep perpendicular to the bankline, dividing this by the total length of bank, and multiplying the resulting quotient by 100. Natural habitats were mapped from visual interpretation of georectified aerial photographs was done in 1999 and 2007 according to methods described in Nelson et al. (2008).

*Results:* As of June 2007, 22.3% of the riparian shoreline was bordered by a buffer of natural habitat that was 500 meters or greater. If restoration areas not included, the value drops to 14.3%. In 1999 the corresponding total value was 15.6%.

*Interpretation:* This represents a 43% increase over 8 years. This indicator increased considerably more than one discussed above (percentage of historical riparian zone in natural habitat). The relatively greater increase may be the result of restoration activities being focused on properties that have river frontage, as opposed to those that are not adjacent to the river. It is appropriate that restoration focus most intensively on the riverbank, as this benefits both riparian and aquatic species and communities. Restoration has increased the amount of riparian habitat in the historical riparian zone that has a buffer of natural habitat by ~56%.

**Number of In-channel Large Woody Debris Aggregations**

*Definition:* The number of in-channel large woody debris aggregations was defined as the total number of mapped aggregations of wood in the main river channel.

*Rationale:* Having a multitude of microhabitats within rivers benefits native species and communities with diverse life history needs. Large woody debris (LWD) provides important habitat for fishes and aquatic invertebrates. It reduces predation risk, provides visual isolation that reduces contact between fish, offers a velocity refuge which minimizes energetic costs, provides increased surface area for growth of prey items. It provides spatial reference points for riverine species to assist with navigation and orientation to surroundings and plays a role in shaping channel and floodplain morphology by influencing sediment deposition and erosion (Crook and Robertson 1999, USFWS 2000). Riparian, riverbank and flow management strategies all have pronounced influences on wood in streams (Meleason et al. 2003).

*Methods:* Debris aggregations were mapped by visually inspecting georectified aerial imagery from Colusa Bridge to Red Bluff Diversion Dam at a 1:2,000 scale on a computer screen. Aggregations of wood were considered separate if they were 5 or more meters apart. Submerged woody debris was included if it caused a noticeable disturbance on the surface of the river. Inspected imagery was from 1999 and 2007.

*Results:* GIS analysis of aerial photos taken in June 2007 revealed 387 aggregations of large woody debris in the river between Red Bluff and Colusa. Analyses conducted by the same technician of the June 1999 aerials documented 738 aggregations.

*Interpretation:* There were approximately twice as many aggregations of woody debris in the river in 1999 as there were in 2007. It may be the case that more wood was in the river in 1999 due to the very high flow events that took place in 1997. Regardless of the cause, it is interesting to note the difference, given the great importance of wood in rivers to aquatic biota.

### Soil Organic Carbon

*Definition:* This indicator is defined as the percent of carbon in the soil.

*Rationale:* Soil carbon and nutrient cycling are of fundamental importance to biological systems and play a central role in water retention, which directly affects site productivity (Aber and Melillo 2001). The dense vegetation of mature riparian forests provides a constant source of plant litter that decomposes to become humic substances that comprise soil organic matter (SOM). Afforestation is generally thought to increase soil carbon and by correlation SOM (Bashkin and Binkley 1998). The development of soil profiles from riparian/floodplain sediments can significantly affect and potentially reflect riparian restoration progress. Soil organic carbon is reliably quantified through instrumental analysis.

*Methods:* Soil organic carbon was measured at 10-cm depth in springtime with Total Organic Carbon (TOC) analytical equipment. Soil organic carbon was measured in 2000 and 2001 over four seasons at two restoration sites (aged 2 and 8-9 years) and at an adjoining remnant forest site. Mean seasonal carbon concentrations were calculated from nine samples collected for each location (Brown and Wood 2002).

*Results:* At 10-cm depth, the natural riparian forest site (WCB) had the highest soil carbon content, and the youngest restoration site (Site VII) had the lowest. The older restoration unit (Site II) had an intermediate level (Fig. 1). This pattern was also evident at other soil depths studied.

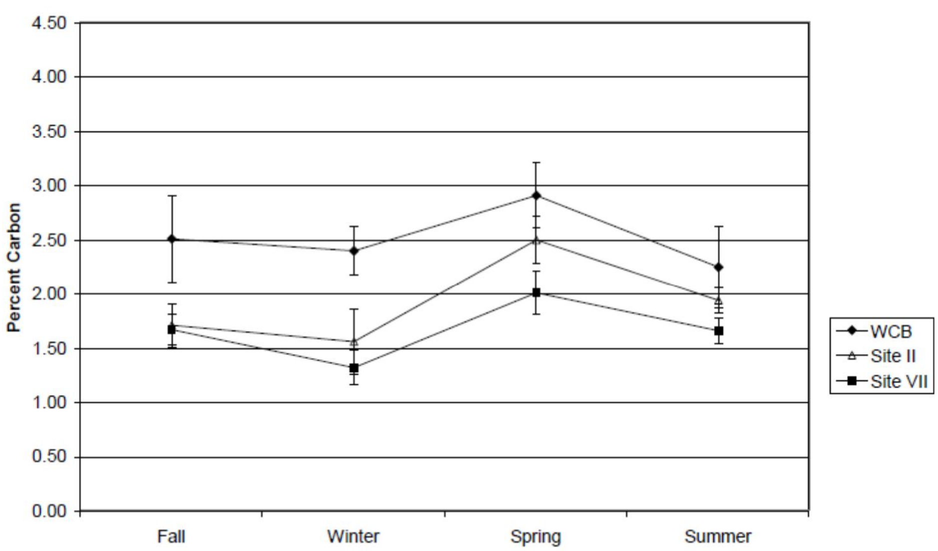



**Figure 1**. Soil carbon at 10-cm depth. Values are means +/- 95% confidence intervals. Reprinted from Brown and Wood (2002).

*Interpretation:* Given the greater amount of standing biomass and subsequent leaf litterfall in the WCB site, it is not surprising that this site should contain a greater amount of soil carbon than the restoration sites. Still, the restoration sites are not deficient in soil carbon. An increase in soil carbon at the older restoration site suggests that this ecosystem process becomes more active as sites mature.

**Areal Extent of Vegetation**

Vegetation maps were used to develop several indicators including a composite indicator of native vegetation and a suite of others that represent individual non-native invasive plant species.

*Definition:* The areal extent native vegetation indicator is defined as the area mapped as annual and perennial grassland, Fremont cottonwood (*Populous fremontii*) forest, mixed riparian forest, riparian scrub, and Valley oak (*Quercus lobata*) woodland. The non-native invasive indicators are measures of the area mapped as giant reed (*Arundo donax*), black walnut (*Juglans hindsii x*), Himalayan blackberry (*Rubus discolor*), and water primrose (*Ludwigia peploides)*.

*Rationale:* One of the fundamental factors influencing whether or not the habitat needs of wildlife are being met is the aerial extent of habitat. Native vegetation generally provides better habitat than non-native vegetation, given that native wildlife evolved to utilize the former. For example, it is not uncommon for a single oak tree to support 20-30 species of cynipid wasps (Pavlik et al. 2000), whereas the highly invasive black walnut, which commonly displaces oaks, supports none. Fremont cottonwood and Valley oak have been shown to be important determinants of riparian bird abundance in the Central Valley (Nur et al. 2008), and the area of cottonwood forest is a fundamental determinant of habitat availability for the state threatened, riparian obligate Yellow-billed Cuckoo (Girvetz and Greco 2009).

Of the non-native species, there is greatest concern for those that are highly invasive. All of non-native vegetation indicator species have this trait. Giant reed is a useful indicator because it displaces native willow species but provides little habitat value. The plant structure is unlike any native riparian plant and offers little useful cover or nest placement opportunities for birds. It has also been shown to lack canopy structure to provide shading of bank-edge river habitats (Bell 1997, Dudley 1998). If giant reed becomes abundant in the riparian system, it can make these areas much more susceptible to catastrophic wildfire. It transpiration rate is three times that of native vegetation (McWilliams 2004). Giant reed is listed in the California Invasive Plant Inventory Database (Cal-IPC) with a “high” rating. Species with this rating have moderate to high rates of dispersal and establishment and have severe impacts on plant and animal communities as well as physical processes (Cal-IPC 2006). It is also listed with the California Exotic Pest Plant Council (CalEPPC) with a List A-1 rating which is reserved for aggressive invaders that displace natives and disrupt natural habitats. Millions of dollars have been spent in the past 10 years to remove *A. donax* from river systems and estuaries in the state (Sawyer et al. 2009).

The naturalized black walnut is a meaningful indicator because its distribution in the riparian forest is indicative of the degree to which certain native riparian species are displaced. There is particular concern over the displacement of the native Valley oak by this species which appears to colonize sites approximately 10 years after they become forested (Wood 2003). All *Juglans* species are allelopathic to other plants (Anderson 2002).

The naturalized Himilayan blackberry is a meaningful indicator because its distribution in the riparian forest is indicative of the degree to which certain native riparian species are displaced. It commonly occurs as an early seral species in relatively open disturbed areas. It grows rapidly in favorable (sunny) conditions, spreading 5 to 15 meters in a growing season and having canes as long as 7 meters. The canes grow more upright at first then cascade onto surrounding vegetation, shading out other shrubs and small trees. As the blackberry thicket matures, the layers of dead canes coalesce to create a single dense, thick mass which provides ideal nesting habitat for rats. Non-native roof rats (*Rattus rattus*) are common in Sacramento River riparian areas (Golet et al. 2007, 2011) and are a concern due to impacts they may have on breeding birds and bats. The dense thickets of mature brambles with dead canes and litter buildup also pose a potential fire hazard. Blackberry does, however, have some wildlife benefits. Fruits are highly palatable to birds and mammals. Thickets of blackberry form suitable nesting sites for many species of birds, and mammals, such as rabbit, squirrel and beaver, use blackberry thickets for cover. It is listed with a “high” rating in the California Invasive Plant Inventory published by the California Invasive Plant Council (Cal-IPC 2006).

Water primrose is a meaningful indicator because its distribution in backwater areas is indicative of the degree to which these areas have had their wildlife habitat value degraded. It grows quickly in warm weather and can take over entire slow-flowing water bodies. Biomass doubling time in California is 23 days (Rejmánková 1992). *Ludwigia* possesses allelochemicals that inhibit growth and survival of native species such as watercress (Dandelot et al. 2008). Because its leaves are above the water surface, *Ludwigia* adds little oxygen to the water column. Sprawling *Ludwigia* mats can impede water flow and increase sedimentation, thus reducing the lifespan of individual off-channel waterbodies. This is detrimental to the ecosystem as off-channel water bodies provide habitat value for a multitude of species (Morken and Kondolf 2003). It is listed with a “high” rating in the California Invasive Plant Inventory (Cal-IPC 2006).

*Methods:* In both 1999 and 2007 vegetation was mapped from aerial photographs (Nelson et al. 2008). The 1999 vegetation data layer was established from analysis of aerial photos taken from May 18-21, and the 2007 data layer was from flights on June 26. Although the mapped categories were not identical in the two years analyzed, a crosswalk of categories was developed which allowed comparisons to be drawn between the time periods.

*Results:* Between 1999 and 2007 the total area comprised of native vegetation increased by at least 16%. Results are detailed in Table 2.

**Table 2.** Comparisons of area mapped as various vegetation classes in two time periods from aerial imagery. Because mapping methodologies changed, not all values are strictly comparable (see text for details). Values are in hectares. Data from Nelson et al. (2008). Analyses by TNC (unpublished).

| **Vegetation Class** | **Years** | | |
|---|---|---|---|
| | **1999** | **2007** | **% Change** |
| **Natives** | | | |
| Annual and perennial grasses and forbs | 1,386 | 1,779 | 28 |
| Fremont cottonwood (*Populus fremontii*) forest | 1,678 | 3,113 | 85 |
| Mixed riparian forest | 2,216 | 456 | -79 |
| Valley oak (*Quercus lobata*) woodland | 663 | 1,594 | 140 |
| Riparian scrub | 893 | 972 | 9 |
| **Total** | 6,836 | 7,913 | 16 |
| **Non-native Invasives** | | | |
| Giant reed (*Arundo donax*) | 49 | 55 | 11 |
| Black walnut (*Juglans hindsii*) | 91 | 1,027 | 1023 |
| Water primrose (*Ludwigia peploides*) | 137 | 157 | 14 |
| Himalayan blackberry (*Rubus discolor*) | 91 | 125 | 37 |
| **Total** | 369 | 1,364 | 270 |

Restoration sites have contributed a considerable amount of habitat along the Sacramento River. Table 3 lists the amount of vegetation in various classes at Sacramento River restoration sites in June 2007, as determined by mapping of georectified aerial photos (Nelson et al. 2008).

**Table 3.** Amount of vegetation in various classes found at Sacramento River restoration sites in June, 2007. Also shown is the total amount of each vegetation class mapped across the entire study area (which approximates the historical riparian zone), and the percentage of this that is contributed by restoration. Values are in hectares. Data from Nelson et al. 2008; analyses by TNC.

| Vegetation Class | Area in restoration | Total area | % in restoration |
|---|---|---|---|
| Box elder (*Acer negundo*) | 18 | 349 | 5 |
| Blackberry scrub (*Rubus discolor*) | 2 | 116 | 2 |
| California annual grasses | 228 | 1,551 | 15 |
| California sycamore (*Platanus racemosa*) | 0.1 | 71 | 0.1 |
| Fremont cottonwood (*Populus fremontii*) | 1,095 | 3,111 | 35 |
| Mixed willow (*Salix* spp.) | 23 | 745 | 3 |
| Perennial grassland | 63 | 188 | 34 |
| Riparian scrub | 77 | 976 | 8 |
| Valley oak (*Quercus lobata*) | 657 | 1,599 | 41 |
| **Total** | 2,162 | 8,704 | 25 |

Of note is the amount of planted Valley oak (41%) and Fremont cottonwood (35%) that is being contributed to the total habitat in the area. It is also interesting to consider that ~25% of the entire area that was mapped in the riparian habitat classes listed above is found on restoration sites.

*Interpretation:* The observed increase in habitat is considerable, and undoubtedly has provided benefits to area sensitive riparian species. The increase is likely more than shown because in 1999 black walnut was not separated out as a distinct vegetation category to the same degree that it was in 2007. Specifically, some of the areas that were classified in 2007 as black walnut (as well as cottonwood forest and Valley oak woodland), were coded as mixed riparian in 1999. This would explain the apparent decline in mixed riparian forest as well as some of the pronounced increase in black walnut between the two time periods. In terms of other non-native species, giant reed increased by 11%, water primrose by 14%, and Himalayan blackberry by 37%.

### Basal Area of Woody Species

*Definition:* Basal Area is defined as the total cross-sectional area of woody species. Basal area includes all tree species as well as shrubs with woody stems such as willows, elderberry, and coyote brush. Shrubs were included because of their high planting density in this system, which contributes a great deal to foliage cover especially in early-stage restoration sites, and also because of their high wildlife value (e.g. willow and elderberry). In plots where trees occur (i.e. most plots) the relative contribution of shrub basal area to total basal area is typically small.

*Rationale:* Basal area is an absolute measure of forest structure, and is useful because it generally is proportional to foliage coverage (Barbour et al. 1999). As restoration sites age, foliage cover is predicted to increase and basal area provides an effective measure of this. Basal area is often used as a target for reforestation/restoration projects. Low values of basal area in restoration sites with no upward trend over time would indicate that forest development is poor, whereas an upward trend towards that of reference conditions indicates that forest development is occurring. A desirable endpoint of restoration in this system is to recreate forests with large-diameter trees (such as Fremont cottonwood and Valley oak), simulating the conditions that existed prior to habitat alteration (e.g. Thompson 1961).

*Methods:* Basal area was studied in 2003 and 2008 at permanent plots located at remnant and restoration sites of varying ages. The diameter (dbh) of all stems in plots sized 20 x 30 m are measured at 1.5 m above the ground. Basal area is calculated at the plot level for any woody species with stems >2.5 cm dbh and is reported on a per-hectare basis ($m^2$/ha) to allow easy comparison with published values.

*Results:* Restored sites had a mean value of 12.7 $m^2$/ha as of August 2008. This is an increase from a mean value of 6.5 $m^2$/ha measured at these same (permanent) plots in August 2003. At the restoration site level there is substantial variability (Table 4). One restoration site (Phelan Island) already has a mean basal area above the desired rating of 28 $m^2$/ha. Forest development at other restoration sites (e.g., Rio Vista) is hindered by poor soils.

**Table 4.** Basal area (in $m^2$/ha) of woody species at Sacramento River restoration sites over three time periods.

| Restoration Site | # plots) | Mean Basal Area 2003 | Mean Basal Area 2006 | Mean Basal Area 2008 |
|---|---|---|---|---|
| River Unit | 25 | 9.4 | | 16.8 |
| Princeton Ferry | 21 | 4.8 | | 11.4 |
| Rio Vista | 27 | 3.1 | | 6.9 |
| Sam Slough | 29 | 8.5 | | 15.7 |
| Shaw | 5 | | 12.2 | |
| Phelan Island | 3 | | 29.3 | |
| Flynn | 3 | | 13.9 | |
| Kopta Slough | 3 | | 13.2 | |
| Lohman | 3 | | 15.5 | |

*Interpretation:* Despite considerable variability among sites, basal area of woody species is increasing over time with the mean value increasing by 6.2 $m^2$/ha. This corresponds to a 95% increase over five years, and suggests that woody species are responding favorably to growing conditions at many of the restoration sites. Increased growth of woody species leads to greater structural complexity of habitat which favors many wildlife species.

### Frequency of Woody Species in Various Size Classes

*Definition:* This is the frequency distribution of stem diameters of the major tree species in this system. Species included are Fremont cottonwood, Valley oak, box elder, and Goodding's black willow (*Salix gooddingii*).

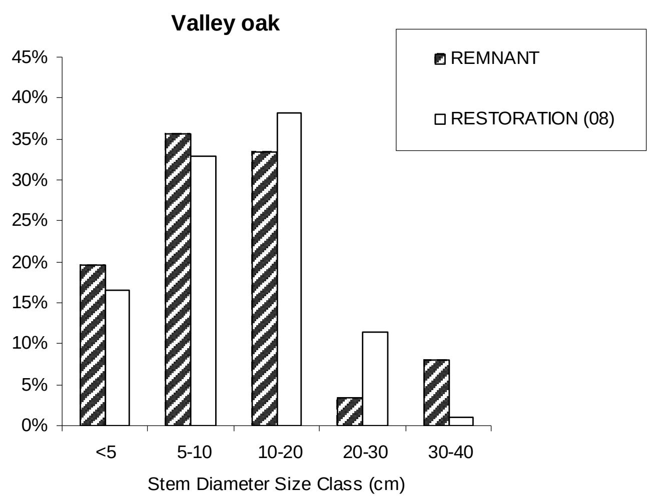
*Rationale:* Frequency distributions of stem size are useful because they directly track tree growth (Bailey and Covington 2002, Minore and Weatherly 1994). The attainment of large trees is a goal of restoration. As restoration sites age, stem size distributions should shift towards a higher percentage of larger trees, approximating that found in reference (remnant) forests. A desirable endpoint of restoration in this system is to re-create forests with large trees (e.g.

Fremont cottonwood and Valley oak), simulating the conditions that existed prior to habitat alteration (Thompson 1961). Large diameter trees have a high degree of canopy cover and leaf surface area to promote insect and bird populations, yield coarse woody debris to the forest floor to provide cover for small mammals, reptiles and amphibians, and provide nesting opportunities.

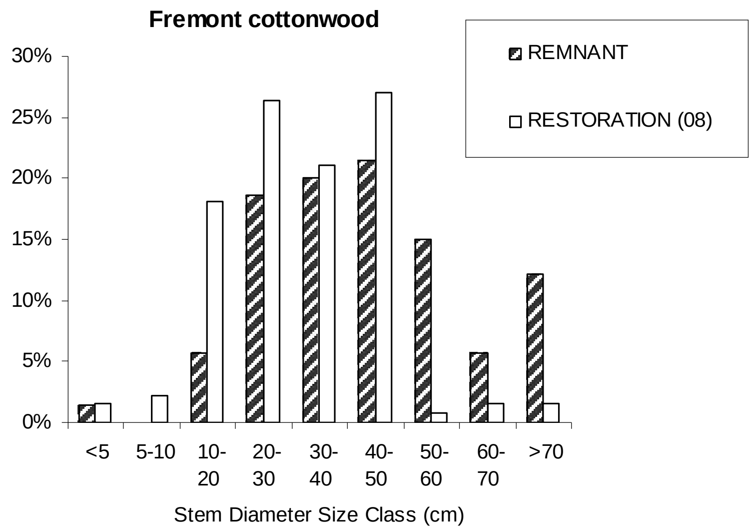
Large cottonwood trees are a critical habitat element for Yellow-billed Cuckoo. Stem size distribution is a useful indicator of the quality of cuckoo habitat because it directly represents tree size, and if tracked over time, tree growth (Minore and Weatherly 1994, Barbour et al. 1999, Bailey and Covington 2002).

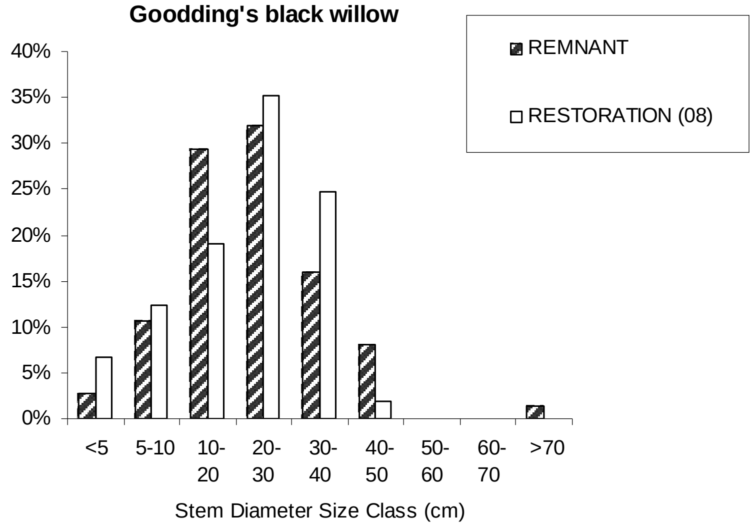
*Methods:* Remnant sites were studied at permanent plots in 2002, 2003 and 2006, and restoration sites in 2008. The diameter of all tree stems >2.5 cm dbh (diameter at breast height, or 1.5 m) was recorded in 20 x 30 m plots. The size classes (in cm dbh) used for the frequency distribution was <5, 5-10, 10-20, 20-30, 30-40, 40-50, 50-60, 60-70, and >70.

*Results:* The figures below compare stem size distribution data collected in 2008 from restoration sites (River Unit, Rio Vista, Princeton Ferry, Sam Slough) and remnant forest habitats (Figs. 2A-2D).


**Figures 2A and 2B.** Stem size distribution for Valley oak and Fremont cottonwood at Sacramento River restoration sites.




**Figures 2C and 2D.** Stem size distribution for Goodding's black willow and box elder at Sacramento River restoration sites.

*Interpretation:* Valley oak and box elder appear to be doing well. They have a distribution at restoration sites that closely approximates what was observed at remnant forests. Fremont cottonwood and Goodding's black willow do not appear to be doing as well because their tree size distribution is shifted to the left (i.e. smaller trees) from that of remnant forest. However, given more time the size distribution of these species should come to match that of remnant forest. In a related study, the average stem size of Valley oak is reported (in dbh) from measurements taken at six restoration sites ranging from seven to eleven years after planting (Griggs and Golet 2002).

## Importance Value of Woody Species

*Definition:* Importance value for a species is defined as the sum of (relative density + relative basal area) with a theoretical maximum of 200. All tree species as well as shrubs with woody erect stems such as willows, elderberry, and coyote brush are counted. Shrubs are included because of their high planting density in this system, which contributes greatly to foliage cover especially in early-stage restoration sites, and because of their high wildlife value (e.g., willow and elderberry).

*Rationale:* As restoration sites age, importance values should continue to increase, and eventually stabilize, for the eventual dominants (DeWalt et al. 2003). Species with high importance values early in succession (e.g., high-light requiring shrubs) are expected to decrease in importance value as the canopy closes. A desirable endpoint of restoration in this system is to re-create forests with large-diameter trees (e.g., Fremont cottonwood and Valley oak), simulating the conditions that existed prior to habitat alteration (Thompson 1961).

Importance Value is widely used in forest ecology as a measure of forest structure and species composition because it combines different elements of relative species abundance. Importance value provides a meaningful way to characterize the prominence of woody species within the riparian community (Pabst and Spies 1999). A high importance value may be due to a woody species being either very dense or very dominant (high basal area), or both. Because importance values are relativized within each plot, their values do not depend on overall cover, and thus changes in species composition can be tracked over time without being confounded by varying levels of growth among plots.

Importance value of blue elderberry (*Sambucus mexicana*) is useful as an indicator for the VELB as it is the sole host plant for this beetle in the Project area. Red elderberry (*Sambucus racemosa*), the other host for this species, does not occur on the middle Sacramento River. All phases of the VELB's life cycle are completed on this shrub.

Cottonwood forests are the primary habitat for Yellow-billed Cuckoo (Hughes 1999). Importance value provides a meaningful way to characterize the prominence of cottonwood within the riparian community (Pabst and Spies 1999).

*Methods:* Importance value was studied in 2003 and 2008 at permanent plots located at restoration sites and remnant sites of varying ages. It is calculated for all woody species within a study plot. Plot values are averaged within and across sites. Within a plot of size 20 x 30 m, the diameter of all woody stems >2.5 cm dbh are measured at 1.5 m above the ground and then diameters are converted to an area basis (basal area).

*Results:* Importance values were calculated for the most common woody species that occur at restoration sites in both 2003 and 2008 (Table 5). All species listed were planted with the exception of non-native black walnut.

**Table 5.** Importance values of woody species at Sacramento River restoration sites (River Unit, Sam Slough, Princeton, and Rio Vista) sampled over two time periods.

| | **2003** | **2008** |
|---|---|---|
| Arroyo willow (*Salix lasiolepis*) | 42.9 | 40.2 |
| Black walnut (*Juglans hindsii*) | 0.4 | 0.6 |
| Blue elderberry (*Sambucus mexicana*) | 50.1 | 39.5 |
| Box elder (*Acer negundo*) | 9.3 | 13.7 |
| Coyote brush (*Baccharis pilularis*) | 4.6 | 13.7 |
| Fremont cottonwood (*Populus fremontii*) | 17.1 | 16.5 |
| Goodding's black willow (*Salix gooddingii*) | 6.8 | 7.3 |
| Valley oak (*Quercus lobata*) | 58.1 | 65.2 |
| Western sycamore (*Plantanus racemosa*) | 7 | 5.6 |

*Interpretation:* Increases were observed for coyote brush (198%), box elder (47%), Valley oak (12%) and Goodding's black willow (7%). The nonnative black walnut also increased (by 50%). Decreases in importance values were observed for arroyo willow (*Salix lasiolepis,* 6%), blue elderberry (21%), Fremont cottonwood (4%) and Californa sycamore (20%). Increases in importance values are considered desirable for all but non-native species, however, the effects on different wildlife species will vary depending upon their specific habitat requirements.

### Native Understory Frequency of Occurrence

*Definition:* Native understory species frequency of occurrence is the proportion of quadrats in which at least one native species is present.

*Rationale:* Frequency of occurrence provides information on abundance and spatial dispersion of native understory plants (Fonda 1974, Holl 2002, Czerepko 2008). As an indicator of the status of understory vegetation, it is complementary to information on relative native cover.

*Methods:* Native understory species frequency of occurrence was determined in 2001 and 2007. It is the frequency of all individual plant species ≤1.5 m tall, including shrubs, vines, and woody seedlings that are ≤1.5 m tall within 1 $m^2$ quadrats. The values presented are all for forest and savannah sites, although it could potentially be used for grassland sites.

*Results:* Table 6 shows native understory frequency in restored sites in 2001, the same restored sites measured again in 2007, and reference sites. These sites did not have understory species planted at them.

**Table 6.** Native understory indicator values at Sacramento River riparian restoration sites and remnant habitats. Values reported are mean, median, and range (in parentheses). The 2001 results are from Holl and Crone (2004).

| | Surveyed in 2007 | Surveyed in 2001 | Remnant Riparian |
|---|---|---|---|
| Native understory species frequency of occurrence (percent) | 56.0, 55.3, (19 - 100) | 48.1, 47.1, (21 - 95) | 87.2, 88.9, (83 - 98) |
| Native understory species richness (species) | 6.7, 6.0, (3 - 10) | 4.7, 5.0, (2 - 6) | 10.1, 10.5, (8 - 13) |
| Relative native understory cover (percent) | 32.3, 24.5, (4 - 80) | 20.7, 22.0, (3 - 61) | 65.1, 61.9, (45 - 88) |

*Interpretation:* There was a modest 8 percentage (16%) point increase at restoration sites over 6 years between surveys, suggesting that some improvement in habitat conditions for wildlife. However, the value is still far below remnant sites, and the colonization and spread of native understory species at restoration sites has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low, even in 2007. Relative to restoration sites, remnant sites had consistently high values. The current practice of planting native understory species should help improve this parameter.

**Native Understory Species Richness**

*Definition:* Native understory species richness is the number of native herbs, shrubs, and vines observed. It does not include tree species seedlings which may be found in the understory.

*Rationale:* Native understory species richness is commonly used as a measure of species composition and ecosystem complexity (Økland et al. 2003). Understory vegetation is shaped by riverine processes (Kamisako et al. 2007) and provides important habitat functions for a wide array of native species (Gilliam 2007). Native understory species richness is useful for making comparisons with reference systems (Holl and Crone 2004, Wassenaar et al. 2007).

*Methods:* Native understory species richness was determined in 2001 and 2007. It is calculated as the number of native herbs, shrubs, and vines ≤1.5 m tall observed in quadrats that are 1 $m^2$. The values presented here are all for forest and savannah sites, although it could potentially be used for grassland sites.

*Results:* Table 6 shows the values for native species richness in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites. These sites did not have understory species planted at them.

*Interpretation:* Restoration sites are well below remnant habitats in native understory species richness. Mean richness increased by 2 species (43%) over 6 years between surveys, however, the value is still far below what was observed at remnant sites, and the colonization and spread of native understory species has been slow. Also there is a wide range of values among restoration sites with some being very low. In contrast, remnant sites had relatively high values. The current practice of planting native understory species should help improve this parameter.

**Relative Native Understory Cover**

*Definition:* Relative native understory cover is the percent native cover divided percent total cover.

*Rationale:* Native understory species contribute to the forest biodiversity and function by mediating energy flow and nutrient cycling with high net primary productivity and rapidly decomposable leaf litter (Gilliam 2007). A major focus of restoration in this system is to increase cover of native plant species which tend to be more supportive of wildlife than exotic plants. Relative native cover allows for comparisons across years and accounts for phenological differences, as absolute cover varies greatly depending on interannual rainfall and when during the growing season it is measured (Cook et al. 2005).

*Methods:* Relative native understory cover was determined in 2001 and 2007. It is defined as percent native cover divided percent total cover (native + exotic + unknown species cover) measured at 1 $m^2$ quadrat level Bakker et al. 1996). It is the cover of all individual native plant species ≤1.5 m tall, including shrubs and vines that are ≤1.5 m tall. The values presented here are all for forest and savannah sites, although it could potentially be used for grassland sites.

*Results:* Table 6 shows the values for relative native understory cover in restored sites in 2001, the same restored sites measured again in 2007, and in reference sites. These sites did not have understory species planted at them. For the 15 restored sites sampled in 2001 and 2007 the mean increase in relative native cover is 11.6% and the median increase is 3.6%. The range was a decrease of 12% to an increase of 62%.

*Interpretation:* Restoration sites are well below remnant habitats in relative native understory cover. There was a 12 percentage point (56%) increase at restoration sites over 6 years between surveys, suggesting an improvement in habitat conditions at these sites. However, the value is still far below remnant sites, and the colonization and spread of native understory species has been slower than was hoped for. Also there is a wide range of values among restoration sites with some being very low. Relative to restoration sites, remnant sites had high values, although there was considerable variability among sites. The current practice of planting native understory species should help improve this parameter.

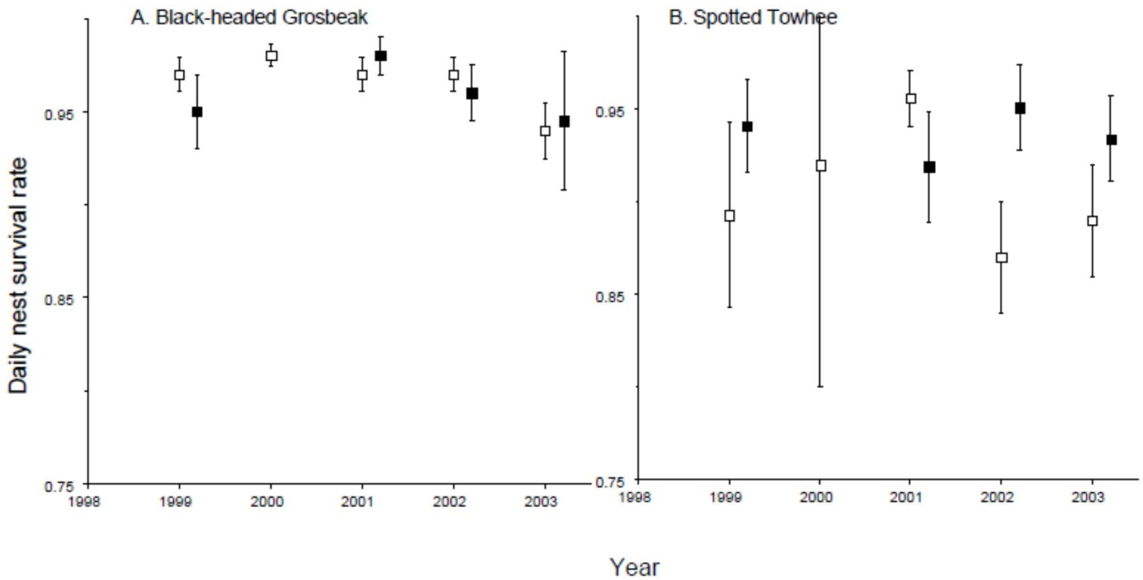
**Nest Survival of Black-headed Grosbeak (*Pheucticus melanocephalus*), *Lazuli Bunting* (*Passerina amoena*), *and Spotted Towhee* (*Pipilo maculatus*)**

*Definition:* Nest survival for these landbirds is defined as the probability of a nest with egg(s) fledging of at least one chick.

*Rationale:* Riparian habitats are the single most important habitat type for landbirds in California (DeSante and George 1994), so it is important that we assess their performance in these key habitats. Birds are high trophic-level species that have specific, diverse, and moderately well understood habitat requirements. Their ability to successfully reproduce requires adequate locally available and safe nesting sites (Martin 1993). Nest survival is a fundamental demographic component that influences population viability and that is strongly influenced by local conditions. Therefore, for migratory species, it may tell us more about the quality of habitats and conditions on the river than other demographic parameters such as adult survival, which may be influenced by habitat conditions in wintering areas or migratory stopover sites. Predation is a primary cause of nest mortality of open-cup nesting birds (Ricklefs 1973, Martin 1993), including on the Sacramento River (Small et al. 2007). Other sources of nest mortality include nest parasitism by the Brown-headed Cowbird (*Molothrus ater*), weather, failure of the nest structure or supporting vegetation, desertion, or human activities. By employing a multispecies approach in nest monitoring efforts we can gain multiple perspectives on landbird habitat condition because different bird species select different vegetation strata and substrates to build their nest (Martin 1992).

*Methods:* Data were collected at restoration and remnant sites of various ages from 1993 to 1999 for Lazuli Bunting, and from 1994-2003 for the other two species. Nest survival was calculated using an analysis method that takes into account the exposure period of the nest (e.g., the Mayfield method or logistic exposure, Mayfield 1975, Johnson 1979).

*Results:* Reproductive success of all three species, as measured by Mayfield estimates of daily survival of nests for all years combined, was not statistically different between restored and remnant sites (Figs. 3A and 3B). Nest survival for Lazuli Bunting (not shown) was low in both restoration and remnant habitats. Rates varied annually for all species, however 95% confidence intervals for restored and remnant sites overlapped in all years.




**Figures 3A and 3B.** Mayfield estimates of nest survival rates for: (A) Black-headed Grosbeak; and (B) Spotted Towhee at restoration and remnant sites within the Sacramento River Project area, California. Solid squares identify restoration sites, and hollow squares indicate remnant sites. Vertical bars indicate 95% confidence intervals. Data from PRBO Conservation Science. Reprinted from Golet et al. (2008) with permission.

*Interpretation:* Similar nest survival rates between restoration and remnant habitats suggest that restoration sites are providing functional habitat for reproduction for these landbird species.

### Adult Survival of Black-headed Grosbeak and Spotted Towhee

*Definition:* Apparent adult survival for these landbirds is defined as the probability that an adult will survive from one year to the next.

*Rationale:* Apparent adult survival for landbirds is an important demographic component in understanding population dynamics and species viability. It is influenced by habitat conditions and indirect evidence suggests that events during the breeding season may influence it (Gardali and Nur 2006). Hence, adult survival can tell us about habitat quality. It is a complementary indicator to nest survival, and estimating both is required to calculate lambda (the intrinsic rate of population increase). Adult survival is influenced by abundance and richness of the predator community, habitat structure (ability to take cover from predators), food availability, and reproductive effort (cost of reproduction). Habitat conditions in the project area exert a strong influence on resident species such as the Spotted Towhee; however, for migratory species, such as the Black-headed Grosbeak, conditions during migration and on the wintering grounds may also influence survival.

*Methods:* Apparent adult survival was calculated from breeding season data collected from 1995-2000 using mark-recapture methods (Lebreton et al. 1992, Nichols 1992).

*Results:* The Black-headed Grosbeak had survival rates at a restoration site that were slightly lower than what was observed at two remnant sites and considerably higher than a third grazed remnant site (Fig. 4). For Spotted Towhee, adult annual survival was lower at the restoration site than at two remnant sites and nearly identical to the grazed remnant site.

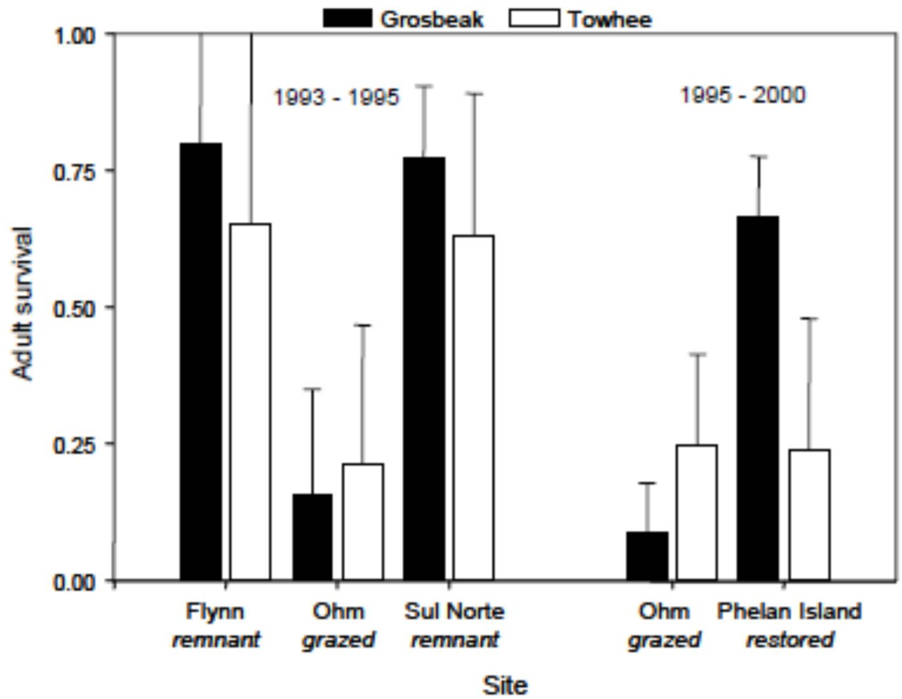



**Figure 4.** Site-specific adult survival of Black-headed Grosbeak and Spotted Towhee at four sites within the Sacramento River Project area, California. Site types are indicated on the x-axis below the site names. Data from PRBO Conservation Science. Reprinted from Gardali and Nur (2006) with permission.

*Interpretation:* Reasons for the different survival response of these species remain to be determined, however, it is plausible that the lack of a well developed native understory layer at the restoration site affected the understory nesting towhee more than the mid-canopy breeding grosbeak.

**Landbird Species Richness**

*Definition:* Landbird species richness is defined as the number of landbird species detected.

*Rationale:* Species richness is an indication of the avian biodiversity at a site. Knowing how many and which species are present in the project area is fundamental to understanding if the wide spectrums of needs (for species with diverse requirements) are being met for landbirds during the breeding season (Reaka-Kudla et al. 1997). Research on the Sacramento River has shown that some species require mature forests while others prefer forests in early seral stages (Gardali et al. 2006).

*Methods:* Landbird species richness was determined from 1993 to 2003 for a suite of remnant and restoration sites of varying ages. Occurrence data was collected from May through mid-July along a survey route with 14 or 15 survey points. At each survey location, bird detections were recorded following standardized point counts methods (Ralph et al. 1993). The duration of each count was 5 minutes, and all birds seen or heard were recorded. Only those birds noted within 50 m of the observer were recorded and it was assumed that detection probabilities were similar within this distance among habitat types and years. Counts began at dawn and continued up to four hours past sunrise (see Gardali et al. [2006] for additional study details).

*Results:* Landbird species richness increased as the sites matured (Fig. 5), and the abundance of many species, with diverse life-history requirements, has dramatically increased as the sites have aged (Fig. 5; Gardali et al. 2006). An exception is the Lazuli Bunting which has been declining at both restoration sites and in remnant habitats (Gardali et al. 2006). The increase in species richness at restoration sites is apparently due to certain species (e.g., House Wren [*Troglodytes aedon*]) being absent until the structural complexity of the sites increase beyond some threshold amount. Nur et al. (2004) found that the abundance of several species (e.g., Ash-throated Flycatcher [*Myiarchus cinerascens*], Tree Swallow [*Tachycineta bicolor*]) was positively associated with tree height and/or canopy cover, factors that typically increase as restoration sites mature. At about 10 years, restoration sites begin to be occupied by primary cavity nesting species (e.g., Nuttall's Woodpecker [*Picoides nuttallii*]).

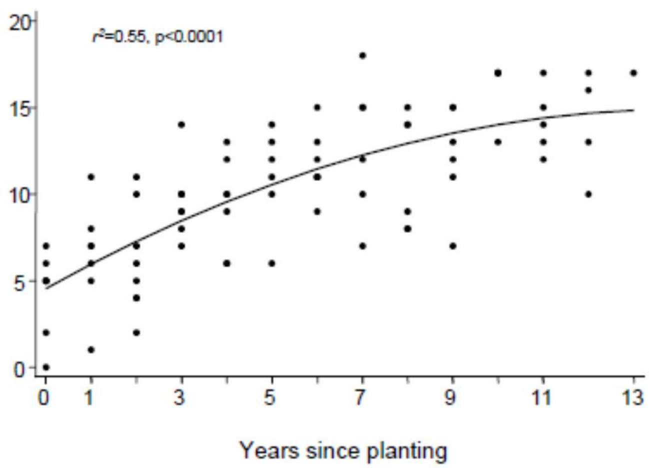



**Figure 5.** Landbird species richness at restoration sites of varying ages within the Sacramento River Project area, California. Data from PRBO Conservation Science. Reprinted from Golet et al. (2008) with permission.

*Interpretation:* Results indicate that restoration sites are providing habitat for a diverse community of landbirds, and that habitat value is increasing as the sites mature.

### Abundance of Black-headed Grosbeak, Common Yellowthroat (*Geothlypis trichas*), Yellow Warbler (*Dendroica petechial*), and Yellow-breasted Chat (*Icteria virens*).

*Definition:* Abundance for these landbirds is defined as the number of birds per hectare during the breeding season.

*Rationale:* Abundance or density is a fundamental component of population health. Knowing what species are setting up territories and exhibiting behaviors indicative of breeding provides an important (although incomplete) measure of whether or not bird’s needs are being met during the breeding season (Bock and Jones 2004, Gardali et al. 2006).

*Methods:* Point count data were collected from 1993 to 2003 at a suite of remnant and restoration sites of varying ages. These data were used to estimate (individuals per hectare) by dividing the number of detections within 50 m by the area of the 50-m radius circle (0.785 hectares), then multiplying by a coefficient derived from spot maps to adjust for species-specific detectability differences (Central Valley Joint Venture 2006).

*Results:* At restoration sites, the abundance of many species, with diverse life-history requirements, has dramatically increased as the sites have aged, such that it is approaching values observed at remnant habitats. Figure 6 shows the response of Black-headed Grosbeak plus several resident species. Further details, including responses of additional migratory species, are presented in Gardali et al. (2006).

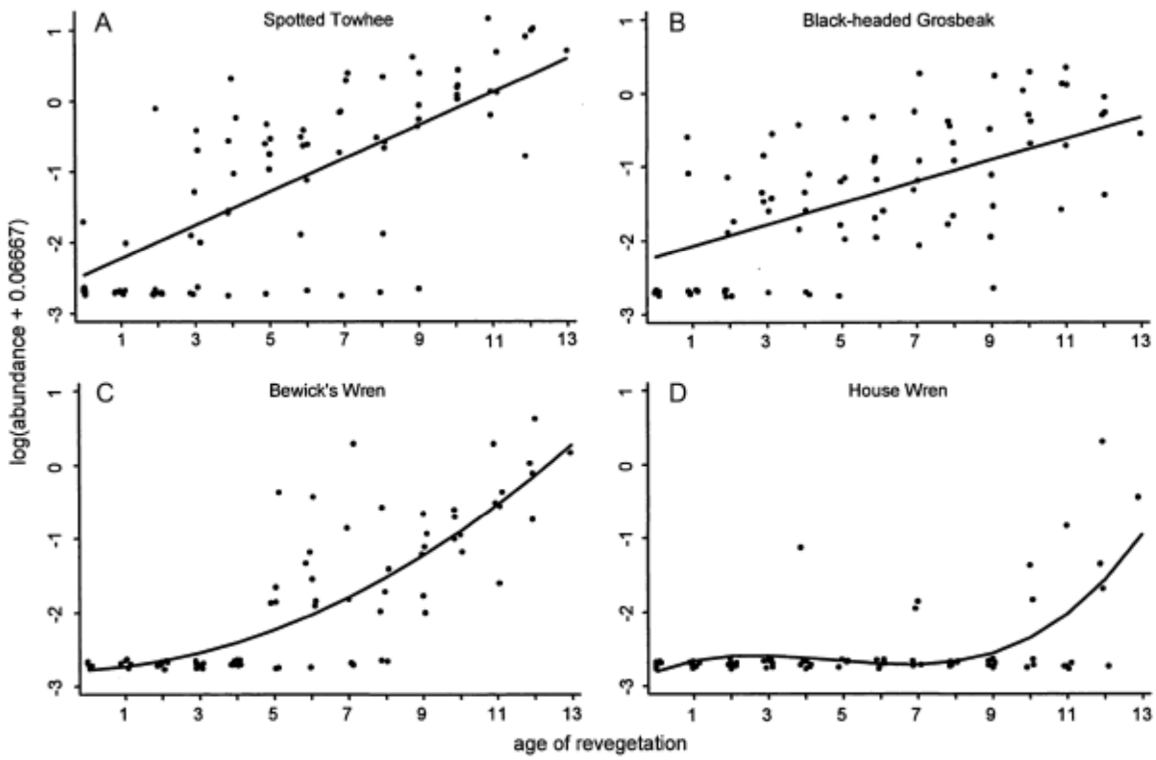



**Figure 6.** Abundance (point count detections) of four landbirds in relation to years since planting at restoration sites within the Sacramento River Project area, California. Lines show values predicted from log-linear regression; quadratic fit for Bewick's Wren (*Thryomanes bewickii*) and cubic fit for House Wren. Each point represents datum from 1 year for each site. Data from PRBO Conservation Science. Reprinted from Gardali et al. (2006) with permission.

*Interpretation:* Interestingly, abundances of many species studied were also increasing at remnant forest sites—although usually at a slower rate perhaps due to an increase in riparian habitat in the landscape (Gardali et al. 2006). These results suggest that restoration efforts may be producing positive spillover effects for bird populations in the larger Sacramento Valley, although other factors (e.g., climate, conditions in wintering areas, etc.) may also be responsible. These results suggest that restoration sites are increasing in habitat value for many species as they mature. Undoubtedly, this is related to the structural development of planted vegetation.

### Number of Occupied Yellow-billed Cuckoo Territories

*Definition:* This indicator is defined as the number of Yellow-billed Cuckoo territories occupied between Red Bluff and Colusa.

*Rationale:* The number of territories is indicative of the breeding population size of the species. The Yellow-billed Cuckoo is an area-sensitive riparian obligate species that has undergone dramatic population declines across the state coincident with the clearing of riparian forests (Halterman et al. 2001).

*Methods:* Territories of this secretive bird were searched for using tape playback methods (Halterman et al. 2010) during the breeding season (mid-June until mid-August) in 2010. Suitable breeding locations were surveyed in riparian habitat between Red Bluff and Colusa within 2km of the Sacramento River. In total ~1500 locations were surveyed.

*Results:* Occupancy estimates predict that approximately 38 territories were occupied in 2010. This yields a population estimate of 38-76 breeding cuckoos because each territory could be occupied by either an individual or a pair (Dettling and Howell 2011).

*Interpretation:* Girvetz and Greco (2009) reported that of the 102 sub-patches identified as potentially suitable as breeding sites for this species, between 13 and 18 were occupied each year from 1987 to 1990, 23 were occupied in 1999, and 28 were occupied in 2000. Together with the results of the 2010 survey, these data suggest an increase in the breeding population. However, survey effort, survey methods, and data interpretation varied considerably among years, making direct comparisons across years impossible. Regardless, the low number of occupied cuckoo territories is of great conservation concern, especially since the Sacramento River is thought to be one of the most important remaining breeding locations for this state endangered species.

### Number of Bank Swallow (*Riparia riparia*) Nest Burrows

*Definition:* This is defined as the total number of active nest burrows at Bank Swallow colonies.

*Rationale:* The number of burrows is representative of the total breeding population size. On alluvial rivers burrows are typically located on actively eroding cutbanks (Garrison 1999). These cutbanks are formed by meander migration, a natural process that regenerates riparian habitat and provides benefits to a multitude of terrestrial and aquatic species.

*Methods:* Bank Swallow burrows are counted during annual boat-based surveys that are conducted cooperatively between the USFWS, CDFW, and CDWR. The surveys are conducted during the breeding season (typically in early June). Survey protocols were drafted by the Sacramento River Bank Swallow Technical Advisory Committee. Burrow counts have been conducted nearly every year from 1986 to the present, however, surveys were not completed in all years. Data from 1999 onwards are considered comparable.

*Results:* Since 1999, the Bank Swallow population on the Sacramento River between Red Bluff and Colusa has fluctuated, but overall has undergone a pronounced decline (Figure 7). The 2012 total burrow count was only 9% below the 1999 count; however, the most recent three-year running average is 31% lower than the first three-year average (Table 7).

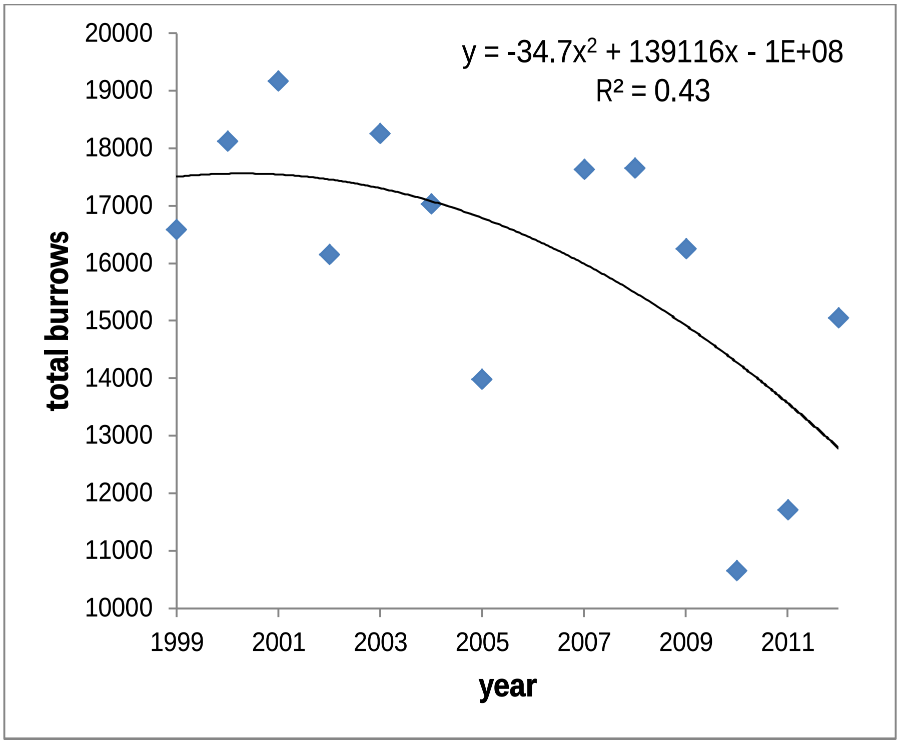



**Figure 7.** Total number of Bank Swallow nest burrows counted on the Sacramento River between the Red Bluff Diversion Dam and the Colusa Bridge, 1999-2012. Data from Bank Swallow Technical Advisory Committee (2013).

**Table 7.** Bank Swallow nest burrow count trends, Sacramento River, Red Bluff to Colusa (RM 243 to RM 143): 1999 through 2012. Data from Bank Swallow Technical Advisory Committee (2013).

| Year | Total Burrows | % Change from Previous Year | 3-Year Average of Total Burrows | % Change from Previous 3-Year Average |
|---|---|---|---|---|
| 2012 | 15,054 | 28.6 | 12,475 | -3.1 |
| 2011 | 11,710 | 9.8 | 12,877 | -13.3 |
| 2010 | 10,662 | -34.4 | 14,860 | -13.5 |
| 2009 | 16,259 | -7.9 | 17,186 | 4.6 |
| 2008 | 17,660 | 0.1 | 16,430 | 1.3 |
| 2007 | 17,640 | 26.1 | 16,223 | -1.3 |
| 2005 | 13,990 | -17.9 | 16,430 | -4.2 |
| 2004 | 17,040 | -6.7 | 17,153 | -4.0 |
| 2003 | 18,260 | 13.0 | 17,863 | 0.2 |
| 2002 | 16,160 | -15.7 | 17,820 | -0.8 |
| 2001 | 19,170 | 5.7 | 17,963 | |
| 2000 | 18,130 | 9.3 | | |
| 1999 | 16,590 | | | |

*Interpretation*: If recent trends continue, the Bank Swallow population may become extirpated from the Sacramento River. Schlorff (1997) established that the population declined considerably from 1986 to 1996, and the data presented here demonstrate a decline from 1999 onwards. Girvetz (2010) found that the spatial structure of the habitat patches was not important to the viability of this population. Rather the total available area of suitable habitat seemed to drive population trends. Importantly, Girvetz found that restoration of riverbank habitat (removal of riprap) reduced extinction probability to less than 10%. This is a 57% reduction in the probability of the population dropping below the quasi-extinction threshold compared to the current condition.

### Number of Bank Swallow Nesting Colonies

*Definition:* This is defined as the total number of Bank Swallow colonies with active nest burrows.

*Rationale:* The number of colonies is an important component of bank swallow population health. Having more colonies can help buffer the population from impacts (e.g., predation, disturbance, etc) that are location specific. It allows risks to breeding birds to be spread among different geographic areas. Having more colonies is also indicative of a larger number of cutbanks, which are beneficial habitat feature in rivers (Rabeni and Jacobson 1993, Malanson 1993).

*Methods:* Bank Swallow colonies are identified between Red Bluff and Colusa during annual boat-based surveys that are conducted cooperatively between the USFWS, CDFW, and CDWR. The surveys are conducted during the breeding season (typically in early June). Survey protocols have been drafted by the Sacramento River Bank Swallow Technical Advisory Committee. Colony counts have been conducted nearly every year from 1986 to the present, however, three years were missed. Data from 1999 onwards have been error checked, and the earlier year's data are being error proofed as well.

*Results:* The total number of Bank Swallow colonies has fluctuated during between 1999 and 2011 (Table 8). Annual percent change has ranged from a 27.7 percent decline in 2000 to a 29.0 percent increase in 2008. No real trend is apparent in the data; however, the three-year running average increased by 10% over the period of record.

**Table 8.** Bank Swallow colony trends, Sacramento River, Red Bluff to Colusa (RM 243 to RM 143): 1999 through 2012. Data from Bank Swallow Technical Advisory Committee (2013).

| *Year* | *Total Colonies* | *% Change from Previous Year* | *3-Year Average of Total Colonies* | *% Change from* **Previous** *3-Year Average* |
|---|---|---|---|---|
| 2012 | 48 | 4.3 | 44 | 0.0 |
| 2011 | 46 | 21.1 | 44 | -2.2 |
| 2010 | 38 | -20.8 | 45 | 0.0 |
| 2009 | 48 | -2.0 | 45 | 7.1 |
| 2008 | 49 | 29.0 | 42 | 5.0 |
| 2007 | 38 | -2.6 | 40 | -7.0 |
| 2005 | 39 | -9.3 | 43 | -4.5 |
| 2004 | 43 | -10.4 | 45 | 4.7 |
| 2003 | 48 | 9.1 | 43 | 10.3 |
| 2002 | 44 | 15.8 | 39 | -2.5 |
| 2001 | 38 | 11.8 | 40 | |
| 2000 | 34 | -27.7 | | |
| 1999 | 47 | | | |

*Interpretation*: The number of colonies is an important component of Bank Swallow population health. Having more colonies may help buffer the population from impacts (e.g., predation, disturbance, etc.) that are location specific. It is beneficial to spread the risk among numerous geographic areas.

### Number of VELB Exit Holes per Shrub

*Definition:* This indicator is defined as the average number of recent VELB exit holes per elderberry shrub.

*Rationale:* The number of recent beetles exit holes per shrub is a basic measure of population density for the VELB. It is a time-delayed measure in that it is the number of beetles that emerged from a shrub in either this year or the prior year. The Valley elderberry longhorn beetle (VELB) is a federally threatened endemic of California's Central Valley that occupies blue elderberry bushes during all stages of its life cycle (Barr 1991).

*Methods:* This indicator is calculated as the average number of VELB exit holes per elderberry shrub with a main stem of at least 2.5cm diameter. It is averaged across all elderberry shrubs within the study area including unoccupied shrubs. Recent exit holes are 1-2 years old and provide the best available estimate beetle abundance, as each emerging beetle makes one exit hole. To be considered a recent exit holes, it must be in living wood and that has not yet darkened, nor has the hole become completely grown over. Beetle emergence occurs from April to July (Barr 1991) and surveys are either performed during this time in the year, or later. Holes remain light-colored and are not grown over by the plant for about a year (Collinge et al. 2001). VELB abundance was measured in 2003 at restoration sites of varying ages (River Partners 2004).

*Results:* Older restoration sites had significantly higher levels of VELB occupancy than younger sites (Fig. 8).

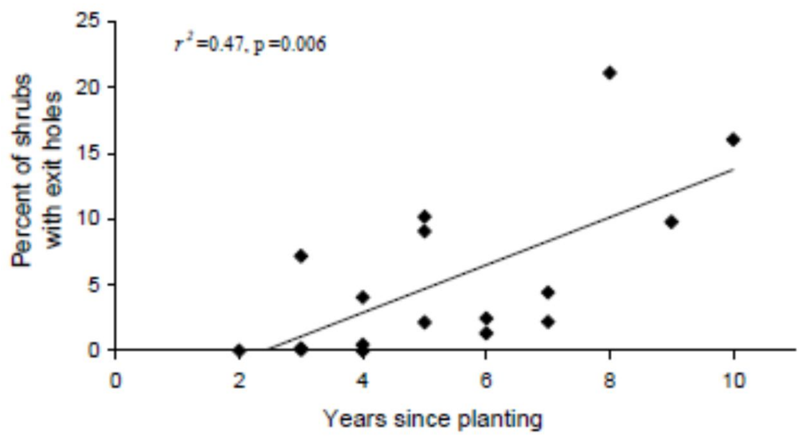



**Figure 8.** Percent of elderberry shrubs with exit holes diagnostic of Valley elderberry longhorn beetle emergence. All shrubs surveyed were within the Sacramento River Project area, California. Data from River Partners. Reprinted from Golet et al. (2008) with permission.

*Interpretation:* These results suggest that VELB colonize and proliferate at restoration sites for at least the first ten years after elderberry is planted. Additional monitoring is needed to determine VELB occupancy rates and density trends over the long term.

**Bee Species Richness**

*Definition:* This is the total number of different species of bees occurring in a standard 1-ha area.

*Rationale:* Bees are an important pollinator of native plants and throughout the world plant species in natural habitats exhibit pollination limitation of reproduction (Knight et al. 2005). As a result changes in pollinator abundance and diversity may greatly affect reproduction. This makes them a valuable indication of biodiversity and ecological function. More generally, insects have tremendous taxonomic and functional diversity and play essential roles in ecosystems as pollinators, predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987, Williams 1993). However, in a review of 68 restoration case studies, only 32% measured some component of arthropod diversity (Ruiz-Jaen and Aide 2005). Restoration monitoring programs often exclude insects for several reasons: they are small, innocuous and generally viewed as non-charismatic; the functional roles that individual species play in ecosystem processes are often not well understood; and the shear diversity of taxa may be overwhelming to the researcher (Williams 2000).

*Methods:* Sampling for this data collection effort involved standard net collecting and pan sampling (Roulston et al. 2007, Westphal et al. 2008) within one-hectare plots at each of five paired restoration and remnant riparian sites over a 6-week period from late February through August, 2003 (Williams 2010).

*Results:* Mean species richness pooled from netting and pan traps was not statistically different between restored (mean=39, se=6.5) and remnant (mean=42, se=1.6) sites (Table 9). A total of 90 species were found at restored sites and 91 at remnant riparian sites (Williams 2010).

**Table 9.** Bee species richness and (abundance) at restored and remnant riparian sites along the Sacramento River, 2003. Data from Williams (2007).

| Site Pair | Restored | Remnant Riparian |
|---|---|---|
| La Barranca | 33 (311) | 42 (299) |
| Rio Vista | 19 (253) | 41 (225) |
| Flynn | 41 (577) | 47 (499) |
| Pine Creek | 46 (492) | 42 (410) |
| Phelan Island | 58 (702) | 37 (416) |

*Interpretation:* Results suggest that restored sites are providing habitat for a wide diversity of bee species, although interestingly the composition of bee communities at restoration sites and remnant sites are quite distinct. Such differences highlight the importance of a mosaic landscape composed of habitat in different successional stages for promoting species diversity. One cause of dissimilarity between bees from restored and remnant sites may be differences in flowering plant communities at these two site types. However, paired sites with greater similarity of plants did not have more bee species in common with one another (Williams 2010), suggesting that other factors are also influencing the distribution of bees among Sacramento River habitat types.

### Bee Abundance

*Definition:* This is defined as the total number of bees occurring in a standard 1-ha area.

*Rationale:* Bees are an important pollinator of native plants and throughout the world plant species in natural habitats exhibit pollination limitation of reproduction (Knight et al. 2005). As a result changes in pollinator abundance and diversity may greatly affect reproduction. This makes them a valuable indication of bioviersity and ecological function. More generally, insects have tremendous taxonomic and functional diversity and play essential roles in ecosystems as pollinators, predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987, Williams 1993). However, in a review of 68 restoration case studies, only 32% measured some component of arthropod diversity (Ruiz-Jaen and Aide 2005). Restoration monitoring programs often exclude insects for several reasons: they are small, innocuous and generally viewed as non-charismatic; the functional roles that individual species play in ecosystem processes are often not well understood; and the shear diversity of taxa may be overwhelming to the researcher (Williams 2000).

*Methods:* Sampling for this data collection effort involved standard net collecting and pan sampling (Roulston et al. 2007, Westphal et al. 2008) within one-hectare plots at each of five paired restoration and remnant riparian sites over a 6-week period from late February through August, 2003 (Williams 2010).

*Results:* Mean abundance pooled from netting and pan traps was not statistically different between restored (mean=467.0, se=83.1) and remnant (mean=369.8, se=48.2) sites (Table 9, Williams 2010).

*Interpretation:* Restored riparian habitats supported communities of native bees with abundance equal to that found in nearby remnants of riparian habitat. Thus, restored sites appeared to provide habitat that was equal in terms of the population size it supported, although the bee species composition was distinct in the two habitat types.

### Beetle Species Richness

*Definition:* Ground Beetle Species Richness is defined as the total number of different morphospecies of beetles occurring in the area. Morphospecies are the lowest taxon that can be distinguished based on morphology, and are surrogates for species (Oliver and Beattie 1996a).

*Rationale:* Beetles are an important member of the insect community. They have tremendous taxonomic and functional diversity and play essential roles in ecosystems as predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987, Williams 1993).

*Methods:* Beetle morphospecies richness was determined from captures made at pitfall traps. Three replicates of each site type (young restoration, older restoration and remnant habitat) were sampled monthly for one full year (December 2000 - November 2001), and average morphospecies richness values were calculated for each site type for each sampling period (Hunt 2004, Golet et al. 2011).

*Results:* Comparisons of ground-dwelling, surface-active beetle assemblages (Order: Coleoptera) among restoration sites of different ages, and remnant riparian habitats, revealed that remnant riparian habitats had significantly higher species diversity than either young (1-3 years post planting) or older restoration sites (6-10 years post planting, Fig. 9).

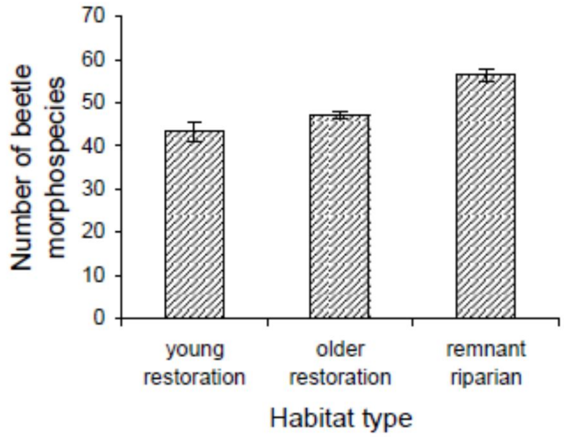



**Figure 9.** Ground-dwelling beetle species richness (mean ± SE) at young restoration sites, older restoration sites, and remnant habitats within the Sacramento River Project area, California. Data from Hunt (2004). Reprinted from Golet et al. (2008) with permission.

*Interpretation:* As restoration sites matured they gained species becoming more similar to remnant habitats in morphospecies richness. In addition, Hunt (2004) compared community compositions and found that Coleoptera species assemblages appear to transition predictably as a function of forest age such that older restoration sites were more similar to remnant riparian sites than were young restoration sites. This suggests that restoration is successful in establishing beetle fauna.

**Bat Abundance**

*Definition:* This is an index defined based on the number of bat calls detected in a given time interval.

*Rationale:* Bats play important roles in ecosystem function, and are appropriate as indicator species for river-riparian-floodplain systems (Wickramasinghe et al. 2003). Like birds, bats have complex habitat needs. They are relatively abundant, can be monitored remotely, and are responsive to changes in habitat quality. Also, many species directly rely upon both terrestrial and aquatic habitats, roosting in trees, and foraging over both land and water.

*Methods:* Bat activity was used as an index of abundance. Activity levels were measured by acoustic monitoring with the Anabat II ultrasound detection system (Titley Electronics, Ballina, NSW, Australia). Measurements were taken in September and October 2002 at young and older restoration sites as well as at orchards and in mature riparian remnant habitats. Bats were identified to species based upon echolocation calls or pulse parameters including base frequency, call shape, pattern of calls within a sequence, interpulse interval and call duration (Waldren 2000, Stillwater Sciences et al. 2003, Golet et al. 2008).

*Results:* The older site (planted in 1991) tended to have higher levels of activity than the newly planted site (Fig. 10).

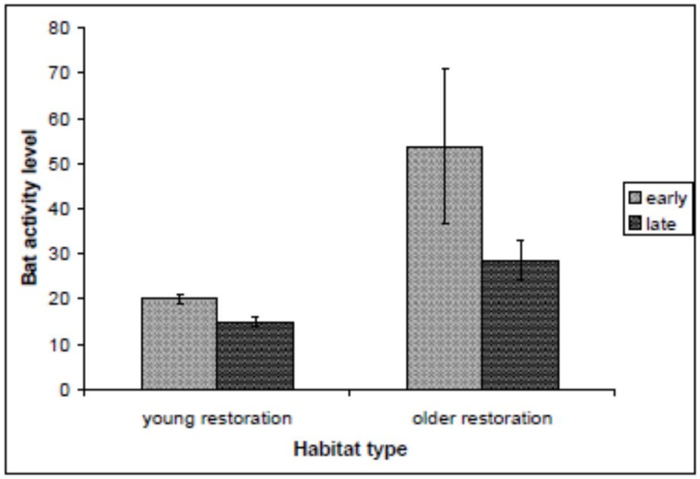



**Figure 10.** Bat activity levels (mean ± SE) at young (planted in 2002) and older (planted in 1991) restoration sites within the Sacramento River Project area, California. Bat activity is defined as the mean number of acoustic files per sampling period. “Early” refers to the September 12–14, 2002 sampling period, and “late” refers to the September 26–27, 2002 sampling period. At each site, detectors were deployed at three locations. Data from B. Rainey. Reprinted from Golet et al. (2008) with permission.

*Interpretation:* Higher recorded activity levels are strongly suggestive of higher bat abundances, although theoretically, they may also result simply from higher calling rates. Increases in abundance at older restoration sites relative to younger sites provide evidence that the habitat value of the restoration sites increases as the sites mature.

### Frequency and Duration of Bed Mobility

*Definition:* The bed mobility flow indicator is defined based on two statistics, both calculated as ten-year running averages: the number of days/yr with flows >55,000 cfs, and the number of years (over the previous decade) in which there were no days >55,000 cfs.

*Rationale:* The importance of variable flow regimes in rivers in now widely accepted (Poff et al. 1997). Within the geomorphic literature, it is well established that gravel-bedded rivers require periodic mobilization to maintain bed sediment quality, recruitment of large wood, undercut banks, and other complex features. The bed mobility flow indicator is a meaningful indicator because geomorphic processes are driven to a large extent by the movement of bed material, resulting in the formation of bars, pools, and other essential geomorphic features that form the building blocks for aquatic and riparian habitat. Movement of bed material is also beneficial because it results in a ‘cleaning’ of sediments, decreasing macrophytes and armored macroinvertebrates, allowing for the colonization of pioneering aquatic species that are valuable food sources for higher trophic level species (Milhous 1982, Suttle et al. 2004, Power et al. 2008).

Bed material size on the Sacramento varies along its length, and as is typical of many rivers, undergoes a transition from gravel to sand (Singer 2008, 2010, Singer and Dunne 2004). Within the reach Red Bluff to Colusa, it is dominantly gravel-bedded. Like most gravel bed rivers, it can be expected to vary widely along its length and across the channel in the flows needed to mobilize sediments, and transport is a function of particle size and channel form. Thus, there is naturally strong spatial variability, which implies that using a generalized value based on empirical observations to identify a bed mobilization threshold is more justified than attempts at precision in specifying a number that is inherently imprecise at the scale of the river.

There is natural temporal variability in frequency of bed mobility that arises from variations in flow from year to year. Because of this, an indicator based on flows in a given year may show swings up and down that are simply artifacts of natural variation in annual precipitation, rather than a real change in river health. Computing a multiyear running average is one method of dampening annual variability that can allow temporal trends to stand out.

*Methods:* 55,000 cfs is used as the flow which fully-mobilizes the bed, based on mobilization data collected by Buer (1994, 1989, and unpublished), at multiple riffle sites of likely habitat importance to fish between Red Bluff and Colusa. These data may provide the best available characterization of flow requirements for bed mobilization for the river as a whole (CH2MHill 2000). Flow data measured at the USGS gauge on the Sacramento River at Red Bluff was used to calculate frequency and duration of bed mobility. Calculations were made of ten-year running averages, and number of years in the previous ten that exceeded (or failed to exceed) the threshold flow.

*Results:* The mobility of the bed was reduced from pre-dam conditions, even though the pre-dam period included the longest dry period on record (Meko 2011, Figs. 11-12). The plot of raw data of the number of days with flows exceeding 55,000 cfs by water year shows strong variation from year to year, and shows a small decrease post-Shasta Dam. More significantly, the number of years with no bed mobilizing flows increased from 22% of pre-dam years to 47% of post-dam years (Fig. 11). The result of fewer years with bed mobilizing flow is that extended periods without bed mobility become more frequent (red symbols). Three periods of four or more years without bed mobility have occurred since 1944; none occurred between 1890-1940, even in the dry period of the 1920's and 1930's. The post dam period also contains three extended periods (4, 5, and 6 years) of consecutive years without bed mobilization (Figure 12). There is an increase from an average of 1.8 (pre dam) to 4.2 (post dam) years out of 10 on average without bed mobility (blue symbols).

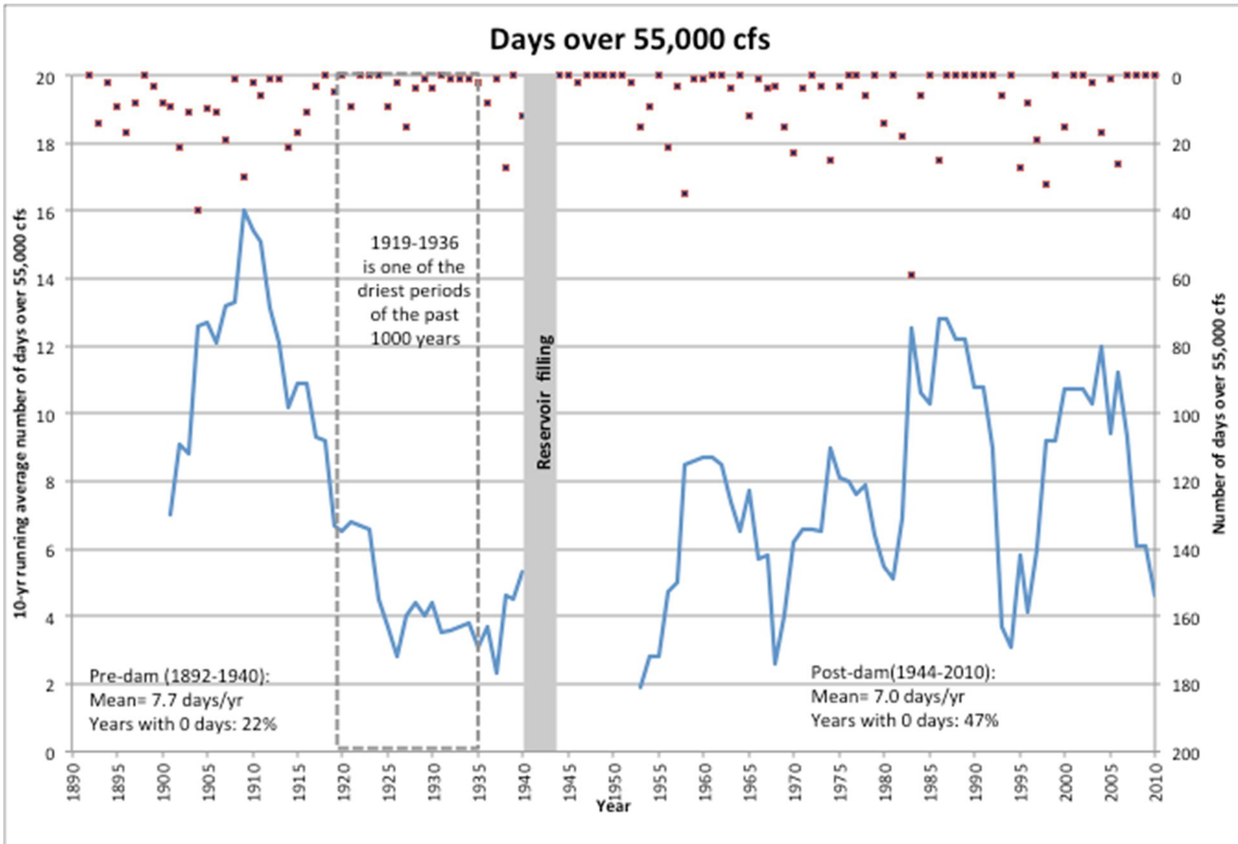



**Figure 11.** Ten-year running average of number of days with flows sufficient to mobilize the bed (exceeding 55,000 cfs) recorded at the USGS gauge Sacramento River at Red Bluff (blue line, left labels y-axis), along with number of days with flows over 55,000 cfs for each year (red data points, right labels y-axis). Figure from M. Kondolf and Z. Rubin (unpublished).

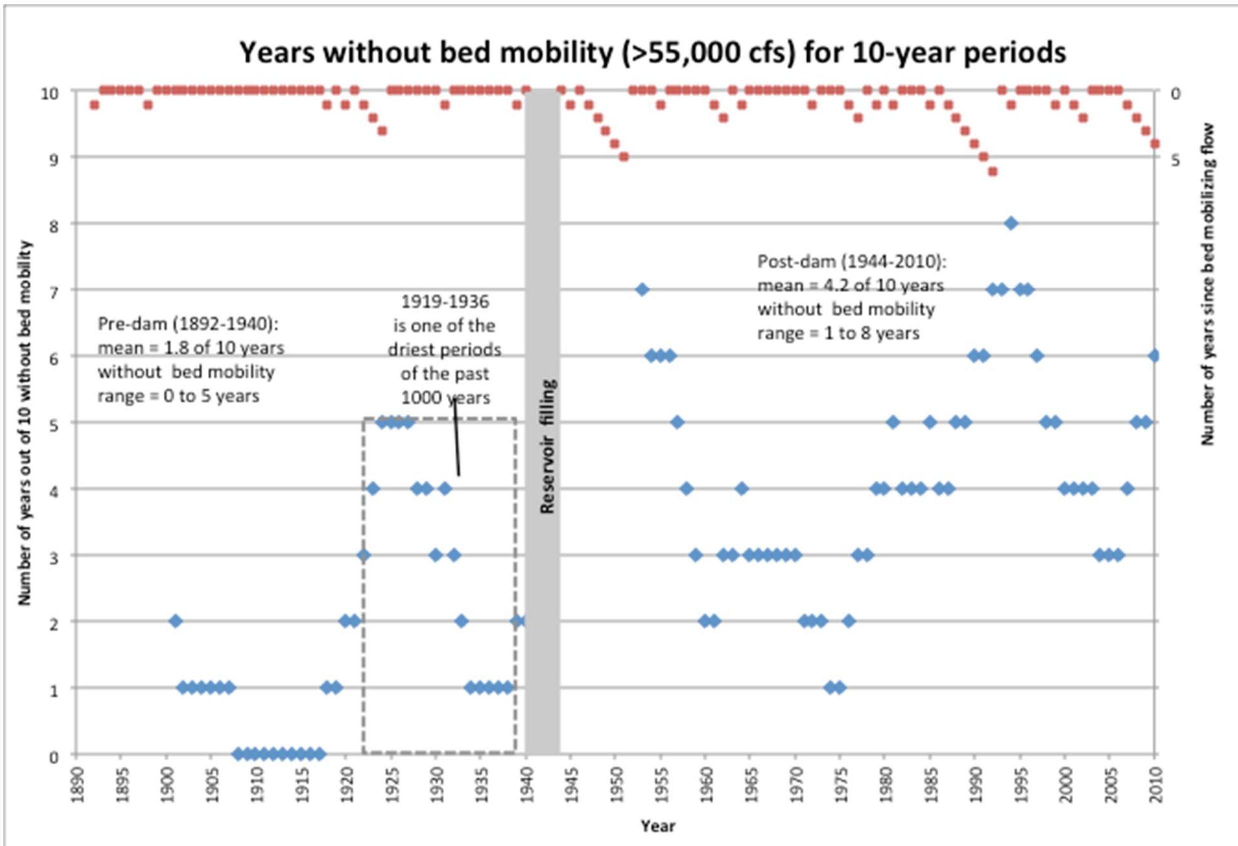



**Figure 12.** Number of years without bed mobility over prior ten-year periods, based on analysis of USGS flow records, Sacramento River at Red Bluff. Figure from M. Kondolf and Z. Rubin (unpublished).

*Interpretation:* While the bed is still frequently mobile, it is mobile in fewer years than during the pre-dam period. This results from storage of high flows and release of higher base flows by Shasta Dam. This reduction in bed mobility is likely to adversely impact components of the river's ecosystem.

### Frequency and Duration of Floodplain Inundation

*Definition:* The floodplain inundation indicator is defined based on two statistics: the average number of days per year in which flow exceeded 70,000 cfs, and the number of years in which there were no flows exceeding 70,000 cfs, both calculated over the previous 10-year period.

*Rationale:* Floodplain inundation is a key component of lateral connectivity in river systems (Kondolf et al. 2006). Overbank sedimentation is a key process in building floodplains, establishing riparian forests, and providing high-flow refugia for fish during floods. If flow diversions or storage result in reduction in frequency or duration of floodplain inundation, it may have negative consequences on geomorphic and ecological processes and the biota that depend upon them. There is considerable literature demonstrating the importance of floodplain inundation on the physical function and ecological health of river systems, including Junk et al. 1989, Poff et al. 1997, and Stanford et al. 2005. The importance of inundated floodplain habitat in the lower Sacramento has been established through documentation of juvenile fish growing faster and to larger size if they spend time on the floodplain as opposed to the main river channel (Sommer et al. 2001a, 2001b, 2004). For the middle Sacramento River, overbank flow occurs at approximately the 2.5-year flood level, or at ~70,000 cfs (SRAC 2003:4-12).

*Methods:* Frequency and duration of floodplain inundation was calculated using flow data measured from the USGS gauge on the Sacramento River at Red Bluff. Calculations were made of ten-year running averages and the number of years in the previous ten that exceeded (or failed to exceed) a given threshold flow.

*Results:* The frequency and duration of floodplain inundation was unchanged in recent decades, and has been greatly decreased post-dam. The average number of days per year with floodplain inundation was reduced by 41% (from 4.4 to 2.6, Figs. 13) relative to pre-dam conditions. Also, the average number of years per decade when flows were insufficient to inundate the floodplain was increased by 129% (from 2.8 to 6.4, Fig. 14) relative to pre-dam conditions.

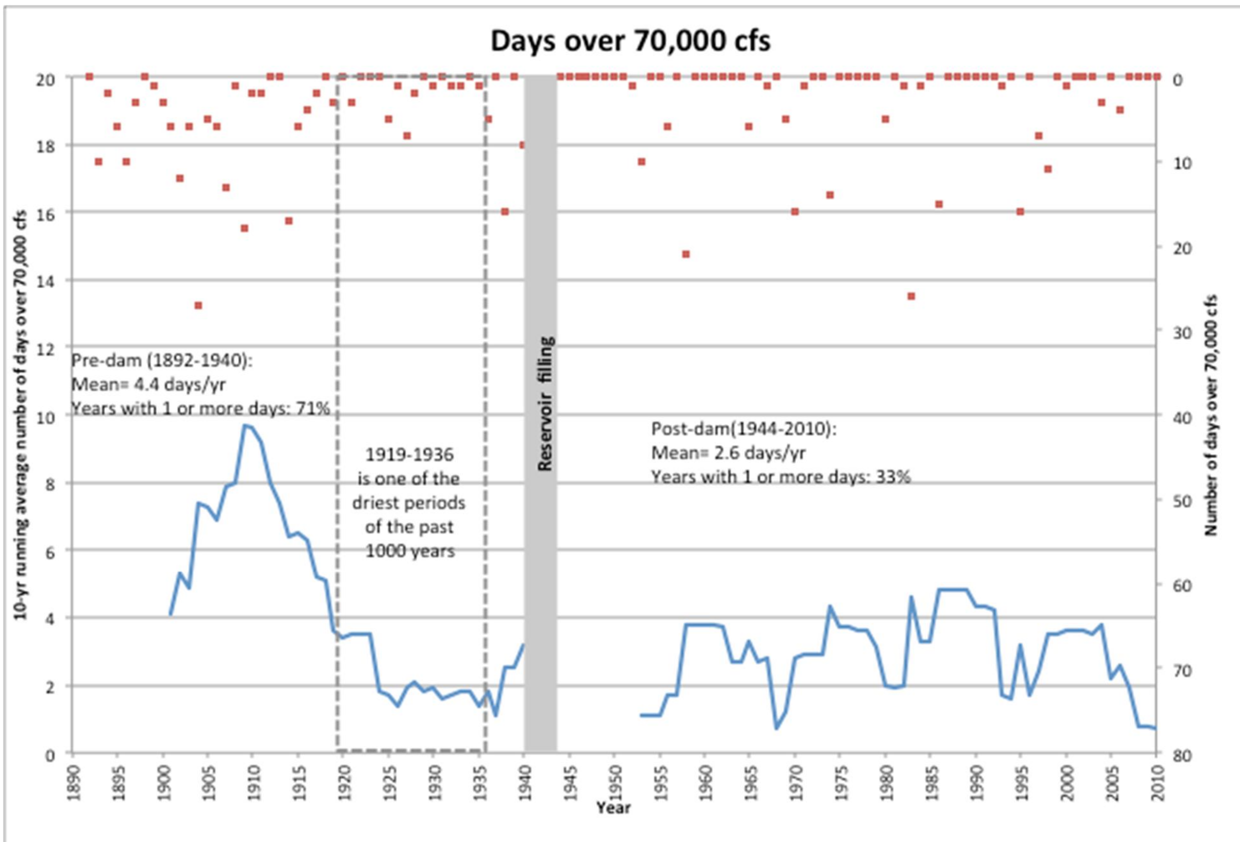



**Figure 13.** Ten-year running average of number of days with flows sufficient to inundate the floodplain (over 70,000 cfs) recorded at the USGS gauge Sacramento River at Red Bluff (blue line, left labels y-axis), along with number of days with flows over 70,000 cfs for each year (red data points, right labels y-axis). Figure from M. Kondolf and Z. Rubin (unpublished).

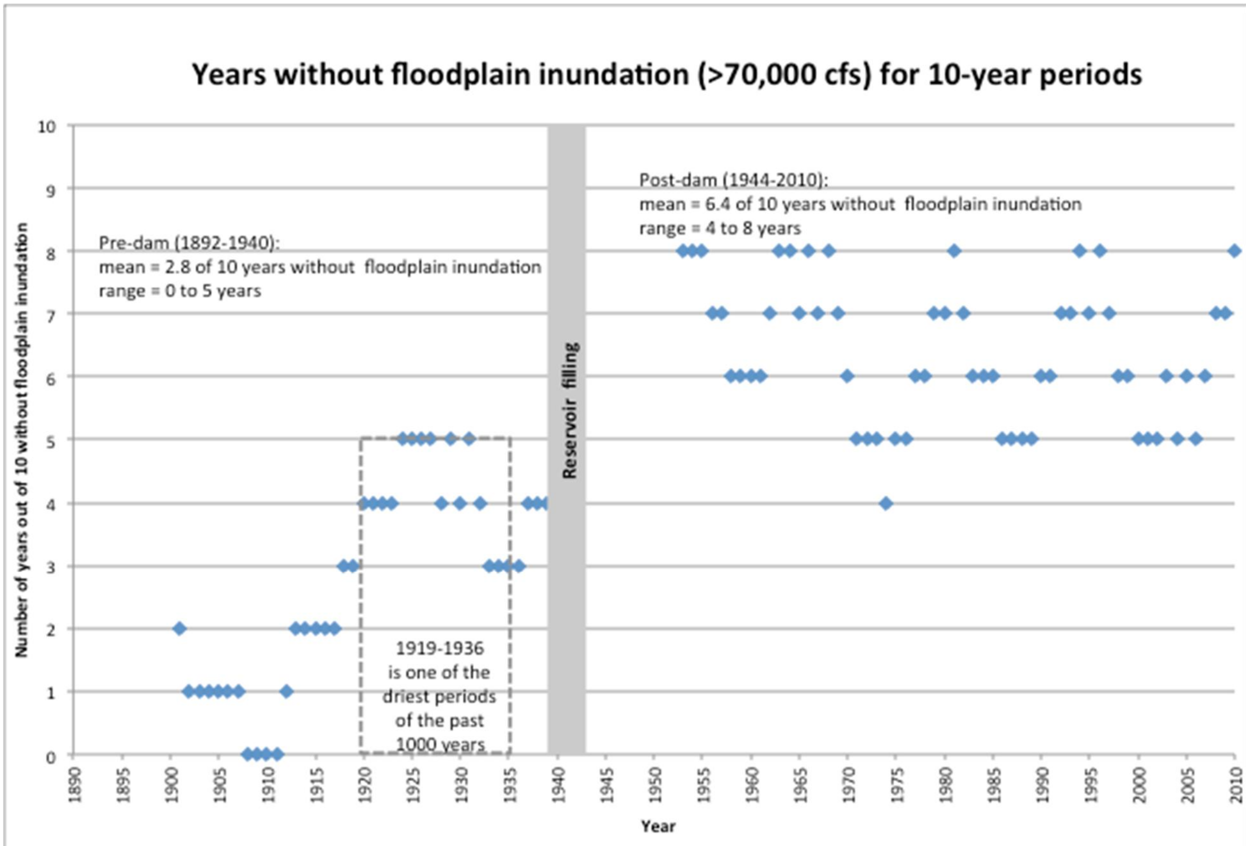



**Figure 14.** Number of years without floodplain inundation over prior ten-year period, based on analysis of USGS flow records, Sacramento River at Red Bluff. Figure from M. Kondolf and Z. Rubin (unpublished).

*Interpretation:* The less-frequent flows capable of overbank flow result from storage of high flows by Shasta Dam, which affected the 70,000 cfs overbank flow threshold more severely than the 55,000 cfs bed mobility threshold. Floodplain disconnection from the channel is even greater than implied by this flow indicator, because much of this reach of the Sacramento River is flanked by levees that prevent overbank flow, even if flows were otherwise sufficiently high to produce overbank flooding.

### Duration of Connectivity of Former Channels

*Definition:* Side channels are connected to the mainstem at flows between 5,000 and 50,000 cfs. This indicator considers separately the 10-year running averages of the number of days per year with flows >15,000 cfs, 50,000 cfs, and dry-season flows (from July 15 to Sept 30$^{th}$), >5,000 cfs.

*Rationale:* Oxbow lakes and other floodplain water bodies, mostly former channels, provide important habitats for a range of species, and are in effect biodiversity hotspots in the river ecosystem. Side channels benefit from periodic, seasonal surface connection to the main channel, including scouring of encroaching vegetation (e.g., *Ludwigia*), refreshing sediments, improving water quality. When connected they provide important rearing habitats for native fishes (Limm and Marchetti 2009). Channels that are artificially cutoff and leveed will lose their periodic hydrologic connection, eliminating dynamic evolution of aquatic and riparian ecology, and ultimately reducing floodplain biodiversity. Similarly, if flows in the mainstem river are artificially reduced, the frequency and duration of hydrologic connection of side channels may be reduced, with loss of beneficial functions of connection.

*Methods:* Side channels along the Sacramento River range widely in age, size, and topographic elevation at which they become connected. Gomez et al (in prep.) studied a broad cross-section of side channels, and through field observation, surveys, and hydrologic modeling, estimated the flow thresholds at which a representative sample population of 17 side channels became hydrologically connected to the mainstem. When ranked by flow at connection, three distinct populations of side channels are evident: a set of side channels that are connected at flows exceeding 50,000 cfs, another set connected at flows exceeding 15,000 cfs, and a set connected by flows greater than 5,000 cfs. Flow data measured at the USGS gauge on the Sacramento River at Red Bluff was analyzed to characterize side channel connection. Calculations were made of both ten-year running averages and number of years in the previous ten that exceeded (or failed to exceed) a given threshold flow.

*Results:* Since regulation by Shasta Dam (and since interbasin water transfers from Trinity River), the first group of side channels has experienced a small decrease in frequency and duration of connection, the second has experienced a larger decrease, when the third group (those connected at flows of over 5,000 cfs) has experienced a substantial prolongation of connection because of augmented base flows (Fig. 15).

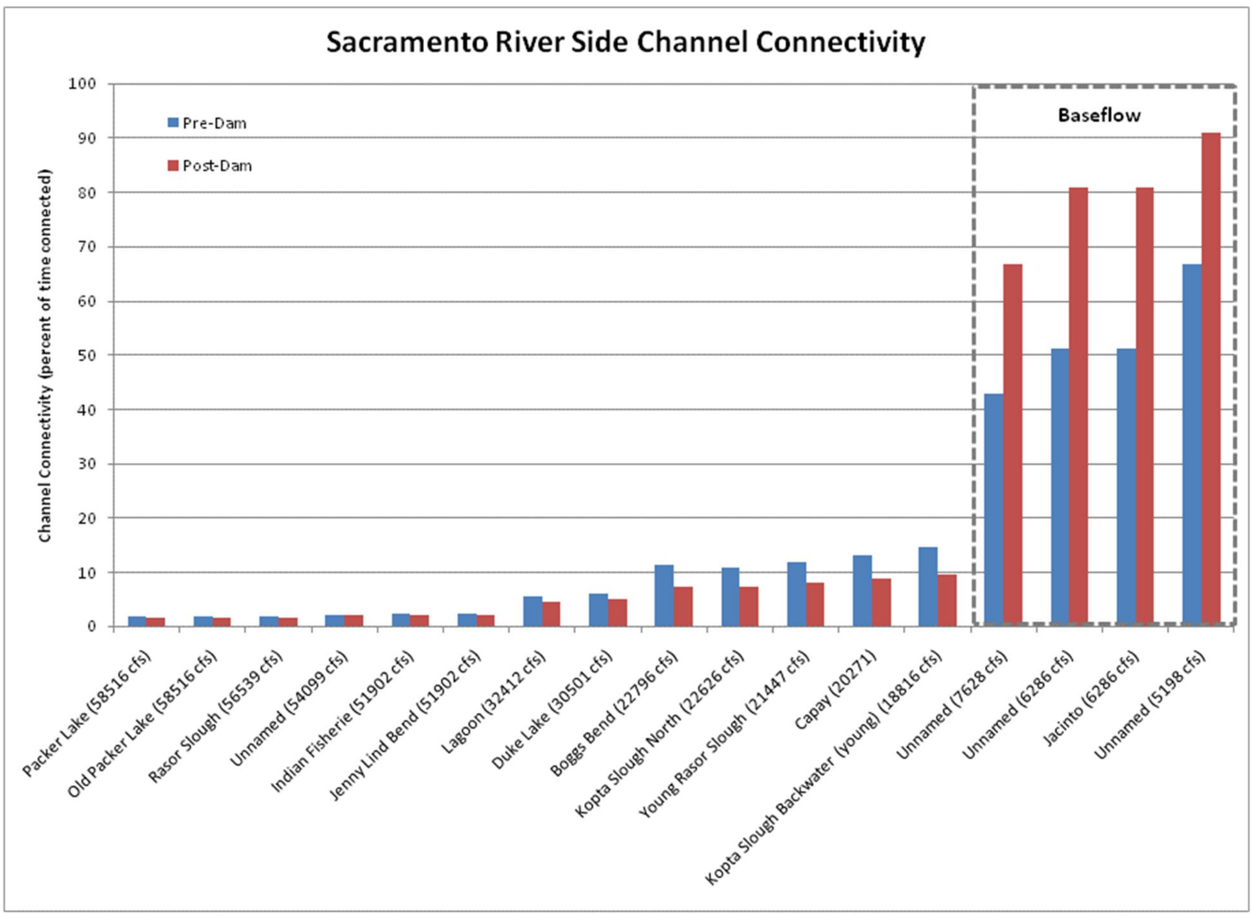



**Figure 15.** Percentage of time that side channels studied by Gomez et al (in prep.) would be connected to the mainstem under pre-Shasta-Dam and post-Shasta-Dam conditions. Note that side channels with

very low plugs and thus low thresholds for connection (under 8,000 cfs) actually stayed connected for longer than would be the case naturally because of artificially increased base flows, which would result in decreased diversity of habitat. All other side channels experienced less frequent connection than under natural conditions. Figure from M. Kondolf and Z. Rubin (unpublished).

*Interpretation:* Reduced frequency and duration of high flows caused by storage in Shasta Reservoir has reduced the frequency of most side channels' connection to the main channel, resulting in loss of natural hydrologic conditions that supported native species. Release of stored winter flood waters from Shasta Reservoir during summer irrigation months, augmented by inter-basin transfer of water from the Trinity River, has resulted in elevated summer base flows. These artificially raised summer water levels now keep some side channels as nearly permanent backwaters to the river, with static, artificially raised water levels in summer. While still providing habitat, these flooded side channels no longer dry out seasonally, and thus are less likely to support native species over exotic.

### Area of Floodplain Reworked

*Definition:* The area of floodplain reworked is an estimate of the amount of newly created floodplain that formed due to lateral migration (Fig. 15).

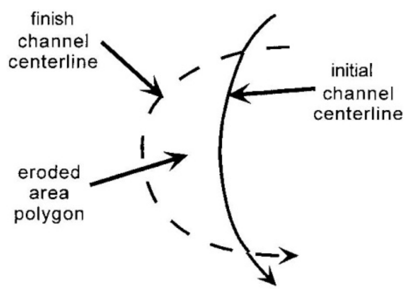



**Figure 15.** Illustration of the eroded area polygon for calculations of area of floodplain reworked.

*Rationale:* The reworking of land and creation of floodplain is critical for ecosystem functions and processes. For example, one of the primary recruitment pathways for Freemont cottonwood takes place on point bars that are newly created (Mahoney and Rood 1998). Other riparian tree species also require a heterogeneity of floodplain ages (Dixon et al. 2002), which is produced by land being eroded and redeposited (i.e., "reworked"). Wildlife species, such as Bank Swallow, have their nesting habitat needs met on cutbanks that are recently eroded (Garrison 1999). The "per year" measurement of land reworked is a indicator of the rate at which such habitats are produced. The degree to which a bend is dynamic provides a characterization of the river's ability to create new floodplains. Dynamic river processes (e.g., erosion, sediment deposition) revitalize riverine habitats and are beneficial to native flora and fauna. Cottonwood and willow forests naturally regenerate on freshly deposited floodplain surfaces, and salmon and other aquatic species benefit from fresh gravel inputs.

*Methods:* The area of floodplain reworked is calculated by 1) determining the area of the "eroded area polygon" that is formed when channel centerlines from two different time periods are intersected, and 2) dividing this area by the number of years between the two time periods (Greco et al. 2007).

*Results:* Comparisons of this geomorphic ecological indicator over time reveal a high degree of variability, but an overall decline (Fig. 16).

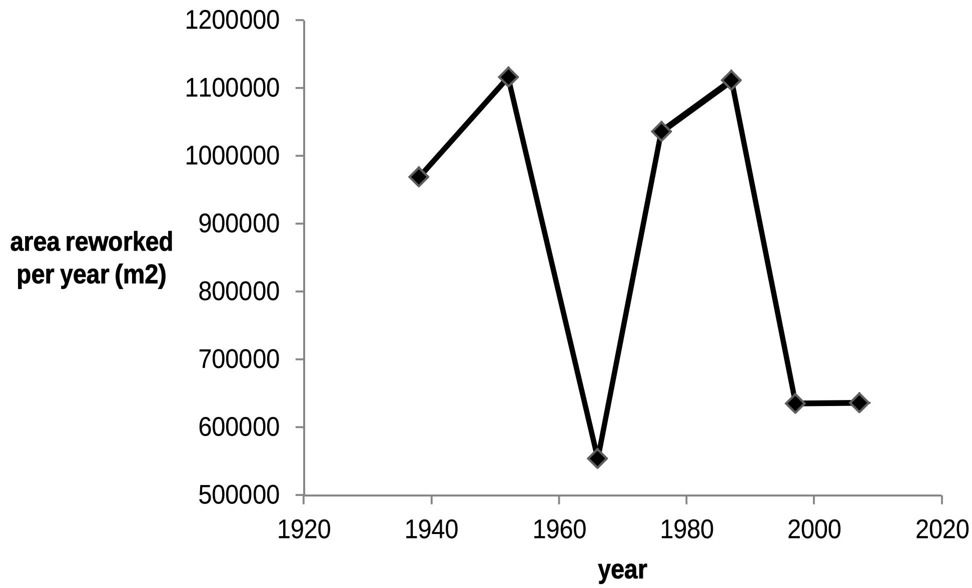



**Figure 16.** Change in area of floodplain reworked per year on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data from E. Larsen, UCD (unpublished).

*Interpretation:* Area of floodplain reworked is a function of flow, but is also influenced by the degree to which the channel is constrained with riprap (which has increased dramatically over time (see Fig. 17). These data suggest that the river is becoming less dynamic over time.

### Length of Bank with Riprap

*Definition:* This is defined as the total length of riverbank that is hardened with revetment.

*Rationale:* Riprap restricts physical fluvial processes on alluvial rivers. Erosion and lateral meander migration and are essential physical processes of river ecosystems. On the Sacramento River these processes create and maintain important habitat elements for a wide variety of biota, including several endangered and threatened species (USFWS 2000). Reduction of riprap is identified as a desired action in recovery plans for Bank Swallow and salmonids (CDFG 1992, USFWS 1992, USFWS 2002).

In this decade, riprap has been installed and is planned to be installed on banks to protect critical infrastructure (i.e. levees and bridges). These installations restrict fluvial physical processes and degrade or destroy critical habitats.

This indicator is only assumed to be representative of the condition of the Red Bluff to Colusa reach of the river, but it may impact species (e.g., salmon) that range much more widely and that utilize this area for only a portion of their lifecycle.

*Methods:* This indicator is measured on both sides of the river between the Red Bluff Diversion Dam and Colusa Bridge (~RM 244-144). Riprap includes cobble, rubble, rock, and any other hardened material placed on the bank of the river to prevent erosion. Riprap locations are derived from mapped products and field investigations, and are documented in GIS datasets. The extent and location of riprap has been mapped on the Sacramento River between Red Bluff and Colusa since the mid-1930s. The most recent survey took place in 2002.

*Results:* The 2002 survey documented approximately 77,000 meters of riprap. It has increased significantly over time (Fig. 17), and at an accelerated rate since the early 1970s. Although comprehensive mapping has not been done since 2002, observations suggest that between 500 and 1000 meters of additional riprap has been installed (A. Henderson, *pers. comm.*).

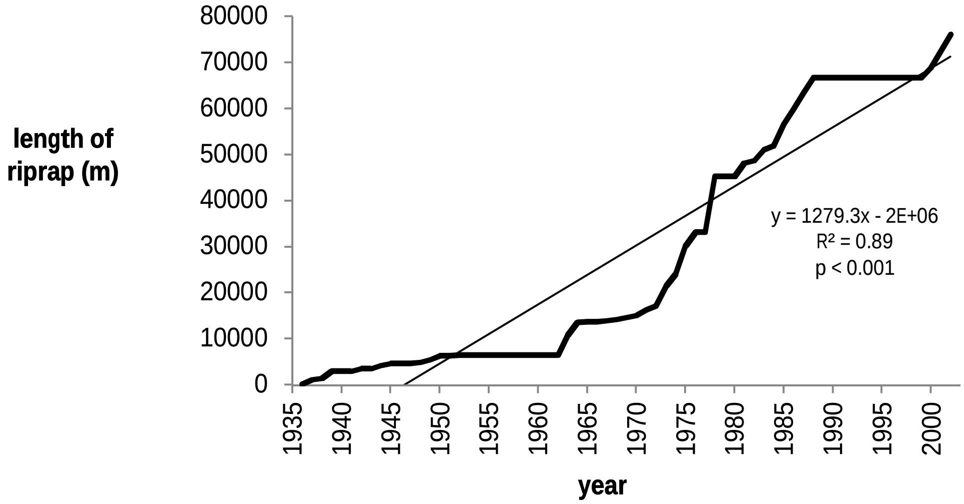



**Figure 17.** Length of riprapped banks on the Sacramento River between Red Bluff and Colusa from 1937 to 2002. Data from A. Henderson, DWR (unpublished).

*Interpretation*: This steady increase in riprap is suggestive of a continued deterioration of riparian and aquatic habitats on the Middle Sacramento River. Riprap brings an abrupt halt to some of the most important ecological processes in river systems. This is an alarming trend that is almost certainly causing adverse consequences for a wide range of species (e.g., Bank Swallow, salmon) and communities (e.g., riparian forest). The continued installation of riprap on the river is reducing the functionality of the riparian ecosystem and making all of the gains that have resulted from two decades of conservation restoration efforts much less significant than they would otherwise be. Of all the indicators that point to problems with the Sacramento River system, this is among the most troubling.

### Whole River Sinuosity

*Definition:* The whole river sinuosity is calculated as the sum of the arc lengths (M's) for all bends divided by the sum of the half wave lengths (L's). The arc length and half wave length are both measured between successive inflection points of single bends. This sum is taken from the Red Bluff Diversion Dam to the Colusa Bridge.

*Rationale:* Whole river sinuosity provides a measure of channel complexity and river dynamism. In alluvial river settings, a sinuous river has more cutbanks and point bars than a straight river. It is also likely to be a more active river in terms of riverine processes of meander migration, erosion and sediment deposition, although such processes may be constrained by the presence of riprap on the river bank. Because sinuous rivers have a greater complexity of habitats and ecological processes (James et al. 2005, Boano et al. 2006, Constantine and Dunne 2008) associated with them they are more supportive of natural species (e.g., Bank Swallow, salmon) and communities (cottonwood forests) than straight rivers (Jungwirth et al. 1993).

*Methods:* The whole river sinuosity (called "reach sinuosity" in Fig. 18) is calculated as the sum of the arc lengths (M) for all bends divided by the sum of the half wave lengths (L). The arc length and half wave length are both measured between successive inflection points of single bends. Whole river sinuosity was calculated for eight points in time periods from 1906 to 2007.

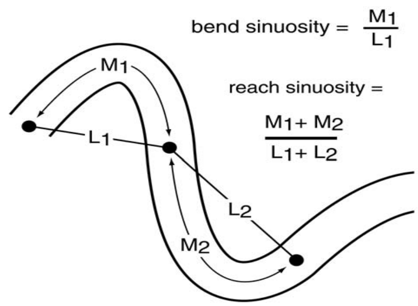



**Figure 18.** Illustration of a generalized river bend showing arc lengths (M) and half wave lengths (L). Also shown are equations for calculating bend sinuosity and reach sinuosity. Solid dots mark inflection points.

*Results:* Whole river sinuosity has decreased steadily and significantly over the period of record (Fig. 19).

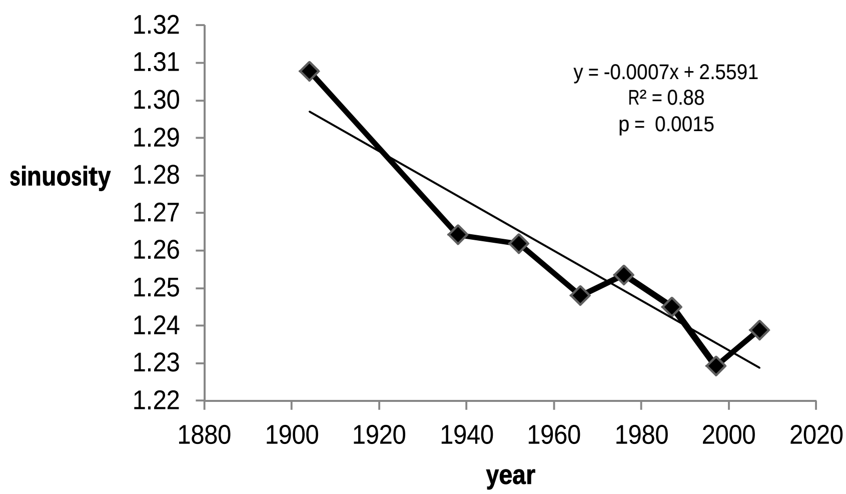



**Figure 19.** Change in whole river sinuosity of the Sacramento between River Red Bluff to Colusa from 1906 and 2007. Data from E. Larsen, UCD (unpublished).

*Interpretation:* The formation of high sinuosity bends susceptible to future cut-off has declined. This suggests that the complexity of the river has decreased over the last century, which is bad for the health of the riparian ecosystem.

### Total Channel Length

*Definition:* This is defined as the distance along the channel centerline from the Red Bluff Diversion Dam to the Colusa Bridge.

*Rationale:* The total length of channel between a starting location and an ending location provides a measure of the linear extent of the river. For ecosystem processes related to aerial extent of river channel or of riparian habitat related to the river bank, a greater total length of channel (given fixed end locations) will provide more area, and therefore more ecosystem functions and processes. For example, a longer channel allows there to be more potential area for all riparian forest dynamics. This indicator was used as a metric of river health on the Willamette River in Oregon (IMST 2002).

*Methods:* The total channel length was measured by measuring the centerline length of the channel using GIS tools. The methodology for drawing a single-threaded centerline was detailed by Greco and Alford (2003). Total channel length was calculated for eight points in time from 1906 to 2007.

*Results:* The river channel length, beginning and ending in the same valley location, has decreased significantly over the period of record (Fig. 20).

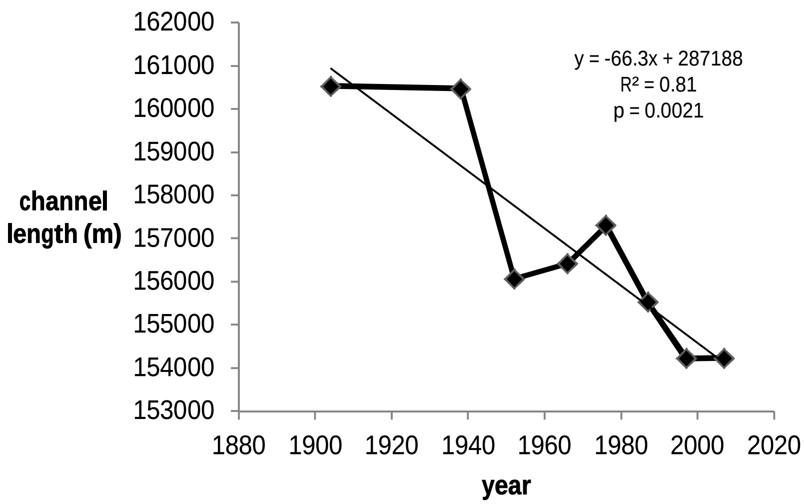



**Figure 20.** Change in total channel length of the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data from E. Larsen, UCD (unpublished).

*Interpretation:* This suggests that over the period of record, river length lost due to cut-off has not been replaced by channel migration. It further suggests that the complexity of the river and its associated habitats has decreased over the last century, which is bad for the health of the riparian ecosystem.

### Average Bend Entrance Angle

*Definition:* This is defined as the average bend entrance angle (θ) for all segments of the river. The angle is defined by the line connecting the bend inflection point and a tangent to the channel centerline at the next upstream inflection point (Fig. 21).

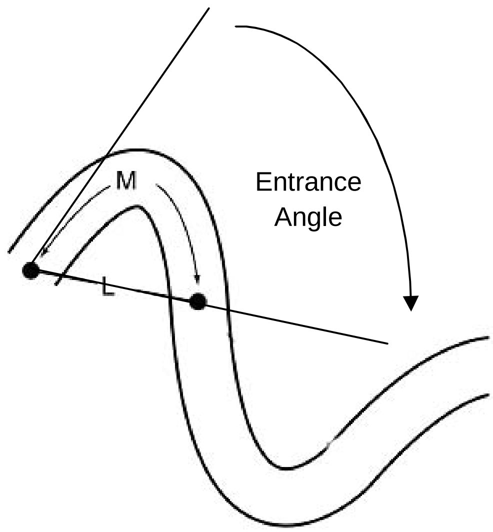



**Figure 21.** Illustration of a generalized river bend showing how bend entrance angle is defined relative to the arc length (M) and half wave length (L).

*Rationale:* Entrance angle represents the upstream curvature of a bend and is representative of a bend's tendency to cutoff (Constantine and McLean 2010, Micheli and Larsen 2010). The greater the entrance angle, the greater the probability of cutoff. Cutoffs lead to increased channel complexity and can produce sloughs and oxbow lakes on the Sacramento River, which are important habitats for wildlife (Morken and Kondolf 2003). The entrance angle of a bend is complementary to other indicator metrics that reflect the shape of the river, particularly the degree of curvature. Therefore, it would be expected that as the sinuosity or curvature (inverse of radius of curvature) *decreases,* there would tend to be a decrease in the entrance angle.

*Methods:* This indicator is an average value for all segments on the river between Red Bluff and Colusa. Individual segments are separated by inflection points. There is no lower threshold for entrance angle in this tabulation. It was calculated for eight points in time from 1906 to 2007.

*Results:* Similar to other channel planform indicators presented here, average entrance angle has been variable over the past century, but overall has shown a significant decrease (Fig. 22).

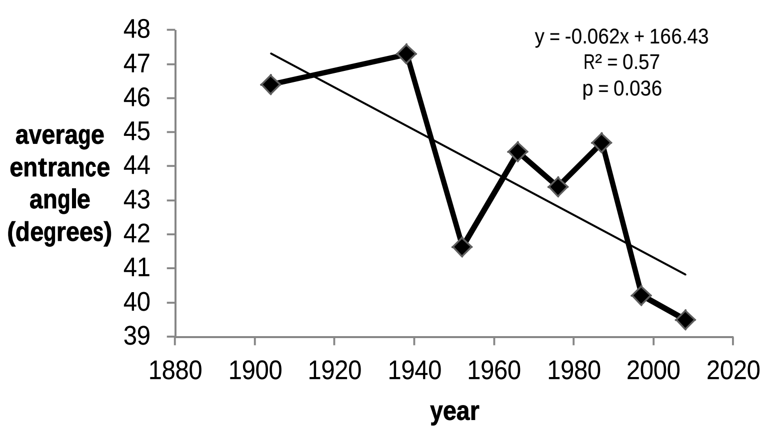



**Figure 22.** Change in average entrance angle on the Sacramento between River Red Bluff and Colusa from 1906 to 2007. Data from E. Larsen, UCD (unpublished).

*Interpretation:* The entrance angle represents the upstream curvature of a bend and can be correlated with the tendency of a river bend to cut-off (Constantine and Dunne 2008; Micheli and Larsen 2010). Cutoffs can produce sloughs and oxbow lakes on the Sacramento River, which are important habitats for a variety of species (RHJV 2004, Morken and Kondolf 2003).

**Length of River with Conservation Ownership on Both Banks**

*Definition:* This is defined as the length of the river that has land in conservation ownership on opposing banks.

*Rationale:* Having land in conservation ownership on both sides of the river helps maintain and preserve existing areas of meander and reactivate meander in other areas that are impaired by bank protection activities. It does so by increasing the likelihood of riprap or levee removal, and decreasing the likelihood of riprap or levee installation or repair.

*Methods:* This indicator is calculated by identifying all locations that have river frontage that are in conservation ownership, and then summing the length of the banklines on both sides of the river in these areas.

*Results:* As of June, 2007, 69,777 meters of the river had conservation ownership on both banks. This compares to between 33,626 and 40,806 meters in June 1999. The value of river frontage in conservation ownership is reported as a range in 1999 because some conservation properties were purchased before 1999 but had more land added to them after 1999. Since the piece-by-piece breakdown of when each bit was added is unavailable, this metric was calculated both with and without those properties that were added to after 1999.

*Interpretation:* This represents a significant increase (between 71 and 108 percent) in the length of river on which there is conservation ownership on both sides. Owning both sides increases the likelihood that natural riverine processes such as bank erosion, sediment deposition and flooding can take place. It also reduces the probability that new riprap or levees will be installed, although it does not guarantee this, as recent events (e.g., at river mile 182) have shown. Ideally owning both sides of the river can allow riprap removal or at least the deterioration of existing bank revetment over time. It also reduces pressure for new rip-rap that may come from adjoining agricultural owners.

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CALFED, Flow Regime, Geomorphology, Goals, Ecological Indicators, Monitoring, Restoration, River Processes, Sacramento River, Wildlife

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**Abstract:**

Large-scale ecosystem restoration projects seldom undergo comprehensive evaluation to determine project effectiveness. Consequently, there are missed opportunities for learning and strategy refinement. Before our study, monitoring information from California's middle Sacramento River had not been synthesized, despite restoration having been ongoing since 1989. Our assessment was based on the development and application of 36 quantitative ecological indicators. These indicators were used to characterize the status of terrestrial and floodplain resources (e.g., flora and fauna), channel dynamics (e.g., planform, geomorphology), and the flow regime. Indicators were also associated with specific goal statements of the CALFED Ecosystem Restoration Program. A collective weight of evidence approach was used to assess restoration success. Our synthesis demonstrates good progress in the restoration of riparian habitats, birds and other wildlife, but not in restoration of streamflows and geomorphic processes. For example, from 1999 to 2007, there was a > 600% increase in forest patch core size, and a 43% increase in the area of the river bordered by natural habitat > 500 m wide. Species richness of landbirds and beetles increased at restoration sites, as did detections of bats. However, degraded post-Shasta Dam streamflow conditions continued. Relative to pre-dam conditions, the average number of years that pass between flows that are sufficient to mobilize the bed, and those that are of sufficient magnitude to inundate the floodplain, increased by over 100%. Trends in geomorphic processes were strongly negative, with increases in the amount of bank hardened with riprap, and decreases in the area of floodplain reworked. Overall the channel simplified, becoming less sinuous with reduced overall channel length. Our progress assessment presents a compelling case for what needs to be done to further advance the ecological restoration of the river. The most important actions to be taken relate to promoting river meander and floodplain connectivity, and restoring components of the natural flow regime.

**Supporting material:**

Appendix A: Detailed Information on Individual Ecological Indicators

OCTOBER 2013

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

# Successes, Failures, and Suggested Future Directions for Ecosystem Restoration of the Middle Sacramento River, California

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## ABSTRACT

Large-scale ecosystem restoration projects seldom undergo comprehensive evaluation to determine project effectiveness. Consequently, there are missed opportunities for learning and strategy refinement. Before our study, monitoring information from California's middle Sacramento River had not been synthesized, despite restoration having been ongoing since 1989. Our assessment was based on the development and application of 36 quantitative ecological indicators. These indicators were used to characterize the status of terrestrial and floodplain resources (e.g., flora and fauna), channel dynamics (e.g., planform, geomorphology), and the flow regime. Indicators were also associated with specific goal statements of the CALFED Ecosystem Restoration Program. A collective weight of evidence approach was used to assess restoration success. Our synthesis demonstrates good progress in the restoration of riparian habitats, birds and other wildlife, but not in restoration of streamflows and geomorphic processes. For example, from 1999 to 2007, there was a >600% increase in forest patch core size, and a 43% increase in the area of the river bordered by natural habitat >500 m wide. Species richness of landbirds and beetles increased at restoration sites, as did detections of bats. However, degraded post-Shasta Dam streamflow conditions continued. Relative to pre-dam conditions, the average number of years that pass between flows that are sufficient to mobilize the bed, and those that are of sufficient magnitude to inundate the floodplain, increased by over 100%. Trends in geomorphic processes were strongly negative, with increases in the amount of bank hardened with riprap, and decreases in the area of floodplain reworked. Overall the channel simplified, becoming less sinuous with reduced overall channel length. Our progress assessment presents a compelling case for what needs to be done to further advance the ecological restoration of the river. The most important actions to be taken relate to promoting river meander and floodplain connectivity, and restoring components of the natural flow regime.

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## KEY WORDS

CALFED, flow regime, geomorphology, goals, indicators, monitoring, restoration, river process, Sacramento River, wildlife.

## INTRODUCTION

For ecosystem restoration programs to receive ongoing support they must demonstrate success in achieving their stated objectives. Increasingly, policymakers are calling for proof of return on investment (Murdoch et al. 2007). The challenges of demonstrating success may be especially great for large-scale restoration programs. Their goals and objectives are often broadly stated, which can make progress assessments difficult. Typically, monitoring is of short duration and limited in scope, making comprehensive assessments problematic (Roni et al. 2008). This results in missed opportunities for learning, and reduces the effectiveness of future projects (Walters and Holling 1990; Holl and Cairns 2002). Also, the extensive geographical scale of large restoration programs often encompasses substantial environmental variation which can make it difficult to determine if observed patterns are caused by implemented actions or environmental factors.

Extensive investment and limited assessment characterize restoration efforts on the Sacramento River, in north-central California. Over the past two and a half decades, the CALFED Ecosystem Restoration Program (ERP) and other entities (e.g., California Wildlife Conservation Board, National Oceanographic and Atmospheric Administration—Fisheries, National Fish and Wildlife Foundation, and private corporations), have invested significant resources in conservation and restoration of terrestrial and aquatic resources in this area (CALFED 2000a). Yet, to date, comprehensive evaluations of the effectiveness of implemented actions have been limited. Isolated studies have been useful in examining the response of specific ecosystem components (e.g., Alpert et al. 1999; Griggs and Golet 2002; Holl and Crone 2004; Borders et al. 2006); however, integrated assessments of progress toward established goals have not been conducted. Unfortunately, this is not uncommon. In a review of U.S. river restoration efforts, Bernhardt et al. (2005) found that only 10% of projects had any form of assessment or monitoring, although the percentage may be higher for large projects than for small ones.

In a retrospective evaluation of ERP-funded restoration projects, Kleinschmidt and Jones & Stokes (2003) concluded that a lack of agreed-upon indicators and the absence of an overall framework for evaluation made it difficult to assess performance. They strongly recommended development and implementation of a multilevel framework for measuring performance, deemed necessary because the ERP had not yet adopted a way to evaluate performance at the program, project, or ecosystem levels. Layzer (2008) also noted that CALFED's approach to performance measurement was limited; "Even where measures were adopted... it was too difficult to get consensus on outcome-level metrics, so the program relented and measured outputs instead" (Layzer 2008, p 159-160). Outputs included parameters such as number of projects funded, total dollars spent, and acres of habitat planted (Kleinschmidt and Jones & Stokes 2003). Measuring only outputs resulted in an inability to demonstrate return on investment (Little Hoover Commission 2005), a failing that ultimately contributed to CALFED losing much of its funding (Layzer 2008). Even now, with enough time having passed to manifest the ecological responses, there has been little synthesis of information. Consequently, many of the restoration program's successes and failures have gone unrecognized, and the reasons underlying each remain obscure.

In this paper, we begin to fill this information gap by synthesizing a suite of quantitative ecological indicators (outcome-level metrics) to evaluate the success of restoration of the middle Sacramento River. Individual indicators developed and applied in our study characterize the status of terrestrial and floodplain resources (including flora and fauna) and channel dynamics (including planform, geomorphology, and flow regime parameters). They do not directly represent aquatic resources such as fish; however, they do characterize habitat elements and physical processes that are important to aquatic biota.

We evaluated restoration success in two complementary ways. Both involved evaluations of trend data derived from quantitative ecological indicators. First, indicators were associated with six broad ecosystem elements (e.g., terrestrial riparian habitats, fluvial and geomorphic processes), and second, they were aligned with specific goals of the CALFED Ecosystem Restoration Program (CALFED 2000a). In both instances the collective weight of evidence from the relevant indicators was used to assess success.

In conducting our indicator assessment we both collected new data and analyzed existing information. Because this system has been intensively studied, we had a wealth of previously collected data to draw from. Although information was not available on every attribute that might characterize a riparian restoration project, our set of indicators is robust, and the picture it presents of the status and trends of the Sacramento River riparian ecosystem is compelling. Our analysis identifies areas where significant progress has been made, and areas where it has not. Based on these findings, we identify specific actions to advance the restoration of the river in the years to come. Because many of the factors that have impeded the progress of restoration on the Sacramento River are common to other rivers, recommendations that we make for future emphasis may be applicable elsewhere.

## BACKGROUND

### Study Area and Anthropogenic Alterations

The Sacramento River is California's largest river, supplying approximately 80% of freshwater flowing into the Sacramento and San Joaquin River Bay–Delta (California State Lands Commission 1993). The 62,000 km$^2$ watershed is the single most important source of water for Californians, and provides critical habitat for a wide variety of species. Historically, the river was lined by approximately 325,000 hectares of riparian forest; however, over 95% of this habitat has been lost to logging, agriculture, urban development, flood control, and power generation projects (Katibah 1984). Levees and riprap further degrade the habitat by confining two-thirds of the river's linear extent. Channelization, bank protection, and the construction of Shasta Dam severely constrain the river's natural processes that promote habitat succession and regeneration. Cumulatively, these changes have greatly stressed the Sacramento River ecosystem leading to reduced wildlife populations and invasion and proliferation of non-native invasive species.

The watershed is under the influence of a Mediterranean climate that is strongly affected by El Niño Southern Oscillation and Pacific–North America teleconnection climatic patterns (Redmond and Koch 1991; Cayan et al. 1999). The watershed typically experiences hot, dry summers and variably wet winters, with periods of drought. Several large foothill storage reservoirs alter the natural flow regime in the Sacramento River. These were primarily designed to store spring snowmelt for farmland irrigation and municipal needs, and to dampen the largest winter flood peaks; however, they are also managed to provide hydropower and recreation, and to meet habitat needs of listed fish species. An analysis of the influence of these storage reservoirs on downstream hydrology is presented in Singer (2007).

This study focuses on the Middle Sacramento River (Figure 1). Situated between the towns of Red Bluff and Colusa (~161 river km), this is an alluvial stretch of the river that still has some riparian habitat and hydraulically connected floodplain. The bed of the river is dominantly gravel-bedded in this reach, transitioning to sand downstream of Colusa (Buer et al. 1989; Singer and Dunne 2001, 2004; Singer 2008, 2010). Below Colusa, levees entirely confine the river along its banks. The middle stretch contains the entire 4,142-ha U.S. Fish and Wildlife Service (USFWS) Sacramento River National Wildlife Refuge, as well as the 1,526-ha California Department of Fish and Wildlife (CDFW) Sacramento River Wildlife Area.

Riparian conservation and restoration efforts have primarily focused on this reach because the degradation that the river has experienced here is largely reversible. Farms (as opposed to human settlements) have replaced floodplain forests, and levees, where present, are often set back from the river by appreciable distances. Along some stretches of this historically meandering reach of the river, bank revetment (riprap) is absent and the natural processes of bank erosion and point bar deposition are still intact.

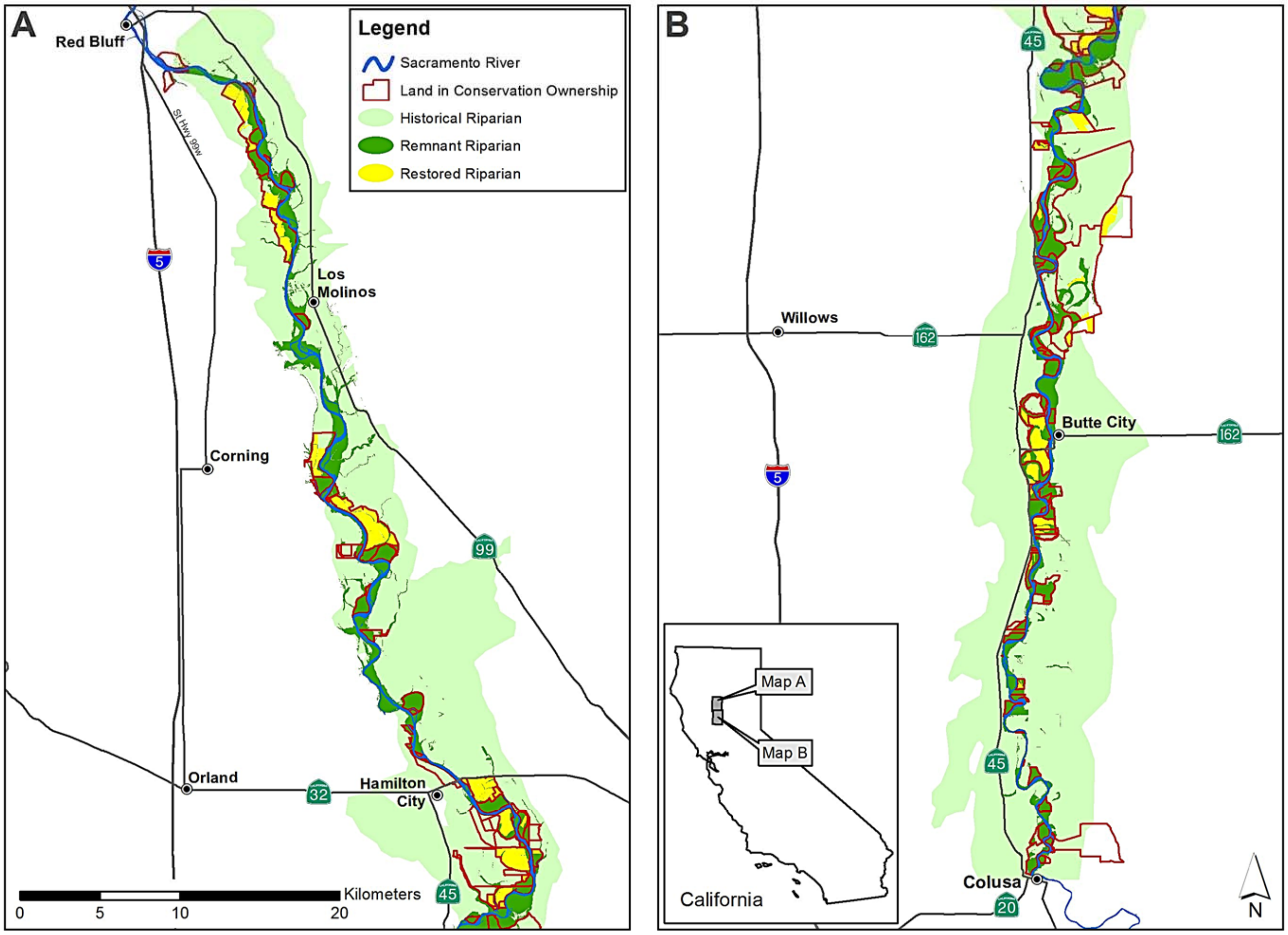


**Figure 1** Map of conservation lands in the 161 river km Sacramento River Project area, located between the towns of Red Bluff and Colusa: (A) northern portion of the project area; (B) southern portion of the project area. Also shown are remnant and restored habitats and the historical riparian zone, drawn from an interpretation of the Holmes and Nelson (1916) soil map.

## At-risk Species

The loss of riparian habitat along the Sacramento River has caused local extirpations and threatens the persistence of important native species. The most well-known imperiled species are anadromous fishes (e.g., salmonids and sturgeons); however, a suite of terrestrial taxa, including mammals, birds and insects are also at risk. Among the special-status mammals are rare and ecologically important bat species [e.g., the western mastiff bat (*Eumops perotis*) and yuma myotis (*Myotis yumanensis*)]. Several migratory birds have declined or have experienced range retractions, including the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), bank swallow (*Riparia riparia*), yellow-breasted chat (*Icteria virens*), yellow warbler (*Dendroica petechia*) and Swainson's hawk (*Buteo swainsoni*). Birds that no longer reproduce along the river include least Bell's vireo (*Vireo bellii pusillus*) and willow flycatcher (*Empidonax trailii*) (Gaines 1977; Shuford and Gardali 2008; Howell et al. 2010). The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*, VELB), is a federally threatened, endemic species of the Central Valley that is absent from large areas within its historical range (CALFED 2000b).

### Restoration Vision for the Sacramento River Ecological Management Zone

The overall vision for the Sacramento River Ecological Management Zone is expressed in the CALFED Ecosystem Restoration Program Plan (CALFED 2000a):

> To improve, restore, and maintain the health and integrity of the Sacramento River riverine-riparian and tributary ecosystems to provide healthy conditions for sustainable fish and wildlife populations and the plant communities on which they depend.

As described in the plan, the path to achieving this vision is through preservation and restoration of erosional and depositional channel and floodplain-forming processes, riparian and wetland habitats, spawning gravel recruitment, and reducing the extent and influence of stressors. It includes goals of restoring elements of the natural flow regime in support of native species and communities. In addition to the overall vision for the ecological management zone, the Restoration Program Plan developed specific vision statements for the two ecological management units that comprise the Sacramento River Project area (Box 1).

### Implemented Restoration

Although severely degraded, the Sacramento River is still one of the most diverse and extensive river ecosystems in California. It is composed of a rich, although fragmented, mosaic of aquatic habitats, oxbow lakes, sloughs, seasonal wetlands, riparian forests, valley oak woodlands, and grasslands. A striking feature of the Sacramento River is the potential for restoration that it presents. Recognizing this potential, and in an effort to restore habitat as well as viable populations of resident and migratory birds, VELB, anadromous fish, and other wildlife, government and non-government organizations have implemented a series of restoration programs[a] along the river.

The Nature Conservancy (TNC) began planting native woody trees and shrubs on Sacramento River floodplain lands in 1989 (Alpert et al. 1999), and in 2000, an understory component was added to the planting palette. Current restoration projects include up to 33 species (see Table 3 in Golet et al. 2008). In total, as of 2012, over 2,500 hectares of riparian habitat have been planted (Figure 2), compared to the 6,000 hectares called for under ERP Milestone 60 (USFWS et al. 2004). Sacramento River riparian restoration costs approximately $12,300 per ha (TNC, unpublished data). Thus over $30 million dollars were invested in restoration plantings over 23 years.

### Monitoring of Ecosystem Response to Restoration on the Middle Sacramento River

Localized surveys confirm the success of restoring Sacramento River riparian habitats for wildlife (Holl and Crone 2004; Gardali et al. 2006; Gardali and Nur 2006; Small et al. 2007; Williams 2007, 2010; Golet et al. 2008, 2011, 2013; Gardali and Holmes 2011; McClain et al. 2011). However, previously implemented projects need more comprehensive assessment. This requires examining the ecosystem as a whole, including both restored and non-restored areas and the major physical processes (e.g., channel and floodplain processes) that drive ecosystem dynamics. The synthesis of indicator information presented in this paper provides an initial step in this direction.

## METHODS

### Ecological Indicators

To characterize the status of the riparian ecosystem and assess progress toward attaining ERP goals, we developed quantitative ecological indicators from data collected in remote sensing and field-based monitoring studies. A great variety of data were ana-

a The California State Legislature, in 1986, passed Senate Bill 1086, which mandated the development of a management plan to protect, restore and enhance riparian habitat along the Sacramento River and its tributaries. In response, the Sacramento River Conservation Area Forum (SRCAF) formed, and set as its primary goal the preservation of remaining riparian habitat and the reestablishment of a continuous riparian corridor from Red Bluff to Colusa (SRCAF 2003). The Nature Conservancy (TNC), and its agency partners (including the U.S. Fish and Wildlife Service, the California Dept. of Water Resources, the CA Dept. of Fish and Game, and the California Dept. of Parks and Recreation) have worked to implement many SRCAF conservation initiatives including horticultural restoration of the historical riparian floodplain. CALFED, the Wildlife Conservation Board, and the Central Valley Project Improvement Act's (CVPIA) Habitat Restoration Program supported riparian plantings, as well as the related expenses of land acquisition, restoration planning, research and monitoring. CALFED alone funded 2,300 hectares of habitat protection along the river between Red Bluff and Colusa (D. Burmester, CDFW, pers. comm.).

**Box 1** Specific CALFED Ecosystem Restoration Program vision statements and interpretations for the two ecological management units that comprise the Sacramento River Project area (see Figure 1).

### The Vision for the Red Bluff Diversion Dam to Chico Landing Ecological Management Unit:

> "To protect and expand the quantity and quality of the stream meander corridor; protect the associated riparian forest and allow it to reach maturity; to maintain flows that emulate the natural hydrology to the extent possible; and recover or contribute to the recovery of threatened, endangered, and special concern species. The existing meander belt should be protected and improved to sustain the riparian and riverine aquatic habitat component that is important habitat for riparian forest-dependent species, such as the yellow-billed cuckoo, other Neotropical migrant bird species, and the valley elderberry longhorn beetle."

In the interpretation of this vision statement, it is noted that restoring endangered species and species of special concern requires that water management activities be consistent with maintaining ecological processes. These include flows that emulate the natural hydrologic regime to the extent possible. Important considerations include flows needed to maintain natural stream meander processes, gravel recruitment, transport, deposition, and establishment and growth of riparian vegetation. It is further stated that the broad riparian corridors throughout the unit should be connected to support increased populations of Neotropical migrants. It is recognized that species such as the bank swallow will benefit from the restoration of processes that create and maintain habitat within this unit (CALFED 2000b).

### The Vision for the Chico Landing to Colusa Ecological Management Unit:

> "To improve habitat and increase survival of many important fish and wildlife resources by preserving, managing and restoring a functioning ecosystem that provides a mosaic of varying riparian forest age classes and canopy structure; maintaining a diversity of habitat types, including forest and willow scrub, cut banks and clean gravel bars, oxbow lakes and backwater swales with marshes, and floodplain valley oak/sycamore woodlands with grassland understory; maintaining uninterrupted gravel transport and deposition; supporting a complexity of shaded and nearshore aquatic substrate and habitats with well-distributed instream woody cover and organic debris; setting back levees. Closing gaps in the shoreline riparian vegetation and nearshore aquatic habitat will be accomplished by several means. These include natural colonization or active restoration of expanded floodplain along channels. The continuance of natural river migration within its meander zone is essential to create and maintain most of these habitats."

The ERP calls for employing a mix of solutions to reduce the need for future additional bank protection or separation of the channel from its floodplain. One such solution is strategic levee setbacks. According to the program plan, in this unit, broad riparian corridors should be interconnected with narrower corridors that are not subject to fragmentation. These corridors should connect larger blocks of riparian habitat—typically larger than 20 ha—to support the river's natural cooling by convection currents of air flowing from the cool, humid forests and across the river water. The wider riparian corridors should generally be greater than 100 m wide to support Neotropical migrants, such as the yellow-billed cuckoo. Cavity nesting species, such as wood duck (*Aix sponsa*), and special-status species, such as bank swallow, will benefit from restoring the processes that create and maintain habitat within this unit (CALFED 2000b).

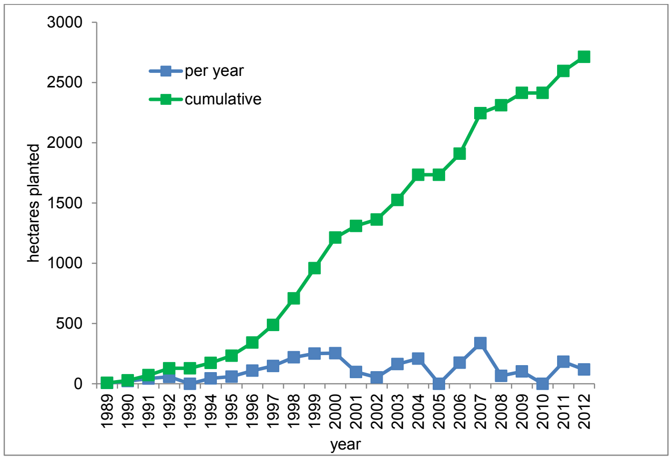


**Figure 2** Cumulative and per-year hectares of riparian habitat restored by TNC and River Partners through horticultural restoration on the Sacramento River between Red Bluff and Colusa. A small amount of additional land has been restored by other entities.

lyzed. Included indicators represent the extent and condition of different riparian habitat types, wildlife species abundances, species richness, percent occupancy, community composition, species distribution, fecundity, growth, survival, reproductive success as well as geomorphic and hydrologic attributes. In total, 36 ecological indicators were included in this assessment.

Methods to compute each indicator are provided in individual indicator accounts (Appendix A). These accounts define the indicators and provide the rationale for each being a meaningful indicator of ecosystem health. In addition they summarize and often graphically display the results, and offer interpretations. Readers interested in reviewing details about the individual studies from which this synthesis is drawn should consult this appendix.

## Sampling Sites

Field sampling locations for data collection varied by investigation (Appendix A), but all were located within the Middle Sacramento River, between the Red Bluff Diversion Dam and the Colusa Bridge (hereafter the "study reach," see Figure 1). An exception is the investigation of streamflow, which analyzed gauge data collected from a location upstream. This was done strategically, so that inferences could be made about conditions in the downstream study reach. Sampling was not necessarily sufficient in all cases to characterize the state of indicators across the entire study reach; however, all of the data included in our analyses are representative of some portion of the area.

All of the riparian restoration sites were previously in agriculture, most commonly as walnut orchards, before being revegetated with local ecotypes of indigenous trees, shrubs and understory species. For information on revegetation methods and approaches see Griggs and Peterson (1997) and Alpert et al. (1999). Restoration sites are located in low lying floodplain areas embedded in a landscape matrix of natural remnant habitats, fallow land and agriculture (see Figure 1 in Holl and Crone 2004); none are close to urban areas or dense residential settlements. Surrounding agriculture primarily consists of orchards, and row and field crops, although a few areas are managed as irrigated pasture for livestock.

## Study Designs

To collect data and analyze the various indicators, we used a variety of sampling methods and study designs (Appendix A). Some indicator studies focused on status and trends at restorations sites (see Figure 1), while others examined larger landscape processes and patterns.

Studies of restoration sites that were designed to characterize trajectories of change took several different approaches. Some compared restoration sites of different ages (see Figure 3 in Golet et al. 2008); others compared restoration sites with remnant riparian forests or agricultural sites. Remnant sites have vegetation that naturally recruited, and were never cleared or used for agriculture. Comparisons among different site types (restoration, remnant, and agriculture) are informative because they enable us to determine if characteristics of restoration sites are more similar to patterns observed at remnant forest sites than at agricultural sites. If so, then this is one measure of restoration success. It is understood, however, that conditions in remnant forests are not ideal.

To varying degrees, they are isolated and invaded by non-native species.

### Synthesis of Indicator Data

We synthesized indicator information in two ways. First, we assessed what all relevant indicators convey about the status and trends of six ecosystem components: (1) riparian habitats, (2) native plant species and communities, (3) invasive riparian and marsh plants, (4) birds and other wildlife, (5) streamflows and flood processes, and (6) river planform and geomorphic processes. We ranked trend information for each ecosystem component—as strongly positive, positive, neutral (no difference), negative, or strongly negative—based upon the status and trends of the individual indicators collectively.

Second, we synthesized relevant indicators to characterize progress toward specific CALFED Ecosystem Restoration Program goal statements. These statements were grouped into three main categories: (1) habitats and vegetation, (2) wildlife, and (3) natural river processes. For each stated ERP goal we assigned qualitative progress rankings of “Poor,” “Fair,” “Good,” and “Very Good,” based on combined evidence derived from analyses of the associated indicators.

Whereas all of the ecological indicators that were included in our analyses contributed important information, the strength of evidence that individual indicators provided differed considerably. Some were calculated from data that were collected over a long time span and/or at numerous sites (including both restoration and reference habitats), while others were based on shorter term or less intensive investigations. For example, songbird data were first collected in 1993, whereas the first geomorphic data analyzed were from the early 1900s. Thus, for some indicators, only recent patterns can be described; for others, current trends can be set in an historical context.

As well, some indicators have a more direct conceptual linkage than others to the particular ecosystem element or ERP goal that they are meant to represent. As a result, not all of the included indicators are equally robust. To address this issue in our synthesis, we did not apply any formalized weighting scheme. Instead we used our best professional judgment in a collective weight of evidence approach that sought to take into account the different factors that influence the information value that each indicator provided. Thus, even though the data that are used in our assessments are highly quantitative and were derived through objective studies, the summarized rankings we report are subjective. Regardless, for any given ecosystem element or goal statement, most indicators were in agreement. Thus, our judgments of the relative importance of different indicators had little influence on the overall rankings assigned in the assessments.

## SPECIFIC ERP VISION STATEMENTS AND ASSOCIATED ECOLOGICAL INDICATORS

Below are specific goal statements that were presented in the ERP Program Plan (CALFED 2000b), followed by relevant indicators. The geographical area of inference for all indicators is the Sacramento River riparian corridor between Red Bluff and Colusa. Brief explanatory text is included below for individual indicators, although the reader is referred to Appendix A for more comprehensive definitions. Appendix A also provides the rationale for why particular indicators are meaningful, the methods for quantifying them, and detailed results. Although we selected these indicators to characterize the status of ecological resources on the Sacramento River, many could be applied to other alluvial rivers, either in their current form, or with slight modification.

### Habitats and Vegetation

**Riparian and Riverine Aquatic Habitats.** The goal is to maintain and restore extensive areas of riparian and riverine aquatic habitats. This entails providing conditions for riparian vegetation growth along channelized portions of the Sacramento River, increasing the ecological value of low-to moderate-quality shaded riverine aquatic (SRA) habitat by changing land use and land management practices, and maintaining existing streamside riparian vegetation.

***Associated Ecological Indicators***

- *Forest Patch Core Size.* This is a landscape pattern indicator (derived by FRAGSTATS, McGarigal and Marks 1994) defined as the size of the forest patch, minus the edge effect zone.
- *Forest Patch Proximity.* This is a FRAGSTATS landscape pattern indicator defined as the proximity of a forest patch relative to other forest patches. It is the corollary of patch isolation.
- *Forest Edge Contrast.* This is a FRAGSTATS landscape pattern indicator defined as the structural contrast between forest habitat and other adjoining habitat types. For example, a high contrast edge is found between a row crop field and a remnant patch of mature riparian forest, while a low contrast edge is present between mature riparian forest and older restored riparian forest.
- *Percent of Historical Riparian Zone Currently in Conservation Ownership.* The historical riparian zone is defined based upon the Holmes and Nelson (1916) soil map of the Sacramento River Valley (see Figure 1). Conservation ownership includes both agency and non-governmental organization lands that are managed for their habitat values.
- *Percent of Historical Riparian Zone Currently in Natural Habitat.* Natural habitat includes remnant areas and restoration sites.
- *Percent of Riparian Shoreline Bordered by >500 m of Natural Habitat.*
- *Number of In-channel Large Woody Debris Aggregations.* This is based on mapping of in-channel large woody debris aggregations that were observed near or above the surface on aerial photographs.
- *Soil Organic Carbon.* This is the percent of carbon in the soil.

**Native Plant Species and Communities.** The goal for plant species and communities is to protect and restore these resources in conjunction with efforts to protect and restore wetland and riparian and riverine aquatic habitats.

***Associated Ecological Indicators***

- *Areal Extent of Native Vegetation.* This is the area mapped as annual and perennial grassland, Fremont cottonwood (*Populus fremontii*) forest, mixed riparian forest, riparian scrub, and valley oak (*Quercus lobata*) woodland from visual interpretation of georectified aerial photographs.
- *Basal Area of Woody Species.* This is the total cross-sectional area of woody species within a plot. It includes all tree species as well as shrubs with woody stems such as willows (*Salix* spp.), blue elderberry (*Sambucus caerulea*), and coyote brush (*Baccharis pilularis*).
- *Frequency of Woody Species in Various Size Classes.* This is the frequency distribution of stem diameters of the major native tree species in this system [i.e., Fremont cottonwood, valley oak, box elder (*Acer negundo*), and Goodding's black willow (*Salix gooddingii*)].
- *Importance Value of Woody Species.* Importance value for a species is defined as the sum of relative density + relative basal area. This parameter was calculated for all native tree species as well as shrubs with woody erect stems such as willows, elderberry, and coyote brush.
- *Native Understory Frequency of Occurrence.* Native understory species frequency of occurrence is the proportion of quadrats in which at least one native species is present.
- *Native Understory Species Richness.* Native understory species richness is the number of native herbs, shrubs, and vines observed. It does not include tree species seedlings which may be found in the understory.
- *Relative Native Understory Cover.* Relative native understory cover is the percent native cover divided by percent total cover.

**Invasive Riparian and Marsh Plants.** The goal is to reduce the spread or eliminate invasive non-native riparian species such as giant reed (*Arundo donax*) and salt cedar (*Tamarix ramosissima*) that compete with native riparian vegetation.

***Associated Ecological Indicators***

- *Areal Extent of Giant Reed.* The areal extent of this plant species (and those listed below) was mapped from visual interpretation of geo-rectified aerial photographs.
- *Areal Extent of Himalayan Blackberry (Rubus discolor).*
- *Areal Extent of Water Primrose (Ludwigia peploides).*
- *Importance Value of Black Walnut.* Importance value is defined as the sum of relative density + relative basal area.

## Wildlife

**Neotropical Migratory Birds.** The goal for Neotropical migratory birds is to maintain their diversity, abundance and distribution by protecting and restoring riparian and riverine aquatic habitats upon which they depend. Wide riparian corridors or patches should be created to help reduce brown-headed cowbird (*Molothrus ater*) predation. Specific goals for yellow-billed cuckoo and bank swallow are listed separately.

**Western Yellow-billed Cuckoo.** The goal for the yellow-billed cuckoo is to contribute to the recovery of this state-listed endangered species. Potential habitat for the cuckoo should be expanded by protecting and restoring riparian and riverine aquatic habitats, restoring ecosystem processes and functions, and reducing or eliminating stressors. Restoration of riparian woodlands along the Sacramento River for cuckoos should focus on natural stream meander, flow, and natural revegetational/successional process.

**Bank Swallow.** The goal for the bank swallow is to contribute to the recovery of this state-listed threatened species. Potential habitat for bank swallows will be improved by sustaining the river meander belt and increasing the coarse sediment supply to support meander and natural sediment erosion and deposition processes.

***Associated Ecological Indicators***

- *Nest Survival of Black-headed Grosbeak (Pheucticus melanocephalus), Lazuli Bunting (Passerina amoena), and Spotted Towhee (Pipilo maculatus).*[b] Nest survival for these landbirds is defined as the probability of a nest with egg(s) fledging at least one chick.
- *Adult Survival of Black-headed Grosbeak and Spotted Towhee.* Apparent adult survival for these landbirds is defined as the probability that an adult will survive from one year to the next.
- *Landbird Species Richness.* Landbird species richness is defined as the number of landbird species detected.
- *Abundance of Black-headed Grosbeak, Common Yellowthroat (Geothlypis trichas), Yellow Warbler (Dendroica petechial), and Yellow-breasted Chat (Icteria virens).* Abundance for these landbirds is defined as the number of birds per hectare during the breeding season.
- *Number of Occupied Yellow-billed Cuckoo Territories.*
- *Number of Bank Swallow Nest Burrows.* This is defined as the total number of active nest burrows at bank swallow colonies.
- *Number of Bank Swallow Nesting Colonies.* This is defined as the total number of bank swallow colonies with active nest burrows.

**Valley Elderberry Longhorn Beetle.** The goal for the valley elderberry longhorn beetle (VELB) is to recover this federally threatened species by increasing its populations and abundance through restoration of riparian systems.

***Associated Ecological Indicators***

- *Number of VELB Exit Holes per Shrub.* This is defined as is the average number of recent VELB exit holes per elderberry shrub.

**Other Wildlife.** The ERP Program Plan (CALFED 2000b) is limited in terms of the components of terrestrial biodiversity that it captures in its goal statements.

b Because of the availability of valuable data, this avian species is included even though it is a resident, as opposed to a migrant.

Even so, it is evident from the plan, as well as from supporting documents (e.g., the Multi-Species Conservation Strategy, CALFED 2000a) that the program seeks to advance a whole systems approach to restoration. In recognition of this, we included four additional indicators in our analyses from three otherwise unrepresented taxonomic groups. These indicators provide valuable perspectives on the status and trends of terrestrial riparian biodiversity on the Sacramento River.

***Associated Ecological Indicators***

- *Bee Species Richness.* This is the total number of different species of bees detected.
- *Bee Abundance.* This is defined as the total number of bees occurring in a standard 1-ha area.
- *Beetle Species Richness.* This is defined as the total number of different morphospecies of ground beetles occurring in the area. Morphospecies are the lowest taxon that can be distinguished based on morphology, and are surrogates for species (Oliver and Beattie 1996).
- *Bat Abundance.* This is an index defined based on the number of bat calls detected in a given time interval.

## Natural River Processes

**Central Valley Streamflows.** The goal for flow patterns is to more closely emulate the seasonal and inter-annual streamflow patterns. This can be attained through supplemental short-term releases from the major storage reservoirs to provide flows that emulate natural peak flow events.

**Natural Floodplain and Flood Processes.** The goal is to maintain existing areas where the Sacramento River seasonally inundates its floodplain and to reestablish this seasonal inundation in additional areas. This entails increasing and maintaining floodplains in conjunction with stream meander corridor restoration and restored flow releases.

***Associated Ecological Indicators***

- *Average Number of Years per Decade without Bed Mobilization.* This is defined as the number of years (over the previous decade) in which there were no flows >55,000 cfs.
- *Average Number of Days per Year with Bed Mobilization.* This is defined as the number of days per year, averaged over the previous decade, with flows >55,000 cfs.
- *Average Number of Years per Decade without Floodplain Inundation.* This is defined as the number of years (over the previous decade) in which there were no flows >70,000 cfs.
- *Average Number of Days per Year with Floodplain Inundation.* This is defined as the number of days per year, averaged over the previous decade, with flows >70,000 cfs.
- *Average Number of Days per Year with Side Channel Connection Flows.* Side channels are connected to the main stem at flows between 5,000 and 50,000 cfs. This indicator considers separately the 10-year running averages of the number of days per year with flows >15,000 cfs, >50,000 cfs, and dry-season flows (from July 15 to September 30) >5,000 cfs.

**Stream Meander.** The goal is to maintain and preserve existing areas of meander and to reactivate meander in other areas that bank protection activities impair. This entails preserving and improving the existing stream meander belt in the Sacramento River between Red Bluff and Colusa by purchase of fee title or through easements.

**Levees, Bridges, and Bank Protection.** The goal is to modify or remove structures in a manner that greatly lessens adverse effects on ecological processes, habitats and aquatic organisms. This entails constructing setback levees along leveed reaches of the river as part of the stream meander corridor restoration.

***Associated Ecological Indicators***

- *Area of Floodplain Reworked.* This is defined as the amount of newly created floodplain that formed from lateral migration over a given time-span.
- *Length of Bank with Riprap.* This is defined as the total length of riverbank that is hardened with revetment.
- *Whole River Sinuosity.* This is defined as the sum of the arc lengths for all bends divided by the sum of the half wave lengths. The arc length and half wave length are both measured between successive inflection points of single bends.
- *Total Channel Length.* This is defined as the distance along the channel centerline.
- *Average Bend Entrance Angle.* This is defined as the average bend entrance angle for all segments of the river. Segments are separated by subsequent inflection points. The angle is defined by the line that connects the bend inflection point and a tangent to the channel centerline at the next upstream inflection point.
- *Length of River with Conservation Ownership on Both Banks.* This is defined as the length of the river that has land in conservation ownership on opposing banks.

## RESULTS

Below we summarize the results of the indicator investigations in terms of what they reveal about the status and trends of the six riparian ecosystem components (Table 1), and the amount of progress that has been made toward the goals of the CALFED Ecosystem Restoration Program. Although especially noteworthy findings are highlighted, the reader is referred to the Results and Interpretations sections of the individual indicator accounts (Appendix A) for more complete presentations of findings.

### Status and Trends of Riparian Ecosystem Components

### *A. Riparian Habitats*

The overall trend in riparian habitats is positive (Table 1A). Especially noteworthy is the >600% increase in forest patch core size that has taken place from 1999 to 2007, and the 43% increase in the percent of the river that has a border of natural habitat >500 m wide. These statistics speak to the success of the horticultural restoration program in building large blocks of connected habitat along the river corridor.

The 48% increase in forest edge contrast from 1999 to 2007 was likely the result of new forest establishment in areas that adjoin agriculture. For core forest-dependent species, an increase in edge contrast is expected to extend adverse edge effects into the forest patch interior; however, in this case, the impact is likely offset by increases in overall patch size.

A substantial (48%) reduction was observed from 1999 to 2007 in the number of large woody debris aggregations in the river. Although such a decline could be caused by a reduction in river meander, we suspect that in this instance the decline was caused by differences in flooding patterns in the years preceding data collection. Large and sustained overbank flows in 1997 may have delivered woody debris that remained in the river through 1999. No similar flood events preceded the 2007 sampling period.

Between 1999 and 2007 the percent of the historical riparian zone in natural habitat increased 11%, and the percent in conservation ownership increased at least 35%. The increase in habitat reflects the implemented restoration, and the more substantial increase in conservation ownership land illustrates that additional properties have been acquired but are yet to be restored.

### *B. Native Plant Species and Communities*

The overall trend in native plant species and communities is positive (Table 1B). Areal cover of native vegetation in the historical riparian zone, between Red Bluff and Colusa, increased by at least 16% from 1999 to 2007 (Table 2). It likely increased by considerably more than this because some of the areas that were categorized as cottonwood forest, valley oak woodland, and black walnut (a non-native species) in 2007 were coded as mixed riparian in 1999. This must be considered when interpreting the apparent decline in mixed riparian forest, as well as the pronounced increases in some of the other vegetation categories between 1999 and 2007.

In total ~25% of the area mapped as riparian habitat was found on restoration sites. These sites contained disproportionately high percentages of the total area mapped as valley oak (41%) and Fremont cottonwood (35%).

At restoration sites, basal area of native woody species increased by an average of 95% in 5 years (Figure 3). At the restoration-site level, there was substantial variability, with forest development at some sites being hindered by poor soils. Nonetheless, this increase suggests that woody species are responding favorably to growing conditions at many of the restoration sites.

Comparisons between restoration sites and remnant habitat revealed that the size distributions of woody shrubs and trees are becoming more similar. The importance of certain species that provide valuable wildlife habitat (e.g., valley oak) increased at restoration sites over time. However, some species such as blue elderberry and western sycamore declined in importance value as other species, such as coyote bush and box elder, increased in prominence in the riparian community.

Native understory cover and frequency did not increase consistently at restoration sites over a 6-year period. Overall native cover increased 12%, but values were highly variable across sites. Where native cover increased, it was largely from increases in bedstraw (*Galium aparine*), a single, widespread spe-

**Table 1** Synthesis of ecological indicator data from studies of the Middle Sacramento River (between Red Bluff Diversion Dam and Colusa Bridge) partitioned into six categories. To characterize magnitudes of change over time, the percent increase or decrease in each indicator is reported (along with starting values, in parentheses). The trend column indicates whether or not the observed results suggest a favorable trajectory of change. A "+" indicates positive result, a "–" indicates a negative result, and a "0" indicates no change. Multiple symbols indicate strong or mixed results. For Streamflows and Flood Processes (E), and Planform and Geomorphic Processes (F), data were analyzed over a long time span, and thus results can be presented both for recent decades, and for the long term (in parentheses). Long-term trends are useful for setting the historical context. Detailed information regarding each indicator, including definition, rationale, methods, results and interpretations is provided in Appendix A.

**(A) RIPARIAN HABITATS**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend |
|---|---|---|---|---|---|
| Forest patch core size | Riparian zone between Red Bluff and Colusa | 1997 and 2007 | Increased by 610% (from 12 ha) | Schott and Shilling (unpublished) | ++ |
| Forest patch proximity | Riparian zone between Red Bluff and Colusa | 1997 and 2007 | Increased by 1,215% (from 16) | Schott and Shilling (unpublished) | + |
| Forest edge contrast | Riparian zone between Red Bluff and Colusa | 1997 and 2007 | Increased by 48% (from 49) | Schott and Shilling (unpublished) | - |
| Percent of historical riparian zone currently in conservation ownership | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased 35% to 43% (from 6,830 ha) | Golet and Paine (unpublished) | ++ |
| Percent of historical riparian zone currently in natural habitat | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased by 11% (from 4,406 ha) | Golet and Paine (unpublished) | + |
| Percent of riparian shoreline bordered by >500 m of natural habitat | Shoreline between Red Bluff and Colusa | 1999 and 2007 | Increased by 43% (from 16%) | Golet and Paine (unpublished) | ++ |
| Number of in-channel large woody debris aggregations | Mainstem river channel between Red Bluff and Colusa | 1999 and 2007 | Decreased by 48% (from 738)[a] | Golet and Paine (unpublished) | - - |
| Soil organic carbon | Restoration and remnant sites of varying ages | All four seasons 2000 – 2001 | Increased with age since restoration | Brown and Wood (2002) | + |
| **Overall** | | | | | **+** |

[a] The amount of wood in the river may have been unusually large in 1999 because of large and sustained overbank flows in 1997.

**Table 1** Continued

**(B) NATIVE PLANT SPECIES AND COMMUNITIES**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend |
|---|---|---|---|---|---|
| Areal extent of native vegetation | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased by ≥16% (from 6,836 ha) | Nelson et al. 2008 | + |
| Basal area of woody species | Restoration and remnant sites of varying ages | 2003 and 2008 | Increased by 95% at restoration sites (from 6.5 $m^2$ ha) | Wood (unpublished) | ++ |
| Frequency of woody species in various size classes | Restoration and remnant sites of varying ages | 2002, 2003, 2006, and 2008 | Distributions among size classes became more similar between restoration sites and remnant habitats | Wood (unpublished) | + |
| Importance value of woody species | Restoration and remnant sites of varying ages | 2003 and 2008 | Increases in coyote brush: (198%, from 5), box elder (47%, from 9), valley oak (12%, from 58), and Gooddings black willow (7%, from 7) | Wood (unpublished) | + |
| | | | Decreases in arroyo willow: (6%, from 43), blue elderberry (21%, from 50), Fremont cottonwood (4%, from 17) and western sycamore (20%, from 7) | | – |
| Native understory frequency of occurrence | Restoration and remnant sites of varying ages | 2001 and 2007 | Increased at restoration sites by 16% (from 48.1%) | Holl and Crone 2004; McClain et al. 2011 | + |
| | | | Values still far below remnant (87%) | | 0 |
| Native understory species richness | Restoration and remnant sites of varying ages | 2001 and 2007 | Increased at restoration sites by 43% (from 4.7 species) | Holl and Crone 2004; McClain et al. 2011 | + |
| | | | Values still far below remnant (10.1 species) | | 0 |
| Relative native understory cover | Restoration and remnant sites of varying ages | 2001 and 2007 | Increased at restoration sites by 56% (from 21%) | Holl and Crone 2004; McClain et al. 2011 | + |
| | | | Values still far below remnant (65%) | | 0 |
| **Overall** | | | | | **+** |

**(C) INVASIVE RIPARIAN AND MARSH PLANTS**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend |
|---|---|---|---|---|---|
| Areal extent of giant reed [b] | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased by 11% (from 49 ha) | Nelson et al. 2008 | – |
| Areal extent of Himalayan blackberry [b] | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased by 37% (from 91 ha) | Nelson et al. 2008 | –– |
| Areal extent of water primrose [b] | Riparian zone between Red Bluff and Colusa | 1999 and 2007 | Increased by 14% (from 137 ha) | Nelson et al. 2008 | – |
| Importance value of black walnut [c] | Restoration and remnant sites of varying ages | 2003 and 2008 | Increased at restoration sites by 50% (from 0.4), but values still very low | Wood (unpublished) | – |
| **Overall** | | | | | **–** |

b This indicator is described under the heading entitled "Areal Extent of Vegetation" in Appendix A.
c This indicator is described under the heading entitled "Importance Value of Woody Species" in Appendix A.

**Table 1** Continued

**(D) BIRDS AND OTHER WILDLIFE**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend |
|---|---|---|---|---|---|
| Nest survival of black-headed grosbeak, lazuli bunting, and spotted towhee | Restoration and remnant sites of varying ages | 1993 – 1999 for lazuli bunting; 1994 – 2003 for other species | Similar for all species at restored and remnant sites, but relatively low overall, especially for lazuli bunting (6%) | Golet et al. 2008 | + |
| Adult survival of black-headed grosbeak and spotted towhee | Restoration and remnant sites of varying ages | 1995 – 2000 | Somewhat lower for both species at restoration sites than remnant sites | Gardali and Nur 2006 | – |
| Landbird species richness | Restoration and remnant sites of varying ages | 1993 – 2003 | Increased by ~300% (from ~5 species) on average, as restoration sites matured, approaching levels at remnant sites | Golet et al. 2008 | ++ |
| Abundance of black-headed grosbeak, common yellowthroat, yellow warbler, and yellow-breasted chat | Restoration and remnant sites of varying ages | 1993 – 2003 | Increased dramatically (although variably among species) as restoration sites matured, approaching levels at remnant sites | Gardali et al. 2006 | ++ |
| Number of occupied yellow-billed cuckoo territories | Suitable breeding sites between Red Bluff and Colusa | 2000 and 2011 | Appeared to decline | Dettling and Howell 2011 | – |
| Number of bank swallow nest burrows | Mainstem river between Red Bluff and Colusa | 1999 – 2010, excluding 2006 | 3-year running average declined by 31% (from 17,963 burrows) | BSTAC 2013 | –– |
| Number of bank swallow nesting colonies | Mainstem river between Red Bluff and Colusa | 1999 – 2010, excluding 2006 | No real trend is apparent in the data; however, the 3-year running average increased by 10% over the period of record. | BSTAC 2013 | 0/+ |
| Number of VELB exit holes per shrub | Restoration sites of varying ages | 2003 | Older restoration sites had higher levels of VELB occupancy than younger sites | River Partners 2004 | ++ |
| Bee species richness | 8-yr old restoration sites and remnant habitats | February – August 2003 | Restoration sites had similar (7% lower) richness to remnant sites | Williams 2010 | + |
| Bee abundance | 8-yr old restoration sites and remnant habitats | February – August 2003 | Restoration sites had similar (26% higher) abundance to remnant sites | Williams 2010 | + |
| Beetle species richness | Young restoration, older restoration and remnant habitats | December 2000 – November 2001 | Remnant habitats had the most species and were more similar to older restoration sites than young sites | Hunt 2004; Golet et al. 2008 | + |
| Bat abundance | Orchards, young and older restoration sites, and remnant habitats | September – October 2002 | The older restoration site had higher levels of bat activity than the young restoration site | Stillwater Sciences et al. 2003; Golet et al. 2008 | + |
| **Overall** | | | | | **0/+** |

**Table 1** Continued

**(E) STREAMFLOWS AND FLOOD PROCESSES**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend[g] |
|---|---|---|---|---|---|
| Average number of years per decade without bed mobilization[d] | Middle Sacramento River | 1892 – 2010 | Unchanged in recent decades | Kondolf and Rubin (unpublished) | 0 |
| | | | Increased by 113% (from 22%) relative to pre-dam conditions | | (–) |
| Average number of days per year with bed mobilization[d] | Middle Sacramento River | 1892 – 2010 | Unchanged in recent decades | Kondolf and Rubin (unpublished) | 0 |
| | | | Decreased by 10% (from 8%) relative to pre-dam conditions, but highly variable from year to year | | (0/–) |
| Average number of years per decade without floodplain inundation[e] | Middle Sacramento River | 1892 – 2010 | Unchanged in recent decades | Kondolf and Rubin (unpublished) | 0 |
| | | | Increased by 129% (from 2.8 years) relative to pre-dam conditions | | (– –) |
| Average number of days per year with floodplain inundation[e] | Middle Sacramento River | 1892 – 2010 | Unchanged in recent decades | Kondolf and Rubin (unpublished) | 0 |
| | | | Declined by 41% (from 4.4 days per year) relative to pre-dam conditions | | (– –) |
| Average number of days per year with side channel connection flows[f] | Middle Sacramento River | 1892 – 2010 | Unchanged in recent decades | Kondolf and Rubin (unpublished) | 0 |
| | | | Declined relative to pre-dam conditions for high and middle elevation side channels | | (–) |
| | | | Greatly increased for low elevation channels | | (– –) |
| **Overall** | | | | | **0/(– –)** |

**(F) RIVER PLANFORM AND GEOMORPHIC PROCESSES**

| Ecological indicators | Geographic study area | Temporal horizon | Results | Sources | Trend[g] |
|---|---|---|---|---|---|
| Area of floodplain reworked | Riparian zone between Red Bluff and Colusa | 1906 – 2007 | Decreased in recent decades | Larsen (unpublished) | – |
| | | | Highly variable over long term, although trending downward | | (–) |
| Length of bank with riprap | Mainstem river channel between Red Bluff and Colusa | 1936 – 2002 | Increased in recent decades | Henderson (unpublished) | – |
| | | | Dramatic increase over long term, especially since the 1960s | | (– –) |
| Whole river sinuosity | Mainstem river channel between Red Bluff and Colusa | 1906 – 2007 | Increased slightly between 1997 and 2007 | Larsen (unpublished) | 0 |
| | | | Decreased significantly (by 6% from 1.31) over the period of record | | (–) |
| Total channel length | Mainstem river channel between Red Bluff and Colusa | 1906 – 2007 | Decreased in recent decades | Larsen (unpublished) | – |
| | | | Decreased significantly (by 4%, from 160,529 m) over the period of record | | (–) |
| Average bend entrance angle | Mainstem river channel between Red Bluff and Colusa | 1906 – 2007 | Decreased since 1987 (to lowest value ever in 2007) | Larsen (unpublished) | – |
| | | | Decreased significantly (by 13%, from 46 degrees) over the period of record | | (–) |
| Length of river with conservation ownership on both banks | Mainstem river channel between Red Bluff and Colusa | 1999 and 2007 | Increased by at least 71% (from 40,806 m) | Golet and Paine (unpublished) | + |
| **Overall** | | | | | **– – /(– –)** |

d This indicator is described under the heading "Frequency and Duration of Bed Mobility" in Appendix A.
e This indicator is described under the heading "Frequency and Duration of Floodplain Inundation" in Appendix A.
f This indicator is described under the heading "Duration of Connectivity of Former Channels" in Appendix A.
g Long-term trends are indicated in parentheses.

cies. Native understory species richness increased, but remained far below what was observed at remnant sites.

## C. Invasive Riparian and Marsh Plants

The areal extent of invasive riparian and marsh plants increased from 1999 to 2007 (Tables 1C and 2). Especially noteworthy was the large (37%) increase in the area mapped as Himalayan blackberry. Giant reed and water primrose increased more moderately, by 11 and 14%, respectively. As noted above, differences in analysis methodology likely explain much of the reported increase in the areal extent of black walnut. Even so, analyses of field collected data (see importance value results) suggest that black walnut increased at least modestly at forest study plots.

## D. Birds

The overall trend in birds is variable, although generally positive (Table 1D). Abundance and species richness of landbirds observed during the breeding season increased dramatically as restoration sites matured, approaching levels observed at remnant sites; however, not all species showed positive trends. Pronounced declines were observed in the number of bank swallow burrows on the river's cut banks (Figure 4), and the number of occupied yellow-billed cuckoo breeding territories declined during the past decade.

Restoration sites appeared to provide similar quality nesting habitat to remnant areas. Lazuli bunting, spotted towhee and black-headed grosbeak all had similar nest survival rates at restoration and remnant sites. However, adult survival for the latter two species was slightly lower at restored sites compared to remnant sites.

## E. Other Wildlife

Other terrestrial wildlife showed more uniformly positive responses (Table 1D). Older restoration sites had higher levels of Valley elderberry longhorn beetle occupancy than younger sites. Bee abundance and species richness was similar at restored and remnant sites, and ground beetles at older restored sites had communities more similar to those at remnant sites than those at more recently planted sites. Finally, among bats, older restored sites had higher levels of

**Table 2** Comparisons of area mapped as various vegetation classes in two time-periods from aerial imagery. Because mapping methodologies changed, not all values are strictly comparable (see text for details).

| | Area mapped (ha) | | |
|---|---|---|---|
| **Vegetation class** | **1999** | **2007** | **% Change** |
| **Natives** | | | |
| Annual and perennial grasses and forbs | 1,386 | 1,779 | 28 |
| Fremont cottonwood (*Populus fremontii*) forest | 1,678 | 3,113 | 85 |
| Mixed riparian forest | 2,216 | 456 | -79 |
| Valley oak (*Quercus lobata*) woodland | 663 | 1,594 | 140 |
| Riparian scrub | 893 | 972 | 9 |
| **Total** | **6,836** | **7,913** | **16** |
| **Non-native invasives** | | | |
| Giant reed (*Arundo donax*) | 49 | 55 | 11 |
| Black walnut (*Juglans hindsii*) | 91 | 1,027 | 1023 |
| Water primrose (*Ludwigia peploides*) | 137 | 157 | 14 |
| Himalayan blackberry (*Rubus discolor*) | 91 | 125 | 37 |
| **Total** | **369** | **1,364** | **270** |

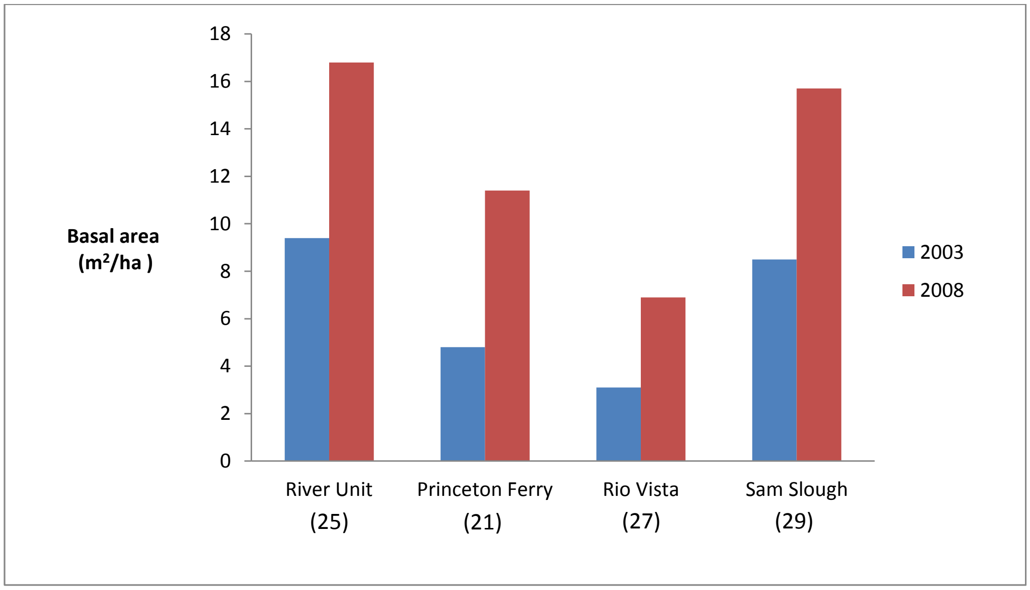


**Figure 3** Basal area of woody species at Sacramento River restoration sites over two time periods.

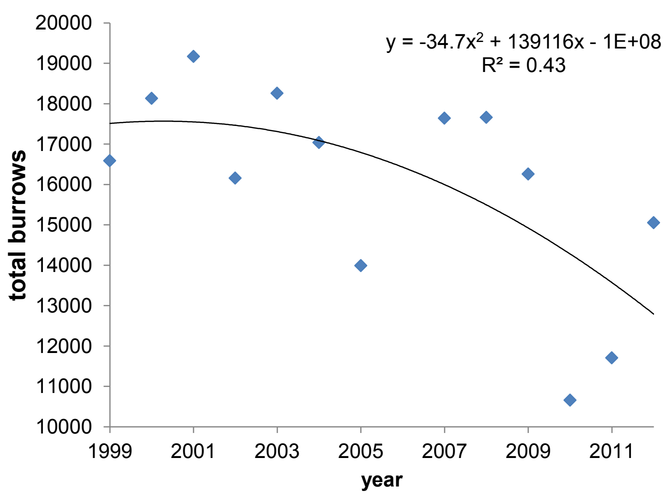


**Figure 4** Bank swallow (*Riparia riparia*) burrow counts on the Sacramento River, Red Bluff to Colusa

activity than younger sites, suggesting that as the sites mature they provide better habitat for these species.

## *F. Streamflows and Flood Processes*

There has been no discernible positive change in recent decades in streamflows and flood processes on the Middle Sacramento River (Table 1E). The degraded post-Shasta Dam (after 1944) conditions have remained. The number of years without bed mobilizing flows increased from 22% of pre-dam years to 47% of post-dam years. Also, since the construction of the dam, reductions have been seen in the number of days per year when the floodplain is inundated, and in the number of days when higher elevation side channels are connected to flows in the main channel (Figure 5).

## *G. River Planform and Geomorphic Processes*

The overall trend in river planform and geomorphic processes is negative over the long term (1906 to 2007), although some of the indicators (e.g., total river length, whole river sinuosity, number of higher sinuosity bends) show a positive or stable pattern in recent years (Table 1F). The recent trend included a reprieve in riprap installation through the 1990s, but this was followed by several large projects. Over the longer term (past 50 years), the length of river bank locked in place with riprap increased dramatically (Figure 6). With less area available to erode, there has been a concomitant decrease in the area of floodplain reworked. Overall the channel has simplified, being less sinuous and having reduced channel length (Figure 7) relative to historical conditions. On a posi-

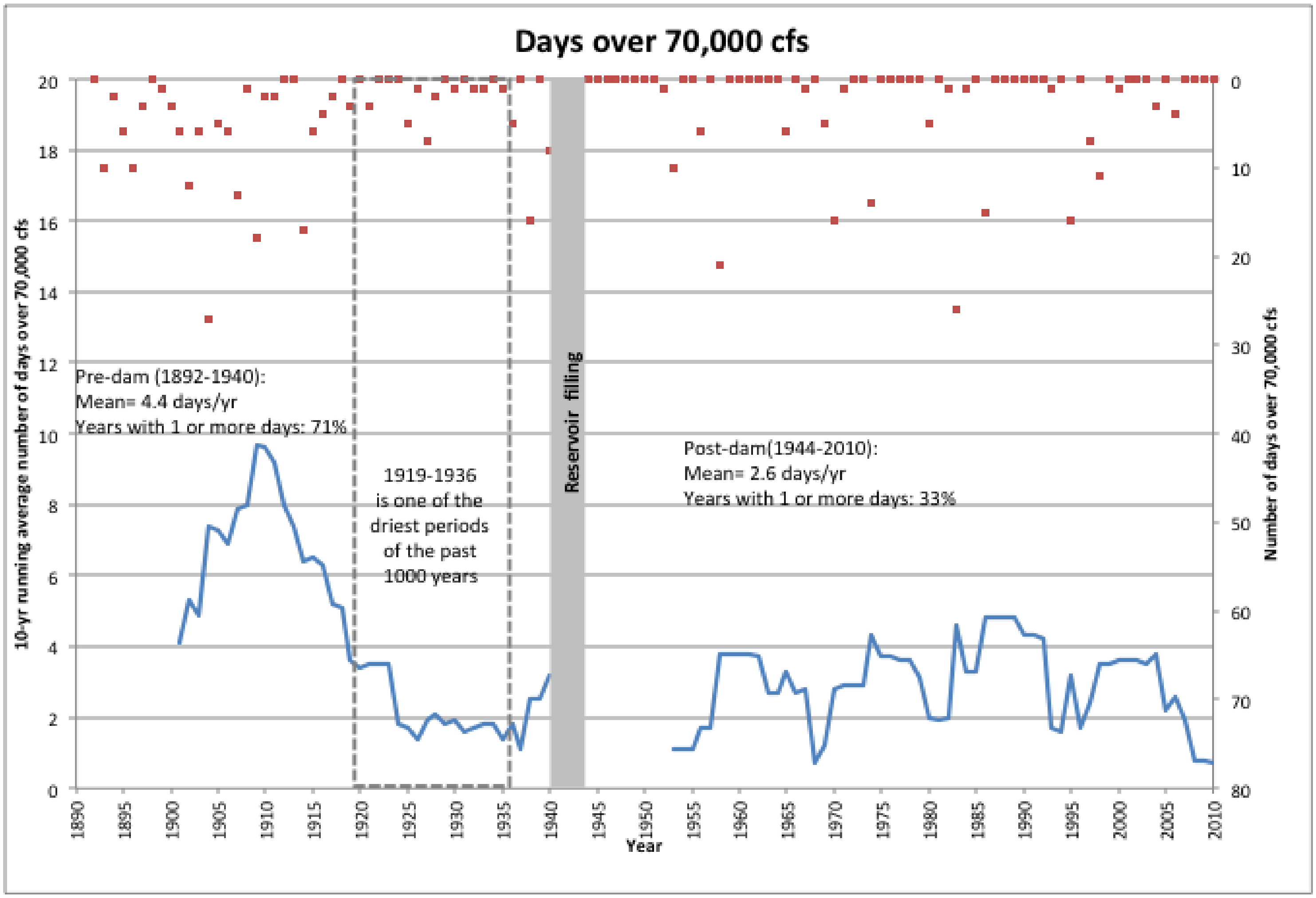


**Figure 5** Number of days each year (red data points, right y-axis labels), and 10-year running average of number of days each year (blue line, left y-axis labels), with flows sufficient (over 70,000 cfs) to inundate the floodplain. Flows recorded at the USGS gauge on the Sacramento River at Red Bluff.

tive note, there has been a large increase in the length of the main river channel with conservation ownership on both banks. This reduces the likelihood that rip-rap will be installed and increases the potential for its removal.

## Progress Toward ERP Goals

Overall, progress toward achieving ERP goals for riparian and riverine aquatic habitats was rated "fair." Small increases were observed over the past 20 years in the percent of historical riparian zone currently in conservation ownership, and the percent of historical riparian zone currently in natural habitat. Landscape metrics such as forest patch proximity, and forest patch core size showed positive changes with restoration. Additional indicators such as length of river with conservation ownership on both banks and percent of the riparian shoreline bordered by >500 m of natural habitat also increased. Indicators that prevented progress toward this goal being rated "good" include total channel length and whole river sinuosity. Both declined since the early

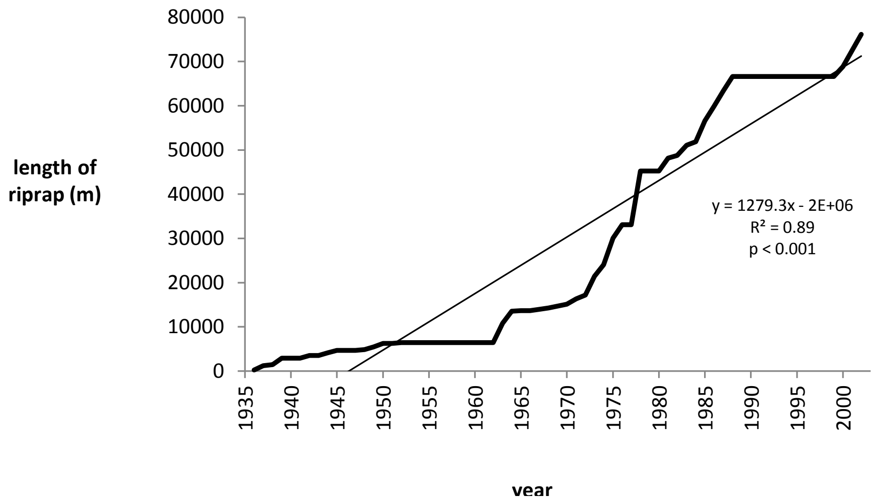


**Figure 6** Length of riprapped banks on the Sacramento River between Red Bluff and Colusa from 1937 to 2002

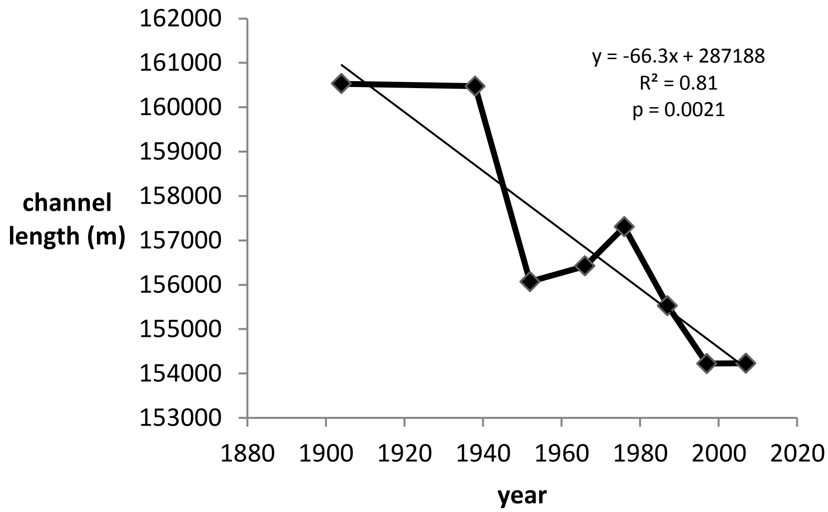


**Figure 7** Total channel length of the Sacramento between River Red Bluff and Colusa from 1906 to 2007

1900s, and have not changed substantially in recent decades.

Overall, progress toward achieving ERP goals for plant species and communities was rated "good." The acreage of native vegetation increased significantly, largely as a result of all the planting that has been done at restoration sites. At restoration sites there were positive responses in terms of habitat development. Basal area of woody species increased, as did diameter at breast height. Changes in importance values of different species suggest that the sites are proceeding along a successional pathway that generally supports native species. Coyote brush, box elder, and valley oak increased, although elderberry and sycamore decreased.

Less encouraging is the status of understory vegetation. At restoration sites native understory species were slow to colonize, and frequency of occurrence of native species was low. These findings have led to the implementation of an understory component to more recent (post-1999) restoration plantings. Survival of understory plantings has generally been good and resulted in modest increases in some native understory species (McClain et al. 2011), although long-term monitoring is needed.

Overall, progress toward achieving ERP goals for Neotropical migratory birds has been "fair." Nest survival remained low for lazuli bunting, black-headed grosbeak, and spotted towhee. Apparent adult survival was variable, with black-headed grosbeaks faring better than spotted towhees; however more data are needed to accurately report trends in these parameters. In contrast, bird species richness increased quite dramatically at restoration sites as has abundance for certain species (e.g., black-headed grosbeak, common yellowthroat), but not others (e.g., yellow warbler and yellow-breasted chat). Numbers of occupied yellow-billed cuckoo territories were very low, and the number of bank swallow burrows has declined strikingly.

Progress toward achieving the goal for valley elderberry longhorn beetle has been "good." At restoration sites there was a dramatic increase in the percent of elderberry shrubs occupied by the VELB. However, the importance value of the VELB's host plant declined as sites matured, raising the question of what the long-term VELB habitat availability will be at these sites.

Progress toward restoring healthy populations of other native terrestrial fauna (not specifically called out in the ERP Program Plan, CALFED 2000a) has been "good." Similar to what was found with land-birds, species richness of beetles was higher at older restoration sites than at younger sites. Bees had similar species richness at restoration sites and remnant habitats, although there were considerable differences in the species assemblages. More bats were detected at older restoration sites than at younger sites, suggesting increased abundances.

Progress toward achieving the goal for Central Valley streamflows and natural floodplain and flood processes has been "poor." While there have been some small scale-efforts to set back levees to permit floodplain inundation, there have been no efforts to increase deliberate high flows to mobilize the bed and inundate floodplains, both of which were reduced as a result of flow regulation. The frequency and duration of floodplain inundation was lower after dam construction than in all pre-dam years except the extended drought of the 1930s. Floodplain disconnection from the channel was made worse along much of the reach by levees, which extend up to Ord Bend, and limit overbank flow. Since regulation by Shasta Dam (and since interbasin water transfers from the Trinity River), the average number of days with flows sufficient to connect the highest elevation side channels decreased slightly. A larger decrease in hydraulic connectivity was observed for middle-elevation side channels, while a substantial increase was seen for the lowest elevation group. These changes are reflective of river management which, since reservoir construction, has emphasized winter storage and summer conveyance.

Overall, progress toward achieving the goal for stream meander was "poor." Channel dynamics and channel complexity indicators varied considerably over time (in part from flow variations), but declined over the period of record (1906 to 2007), with no improvement in recent years. Despite goals being set to achieve the opposite, some of the most important indicators of stream meander (e.g., meters of bank with riprap) have continued to decline.

Overall, progress toward achieving the goal for levees, bridges and bank protection also has been "poor." New riprap has been installed, and although the length of river with conservation ownership on both banks has increased, little on-the-ground work has been done to remove or modify infrastructure that currently limits natural river processes.

Progress toward achieving the goal for invasive riparian and marsh plants has been "poor." Reductions were not observed in the areal extent of non-native riparian and marsh plants—quite the contrary—giant reed, black walnut, Himalayan blackberry, and water primrose all increased from 1999 to 2007. Thus competition that native flora face from non-native species does not appear to be diminishing.

## DISCUSSION

Our analysis provides clear evidence of both successes and failures in the restoration of the Sacramento River riparian ecosystem. It demonstrates where progress has been made, where conditions have remained unchanged, and where there has been continued degradation—information that is vitally important for guiding future restoration efforts. Our study has wide application. It shows that through simple association of indicators with ecosystem elements and programmatic goal statements, the effectiveness of large-scale restoration projects can be assessed, despite this seldom being done (Bernhardt et al. 2005; Roni et al.

2008). In fact, many of the indicators that we developed and applied may be suitable for characterizing other lowland river systems.

Our synthesis of ecological indicator data suggests that the status of vegetative floodplain habitats and the terrestrial species that inhabit them on the middle Sacramento River is fairly good and that conditions are generally improving. This is mostly the result of successful reestablishment of relatively large swaths of native vegetation across the floodplain over the past two and a half decades. Many positive outcomes have been observed as a result of these efforts, as revealed by landscape analyses, comparisons over time at restoration sites, and comparisons between restoration sites and remnant habitats. An exception is the continued proliferation of invasive riparian and marsh plants in remnant areas, and the limited success that has been made in restoring understory plant communities at restoration sites.

In contrast, the status of natural riverine habitats appears to be generally poor and declining. This is the direct result of the river's hydrologic and geomorphic processes being constrained by continuing anthropogenic alterations. For the most part, the impacts to these parameters occurred before the restoration initiatives that we are evaluating took place. Even so, our characterizations over the longer time frame are important. They provide a meaningful baseline of current conditions that can be used to evaluate the effects of any future restoration actions, while also characterizing pre-impact conditions which may be useful for refining restoration objectives.

Major factors responsible for continued degradation of riverine habitats include riprap, which has been steadily increasing since the 1930s, and alteration of the natural flow regime, which has taken place since the mid-1900s. As more and more riprap has been installed, and the hydrology has been increasingly altered, the river has lost much of its natural dynamism, and with that a reduction in its ability to create and maintain the habitats essential to native species and communities. Planting of native riparian vegetation in recent decades has been an important stopgap measure; however, without the restoration of natural riverine processes, these planted areas will likely follow an altered successional pathway, and not provide the long-term habitat value that they otherwise would (Stromberg et al. 2007; Shafroth et al. 2010).

Ecological research demonstrates that past notions which consider 'stability' to be desirable in ecosystems are outdated, and that disturbance is not only inevitable in many systems, but is essential to their regeneration (Naiman et al. 2005). The greatest riparian and aquatic habitat complexity and biodiversity result from dynamic river processes. These include erosion, deposition, and overbank flooding which lead to the recruitment of large wood, and the creation of vertical cutbanks, fresh bar surfaces, and diverse floodplain habitats (Gurnell et al. 2002; Stanford et al. 2005; Florsheim et al. 2008). When these processes are inhibited through human alterations such as riprap installation, or a reduction in flood flows and sediment supply by upstream dams, a net reduction in habitat complexity results (Ward and Stanford 1995).

The desired endpoint in ecological restoration is to have a mosaic of habitat types of appropriate size and connectivity to support native species and communities, and to restore the important natural processes required to maintain these habitats (SER 2004). Research from this project and others demonstrates that the future of Sacramento River riparian resources depends on the degree to which natural riverine processes of erosion, sediment deposition, and flooding can be restored (Florsheim et al. 2008). Native species have evolved with these processes intact, and many attributes of their life history are uniquely suited to conditions that result from their interplay across the landscape. Examples include cottonwoods, which are specifically adapted to colonize gravel point bars on the receding limb of the spring hydrograph (Mahoney and Rood 1998), and bank swallows, which require recently eroded cutbanks for their breeding colonies (Garrison 1999).

One of the most effective ways to advance restoration in alluvial river systems, such as the Sacramento, is to restore river meander. This can only be done, however, where it does not cause adverse effects on important human infrastructure (e.g., roads, bridges). Meander migration is beneficial to the ecosystem because it initiates a process of floodplain regeneration that can advance fairly quickly, especially when coupled with high flow events. On the Sacramento River, the rate of meander migration has been shown to increase in direct proportion to cumulative effective stream power (Larsen et al. 2006). In fact, on rivers with sufficient stream power to actively erode and deposit sediment, the most efficient and cost-effective approach to habitat restoration may be to allow the river a zone in which to erode and deposit freely (Kondolf 2011, 2012). This basic restoration concept has been promoted by agency and stakeholder groups for the Sacramento River (CALFED 2000a; SRCAF 2003).

Why then, has restoring hydrogeomorphic processes on the Sacramento River been so difficult? Have other river projects been successful in this, and what, if anything, can be done to facilitate greater success in this system? Below we consider these questions separately for restoration of river meander and restoration of the flow regime.

### Restoration of River Meander

Meander migration has not been restored on the Sacramento River because riprap has not been removed and continues to be installed. From a permitting standpoint, it is much simpler to install new riprap than it is to remove it. There is a longstanding and well established process for its installation, yet no process exists for its removal. When riprap is installed in response to “emergency” repair needs—as is done on the Sacramento River by the U.S. Army Corps of Engineers (USACE) and the California Department of Water Resources—permitting is streamlined and environmental review is waived (CDWR 2006). Also, private landowners commonly dump riprap on the riverbanks, and despite this being illegal, there is little enforcement.

Removal of riprap at sites where it is no longer needed may be the most appropriate mitigation for installation of new riprap; however, to date, this has not occurred. Removing USACE riprap, or even allowing it to degrade naturally through the erosive forces of the river, requires de-authorization and quantitative analysis of the likely consequences, which the USACE has yet to do anywhere. Instead “onsite” mitigation is done at the repair sites. This entails incorporating wildlife habitat elements (e.g., woody debris) into the construction of the project. A fundamental flaw in this approach is that the onsite habitat features that are typically constructed as mitigation do not serve the same ecological functions that were lost. At other times the protection of existing habitat is counted as mitigation; however, this still leads to in a net loss of habitat.

Both internationally and in California riprap has been removed and levees have been set back to promote meander migration and floodplain reconnection. In Western Europe, levees were set back on lengthy channelized sections of the Rhine to retain floodwaters and retard river discharge, imitating the historical situation to the extent possible (Grift et al. 2001; Nienhuis and Leuven 2001). On the Cosumnes River in California’s Central Valley, revetted levees were intentionally breached for ecosystem benefits (Florshiem and Mount 2002; Swenson et al. 2012). Progress made on these other rivers suggests that it may be possible to take these important restorative actions on the Sacramento River, although some different stakeholders would need to be involved in the process.

To promote meander restoration, we recommend that mitigation requirements for riprap installation projects be made more stringent. Mitigation should entail replacing the same ecological functions that are lost. This necessitates the removal of riprap, which would have to follow an as-yet-unestablished process and include analyses of likely consequences. In addition, mitigation should be implemented for all previously implemented rocking projects that have unmet mitigation requirements. Finally, responsible agencies should enforce existing laws prohibiting unauthorized placement of riprap by private individuals.

### Restoration of the Flow Regime

Inadequate consideration of ecosystem flow needs in reservoir operations could contribute to the lack of progress in restoring the flow regime on the

Sacramento River. The river is managed primarily for flood control, water storage and conveyance. Environmental parameters considered are limited to requirements of the federal Endangered Species Act (e.g., providing sufficient flows for outmigration of endangered juvenile winter-run Chinook salmon). The challenge is to expand these considerations to include the life-history needs of broader ranges of species without diminishing important services that the river provides to society.

Yet developing an understanding of how alternative flow patterns affect river ecosystems is challenging. The task is made more difficult because relationships between environmental flow alterations and biotic response may not be readily transferrable from one river system to another (Arthington et al. 2006; Poff et al. 2010), and thus there is a need to develop river-specific empirical relationships. Although many uncertainties exist, progress has recently been made along these lines for the Sacramento River through the development of the Ecological Flows Tool (EFT, *http://www.essa.com/tools/EFT/download.html*). This decision analysis tool models how a suite of focal species (including bank swallow, Fremont cottonwood, Chinook salmon, and steelhead) are affected by flow management actions, and thus may be used to expand consideration of ecosystem effects in Sacramento River flow management decisions.

Working collaboratively to establish a more naturalized flow regime may seem a daunting task; however, there are examples to draw from in the United States, Australia, and South Africa (Postel and Richter 2003). For example, on the Green River in Kentucky, conservation groups worked with the USACE to make relatively minor adjustments to flow patterns for the benefit of the ecosystem (especially native fishes and mussels), without adversely affecting water supply for people (Richter et al. 2003). Similarly, on the San Pedro River in Arizona, a diverse partnership of stakeholders developed a consensus-based flow prescription to reduce human impacts while simultaneously setting realistic limits on ecosystem allocations. On Australia's Brisbane River, a stair-stepping approach was used to develop scenarios relating flow thresholds to biodiversity functions. These scenarios were then incorporated into a model used to manage the dam-and-reservoir system to define the feasibility of providing environmental flows while ensuring water supply reliability (Postel and Richter 2003). A common ingredient in these successful collaborations is the understanding that water management that supports a healthy ecosystem while simultaneously meeting human needs is highly desirable. It provides society with a suite of valuable ecosystem services (e.g., water quality, flood control, groundwater recharge, fisheries, recreation) that are diminished when the river is in a degraded state (Wilson and Carpenter 1999; Baron et al. 2002; Golet et al. 2006, 2009).

## CONCLUSIONS

By characterizing the current status of the Middle Sacramento River ecosystem, and showing where restoration has been successful and where it has not, our indicator assessment provides vital information that can be used to inform strategic decision-making. Our analyses confirm that horticultural restoration has been effective in creating terrestrial floodplain habitats that are utilized by a broad suite of native and special-status species. Yet, at the same time, they reveal that there has been little progress in the restoration of the natural river processes that are required to create and maintain the dynamic landforms and habitat conditions of larger riverine landscape. Addressing this deficiency will require management entities to develop creative new solutions to old problems. It will require novel partnerships to be formed, and the development of new business models that support experimentation and adaptive management. Examples from elsewhere demonstrate that this is possible, but the challenge remains to identify and set into action the most productive approach for our particular situation; however before any of this can happen, public support for restoration must increase. Whether or not such support will come remains to be seen, but it is encouraging that increasingly people are recognizing that healthy and productive ecosystems benefit not just nature, but also human society at large.

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# THE HEALTH OF BLUE ELDERBERRY (*Sambucus mexicana*) AND COLONIZATION BY THE VALLEY ELDERBERRY LONGHORN BEETLE (*Desmocerus californicus dimorphus*) IN RESTORED RIPARIAN HABITAT

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A Thesis

Presented

to the Faculty of

California State University, Chico

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Biological Sciences

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by

Meghan Gilbart

Summer 2009

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# ABSTRACT

THE HEALTH OF BLUE ELDERBERRY (*Sambucus mexicana*) AND COLONIZATION BY THE VALLEY ELDERBERRY LONGHORN BEETLE (*Desmocerus californicus dimorphus*) IN RESTORED RIPARIAN HABITAT

by

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Horticultural restoration of floodplains recreates riparian habitat that is critical to a diversity of wildlife, including many endemic, threatened and endangered species. This type of restoration frequently occurs on highly regulated rivers, where the natural processes that shape riparian plant communities have been modified and truncated. The truncation of river processes places importance on restoration planting designs, which must consider the heterogeneous nature of the environment, complex natural vegetation structure as well as the succession of plants adapted to fluvial systems. One of the largest riparian restoration efforts in the country is along the regulated Sacramento River in the Central Valley of California, where restoration targets imperiled wildlife such as the federally threatened Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*, VELB). The VELB is endemic to the Central Valley and specializes on facultative riparian blue elderberry shrubs. As a target species of the restoration, over 96,000 elderberry shrubs have been planted in the last 16 years in a range of planting designs to create VELB habitat. The planting designs that include elderberry range from open to closed canopy communities, yet there has been no monitoring of elderberry among the different planting designs beyond the initial three-year monitoring period. Using a factorial design, I sampled elderberry shrubs across both open and closed planting designs, and in old and young sites in 23 restoration fields of the Sacramento River National Wildlife Refuge to evaluate the current health of planted elderberry and the corresponding occupation by VELB. My results indicate that open, low cover planting designs can allow elderberry to develop into larger, more robust shrubs that will reach maturity, whereas closed canopy designs likely stress elderberry shrubs and reduce living material over time. Recent VELB occupation was observed in 78% of all fields but only 21% of all shrubs searched. Beetle occupation increased with restoration age but showed a weaker and inconsistent relationship with cover. Closed canopy planting designs may attract beetles initially through chemicals released by stressed elderberry shrubs, but in light of successional changes that will take place in the planted fields over time, open canopy planting designs provide more consistent habitat. A diversity of planting designs is therefore recommended for restoration of VELB habitat, but both elderberry health and VELB occupation should be monitored over time in these sites as plants continue to age.

# CHAPTER I

## INTRODUCTION

With enormous losses of riparian habitat by anthropogenic induced disturbance, riparian restoration efforts have increased over the past few decades to mitigate for biodiversity and ecosystem function loss (Naiman and others 1993; Ward & Tockner 2001; Ward and others 2002). River systems that are intensively managed have experienced some of the highest percentages of riparian habitat loss and or species diversity in large part due to reduced river flows and a temporally altered hydrologic regime (Nilsson and Berggren 2000). Alteration and truncation of the flow regime can critically impede succession and establishment of riparian vegetation by reducing the scouring of established vegetation and the distribution of nutrient rich sediments (Poff and others 1997; Stromberg 2001; Stromberg and others 2007). Large-scale restoration projects on highly regulated rivers are therefore challenged with designing plant communities that are sustainable in the absence of these natural river processes.

One of the larger restoration projects in the United States is along the Sacramento River in the Central Valley of California where restoration efforts have primarily focused on a 100-mile stretch of the river spanning from Red Bluff (River Mile 244) to Colusa (River mile 140, Figure 1). Restoration efforts have focused on restoring natural river processes in combination with reestablishing riparian habitat and function. For example, the Sacramento River National Wildlife Refuge (the Refuge) was established by the US

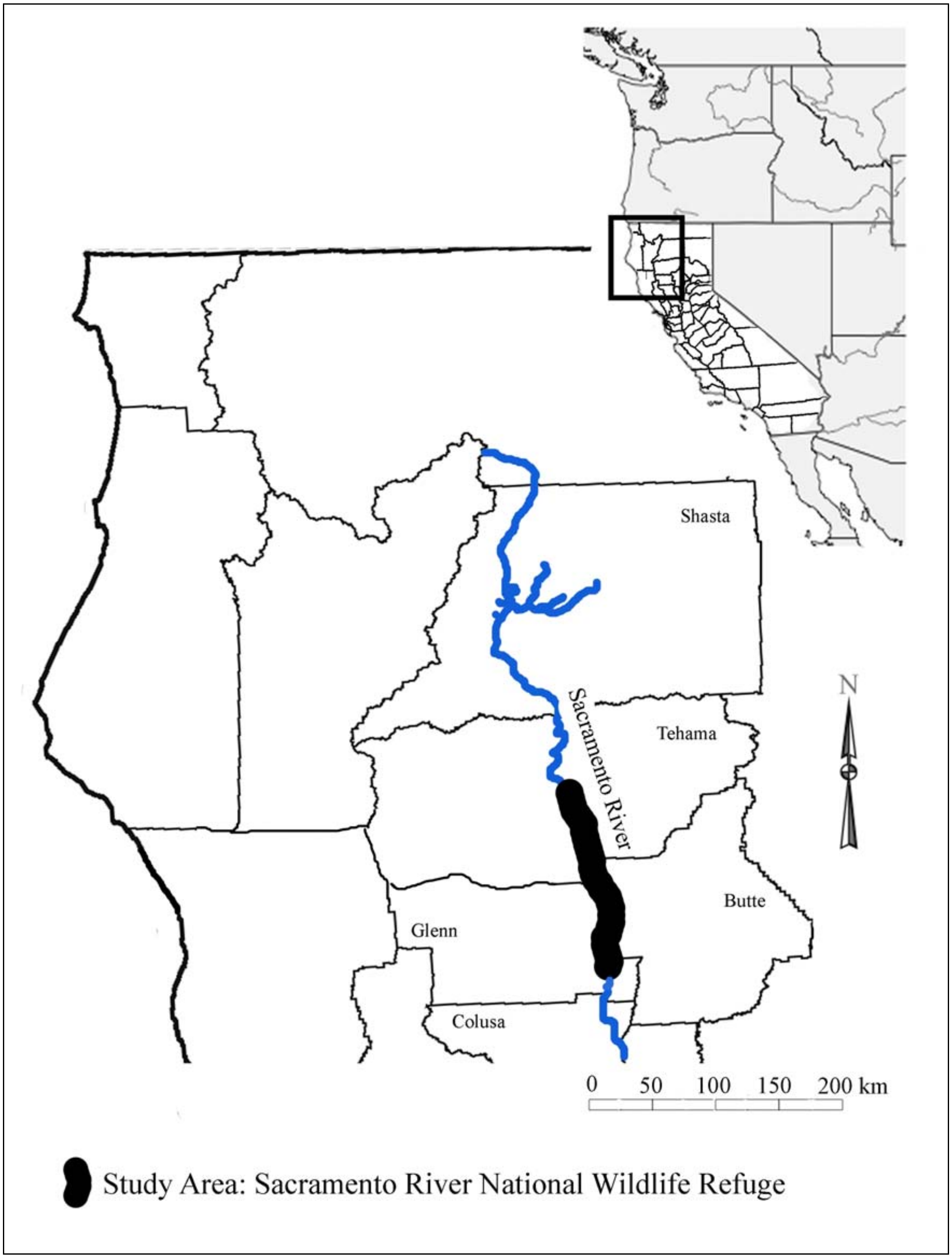



**Fig. 1** Location of the Sacramento National Wildlife Refuge in Northern California

Fish and Wildlife Service in 1989 with the goal of providing 7,284 hectares of protected or restored riparian habitat to connect with existing habitat for wildlife (Alpert and others 1999; Golet and others 2003). The Refuge also aims to protect the fifty-five state and federal special status species that depend on these multiple habitats (USFWS 2005).

One of these target species is the Federally Threatened valley elderberry longhorn beetle *Desmocerus californicus dimorphus*, Fisher (Coleoptera: Cerambycidae) VELB, one of few endemic riparian species in the Central Valley and one of three species the Refuge was originally established to protect (Linsley and Chemsak 1972; USFWS 2005). The VELB are wood boring specialists that require blue elderberry, *Sambucus mexicana*, as host plants to complete their life cycle (Barr 1991), and most commonly select elderberry bushes in riparian areas (Barr 1991; Collinge and others 2001). The range distribution of the VELB coincides with intensive urban and agricultural practices which have cleared more than 90% of riparian cover to develop associated infrastructure (Katibah and others 1984). Regulation of the river flows to support these uses and reduce flood impacts has further degraded existing habitat (Lang and others 1989). The VELB was listed as Federally Threatened in 1980 in response to significant habitat loss (Federal Register 1980; USFWS 1984).

Elderberry shrubs are important components of remnant riparian forests and shrublands that provide resources for many wildlife species along with the VELB. Elderberry has been used in a range of restoration planting designs that vary in species composition and planting densities. Vegetation community types with elderberry plantings range from widely spaced savannas to dense mixed riparian forests. This range of planting designs that include elderberry is a reflection of the wide distribution and occurrence of blue elderberry in multiple natural plant communities (Barr 1991; Vaghti and others 2009; Fremier and Talley 2009). The seeds of elderberry are dispersed by vertebrates, and this has been used to explain their somewhat haphazard, patchy distribution (Fremier and Talley 2009).

When VELB is a target species for restoration, elderberry are planted in a wide range of plant communities because the beetle shows weak correlations with measured environmental variables (Talley and others 2006; Fremier and Talley 2009). Since the VELB was listed there have been several studies that have tried to attribute variation in VELB colonization to local habitat and landscape level characteristics. Talley (2007) collected landscape and individual elderberry shrub data along stretches of four Central Valley rivers. Despite this comprehensive study, very little of the variation in VELB distribution across the landscape could be attributed to the measured variables. Landscape-scale studies of the beetle have indicated that large patches of habitat, even when unoccupied, are likely important to maintain the possible metapopulation structure of the VELB (Talley 2007) and account for stochasticity present in both beetle and host plant distributions (Talley 2007).

The value of elderberry for VELB and wildlife has lead researchers to study the landscape and local controls of elderberry distribution in remnant patches and in mitigation sites, but not in restoration sites (Talley 2005; Fremier and Talley 2008; Holyoak and Koch-Munz 2008; Koch-Munz and Holyoak 2008; Vaghti and others 2009). The occurrence of elderberry in remnant riparian floodplains appears to be controlled most strongly by hydrologic factors such as floodplain width, lateral distance and relative elevation to the river channel (Fremier and Talley 2009). Slower growth rates of elderberry shrubs in mitigation sites relative to remnant sites were associated with lower soil nutrients, possibly due to increased competition from high densities of planted elderberry shrubs (Koch-Munz and Holyoak 2008). The influence of abiotic controls on elderberry presence likely contributes to the high variability in survival of planted and seeded elderberry shrubs in restoration and mitigation sites. Multiple abiotic and biotic factors contribute to riparian plant survival, and initially, differences in hydrology and soils throughout a restored site are the biggest obstacles to plant survival (Griggs 1993; Naiman and Decamps 1997).

One common observation of elderberry occurrence in remnant riparian areas is their frequency in woodlands and savannas with little canopy cover (Talley 2005; Vaghti and others 2009). The preference of elderberry shrubs for open conditions has also been observed in older mitigation sites as well (Koch-Munz and Holyoak 2008). Observations and studies of elderberry suggest that along with abiotic factors such as soils and hydrology, the biotic competition with associated vegetation for resources affects elderberry health, and these effects most likely become more pronounced over time. For example, elderberry shrubs planted in a dense mixed riparian community with high canopy cover will develop differently from a shrub grown in a more open woodland. Biotic interactions among plants can affect the persistence of many species and ideally this successional trajectory is considered during restoration planting design. Consideration of successional processes in such designs is especially important for restoration on the highly regulated Sacramento River where flooding, erosion, and sediment deposition do not occur with enough frequency or duration to continually recharge plant succession (Stillwater Sciences 2007).

There is still little known about optimal habitat needs for the VELB in terms of elderberry health (growth form and percent dead biomass) and the associated plant community. Elderberry shrubs exhibit multiple growth forms that range from dense shrubs with multiple stems to taller, narrow trees with a single main stem, and can also vary widely in the overall percentage of dead stems (per obs) independent of VELB occupation. Studies have found that VELB occupation of elderberry shrubs increases with the size and age of the shrub, and with the density of elderberry shrubs in an area (Barr 1991; Collinge and others 2001; River Partners 2004; Talley 2007; Holyoak and Koch 2008). Multiple studies have found VELB presence to be correlated with moderate levels of dead biomass or moderately stressed elderberry shrubs (Arnold 1984; Collinge and others 2001; Talley and others 2007; Holyoak and Koch-Munz 2008). Talley (2007) also found VELB presence was marginally associated with increased pith nitrogen levels. Increased nutritional quality of plant tissue has been linked to increased growth rates of wood boring beetles (Haack and Slansky 1987) and wood borers are among a guild of insects considered most likely to be affected by stress-induced changes to nutrient loads within woody stems (Larsen 1989). Some studies report increases in total nitrogen as stress increases (for a review see Mattson 1980) but the connection between plant stress and nitrogen is highly debated (Larsen 1989). If elderberry shrubs with moderate levels of dead biomass also have increased nitrogen levels, including higher nitrogen levels in pith tissue, then this could explain the correlation of beetle presence with moderate levels of dead biomass. The VELB genus, *Desmocerus,* is the only genus of its subfamily whose members have not been documented to intentionally stress their host plant (Hanks 1999). If VELB do not intentionally stress elderberry shrubs, their occupation simply may injure elderberry stems. Because VELB tend to reoccupy individual shrubs overtime (Barr 1991; Collinge and others 2001), possibly due to their weak dispersal capabilities (Talley 2007), VELB may eventually increase the overall dead biomass of the shrubs.

Between 1989 and 2006, 96,000 elderberry shrubs were planted throughout the Refuge restoration units. Despite the extensive planting of elderberry and importance for maintaining VELB populations, there have been no studies to assess the long-term health and status. The only study that has evaluated elderberry condition within the Refuge restoration sites found planted elderberry between one and four years old had highly variable growth rates and percentages of survival (Alpert and others 1999), older restoration sites were not included in the study. In legally required elderberry mitigation plantings, seedling mortality rates were estimated at 28% in the first year after planting (Holyoak and others 2009). In a study of elderberry distribution in remnant riparian areas of the Sacramento River, less than 5% of measured plants were seedling size, possibly suggesting that natural elderberry recruitment is low (Vaghti and others 2009). Further, the highest number of seedling size elderberry stems was found on an undammed river (Vaghti and others 2009). If flow regulation has caused reduced recruitment of elderberry on the Sacramento River, restoration plantings may be critical for their establishment and growth and persistence and hence VELB persistence.

VELB use of restoration sites has been documented and beetle populations are widely distributed (River Partners 2004). River Partners found evidence of beetle occupation in all five Refuge units surveyed, however, the overall shrub occupancy rate was only 5%. These restoration sites create some of the largest expanses of VELB habitat and may be critical to their persistence, especially since the species has been proposed for delisting. If delisted, the VELB would lose both protection of existing habitat and mitigation of future losses.

In light of potentially low recruitment and extensive efforts to reestablish elderberry along the Sacramento River, there is a clear need to better understand how elderberry health varies with time since planting (age), with different planting designs and the relationship between plant health and VELB occupancy. This is essential information for informing restoration and management efforts and will also contribute to the limited understanding of VELB habitat requirements. The goal of my study is to assess elderberry plant health across a range of restoration ages and planting designs and to determine how these factors interact with VELB occupancy.

My study was designed to elucidate the effects of restoration site age and cover by woody species to answer three questions: 1.How do age of a restoration site and cover by associated woody species affect the health and nutrient levels of elderberry shrubs?; 2. How do age and cover affect VELB colonization rates?; and 3. What is the relationship between elderberry health and VELB colonization? Results from this study will inform future restoration design for VELB and other wildlife that benefit from elderberry riparian plantings.

# CHAPTER II

# BACKGROUND

## Riparian Ecosystem

Riparian vegetation grows in the zone where hydrology connects terrestrial and aquatic habitats. In this dynamic zone, physical river processes are critical to establishment and early succession of riparian vegetation (Naiman and others 1993; Scott and others 1997; Larsen & Greco 2002). Over time, the floodplain becomes fragmented with vegetation in varying stages of succession, forming a mosaic of riparian plant species. Multiple intersecting canopy layers interspaced with open sun-filled gaps create habitat and natural corridors for a rich diversity of birds, reptiles, amphibians, mammals and invertebrates (Knopf and others 1988; Naiman and others 1993; Knopf & Samson 1994; George & Zack 2001).

Along with their importance to native plants and animals, riparian ecosystems can improve stream and ground water quality by removing constituents and filtering fine sediment, and they can lessen the damage from heavy flooding by trapping large debris and slowing flows (Lowrance and others 1985; Stromberg and others 1993). Even though riparian areas often occupy a small proportion of the landscape, their sheer complexity and significance to maintaining biodiversity and ecosystem function make them important targets for conservation and restoration (Naiman and others 1993; Ward and Tockner 2001; Ward and others 2002).

The Sacramento River

The headwaters of the Sacramento River are in northern California near the Oregon border in Shasta and Siskiyou counties. Shasta Dam in the upper reaches of the Sacramento River stores water and regulates downstream flows. From the dam to Red Bluff the river flows through a steep canyon. The Middle Sacramento River, from Red Bluff to Colusa, (River miles 244 to 140) meanders through a broad alluvial floodplain which is largely developed with farmland. South of Colusa, the river is completely confined by bank stabilization into a narrow channel.

Physical river processes such as flooding, erosion, deposition, and channel movement still occur to some extent on the Middle Sacramento River because there are sections of set-back levees and stretches free of bank revetments. As the river meanders through the alluvium it creates oxbow lakes, backwater sloughs, seasonal wetlands, and uplands with mixed riparian communities.

The floodplains and riparian areas along the Sacramento River originally extended for miles and encompassed over 324,000 hectares (Barbour and others 1993; Katibah and others 1984). Over 95% of this land has been lost due to direct conversion for agricultural and urban development and modifications for flood control and water allocation (Katibah and others 1984). Loss of riparian areas along the Middle Sacramento River has resulted primarily from flood control efforts and agriculture (Scott and Marquiss 1984; Patten 1998). Some of the land converted to agriculture has proven unprofitable over the years because it is flood-prone, and a portion of these lands have been purchased and established as restoration units.

Restoration on the Sacramento River

Virtually all of the restoration efforts for the Sacramento River Project are located in the relatively functional Middle Sacramento River. Though the Shasta Dam regulates the frequency, duration and magnitude of flows, remnant and restored riparian habitat flood occasionally and maintain a connection to the river. Even though the Middle Sacramento River is less regulated than its northern and southern reaches, the natural variability in flows to which many riparian plants and animals are adapted has been reduced (Stillwater Sciences 2007). Riparian restoration design on the Sacramento River is therefore faced with the challenge of planting vegetation that can persist and provide the necessary habitat requirements of native wildlife despite the altered hydrograph.

On regulated rivers, horticultural restoration is the method used to plant native vegetation. Selected species are planted according to a planting design in rows with irrigation. The vegetation is irrigated and monitored for three years to ensure 95% survival, at which point irrigation and monitoring ceases.

Horticultural restoration of riparian forests proceeds similarly to the way the sites were farmed. Native trees and shrubs are planted in disked rows, then irrigated and managed for weeds for three years (Alpert and others 1999). Throughout the restoration sites on the Sacramento River a number of planting designs have been applied which vary by species composition and planting density. The focal species used in restoration include five native tree species: *Acer negundo* (box elder), *Fraxinus latifolia* (Oregon ash), *Platanus racemosa* (western sycamore), *Populus fremontii* (Fremont cottonwood), and *Quercus lobata* (valley oak); and five native shrub species: *Rosa californica*

(California rose), *Baccharis pilularis* (coyote brush), *Salix exigua* (sandbar willow), *S. gooddingii* (Goodding's blackwillow), *S. lasiolepis* (arroyo willow), and *Sambucus mexicana* (blue elderberry) and a mix of understory species that include herbs, vines and low shrubs (see Table 3 in Golet and others 2008 for a complete list). Densities of plantings range from 400 to 1300 plants per hectare, and the frequency a species is planted depends on the plant community type. The communities used in restoration include mixed riparian forest, valley oak riparian, valley oak woodland and savannah, riparian scrub and herbland, and elderberry savannah. Overtime, the plant community changes from the initial planting design because of the tolerances of individual plants to spatial differences in soils and hydrology and competition with other plants.

Horticultural restoration practices have been implemented on the Sacramento River for the last couple of decades and some of the older restoration sites are approaching 16 years old. These horticultural restoration efforts have experienced varying degrees of success (Hujik and Griggs 1995a and 1995b; Griggs and Peterson 1997; Alpert and others 1999; Griggs and Golet 2002; Golet and others 2008; Golet and others 2009). Most evaluations of restoration success on the Sacramento River have focused on the first few years after implementation (Hujik and Griggs 1995a, 1995b; Griggs and Peterson 1997; Alpert and others 1999). Few studies have evaluated the long-term success of restored sites. Only Griggs and Golet (2002) looked at survival of Valley Oaks (*Quercus lobata*) 7 to 12 years after planting. Documented accounts of restoration success for establishing wildlife habitat are even fewer, but see Golet and others (2008, 2009). Without long-term monitoring, these projects proceed on the untested assumption that horticultural riparian vegetation plantings will persist, thrive *and* provide quality wildlife habitat (Hilderbrand and others 2005). The lack of monitoring of the Refuge restoration sites is most striking when much of the restoration is designed for target wildlife species and it can take several years for the restored habitat to reach the level of maturity required to support particular species.

Blue Elderberry

Blue elderberry (*Sambucus mexicana* C. Presl: Caprifoliaceae) are common shrubs in the Central Valley that grow naturally in remnant mixed riparian floodplain and upland elderberry savannas (Vaghti and Greco 2007). Their location on the floodplain is largely controlled by inundation regime and floodplain age (Talley 2005; Fremier and Talley 2009). They are most common at intermediate relative elevations to the water table, where flood level and duration is also intermediate (Talley 2005; Vaghti and others 2009). In natural areas, elderberry shrubs have also been shown to grow best with little canopy cover from associated vegetation (Talley 2005).

Studies of planted elderberry in mitigation sites showed survival was highly variable, and site explained the most variation (Holyoak and others 2009). Survival declined with site age (Holyoak and others 2009). Elderberry growth also declined with site age, which correlated with the level of soil nutrients (Koch-Munz and Holyoak 2008).

Elderberry are planted in restoration and mitigation sites primarily because they are the sole host plant for VELB, but other wildlife such as birds, mammals, and reptiles use elderberry shrubs for cover, nesting, and perching. The VELB and many animals feed on the foliage, and the berries provide an important summer food source for neotropical migratory landbirds, resident birds, mammals, and reptiles (Martin and others 1951).

Elderberry shrubs attract a suite of pollinators and other beneficial insects that could disperse to adjacent agricultural lands (Allen-Wardell and others 1998; Neal 1998).

Valley Elderberry Longhorn Beetles

Valley elderberry longhorn beetles are wood boring beetles within the cerambycid family. There are three species of *Desmocerus* in North America and all use elderberry (*Sambucus*) species as host plants (Linsley and Chemsak 1972). There are two subspecies of *Desmocerus californicus* found throughout the Central Valley and coastal range of California; the California elderberry longhorn beetle (*Desmocerus californicus californicus*, CELB*)* can be found in the coastal range from Mendocino County to Los Angeles and the VELB is limited to the Central Valley from Tehama County to Fresno County (Halstead & Oldham 2000; USFWS 1984; Talley and others 2006). The CELB is more common throughout its range than the VELB (Collinge and others 2001).

There is little known about VELB behavior, as there have been only a handful of studies that directly encountered live adult beetles (for a review, see Talley and others 2006). VELB are members of the subfamily Lepturinae, whose members are not widely studied because they typically bore into dead trees or shrubs and thus do not damage crop or ornamental trees, and they are difficult to observe. The VELB genus *Desmocerus* is unusual among other subfamily members in Lepturinae in that its members use healthy to weakened hosts for oviposition. VELB females can therefore oviposit and eat from the same shrubs. The interaction between the feeding behavior of adults and the state of their host plants in many cases indicates whether or not adults produce long range pheromones (Hanks 1999). For example, female beetles that can feed and oviposit on the same host are often sedentary relative to the males, and rely on pheromones to attract males. In one VELB study, when10 adults were first observed before capture, all females were “resting” and 4 of the 6 males were either flying or walking (Lang and others 1989). VELB females are also larger than males. These physical and behavioral characteristics are often associated with female produced sex pheromones and sex pheromone production in longhorn beetles (Gemeno and others 2003; Hanks 1999). While there have been no studies to document longrange pheromone production in VELB, this is most likely the method by which males locate females.

Adult VELB are alive for only a few weeks between mid-March and mid-May (Linsley and Chemsak 1972; USFWS 1984). The adults feed and mate in the elderberry canopies and females oviposit directly onto the leaves and stems of the shrubs (Linsley and Chemsak 1972; USFWS 1984; Barr 1991). After the eggs hatch, larvae bore into the stems where they feed on internal pith tissue and develop for one to two years before emergence in the spring as adults (Linsley and Chemsak 1972).

While VELB larva grow and develop inside the elderberry shrubs, they feed on pith tissue inside the stems. The nutritional quality of the pith tissue affects the development of wood boring beetles, and often this tissue does not provide enough nitrogen for the beetles (Haack and Slansky 1987). Elderberry shrubs with higher nitrogen levels relative to other shrubs may provide better VELB habitat, and there is some evidence that VELB presence is correlated with increased levels of pith tissue nitrogen (Talley 2007).

The VELB is widely distributed throughout its range, but consistently occurs in very small populations – even when there are large areas of elderberry shrubs, a low percentage of them will contain VELB (Lang and others 1989; Barr 1991; Collinge and others 2001; Talley 2007). The low percentages of VELB present among all shrubs searched in these studies indicate that shrub quantity is not limiting VELB populations. This also suggests that while VELB are well distributed, the small size of local populations makes them vulnerable to stochastic events.

The fragmentation of remaining suitable habitat is a threat to VELB populations because of the beetle's poor dispersal abilities (Collinge and others 2001). It is not known how far VELB can travel in a lifetime, but it is likely no more than five kilometers (Huxel and Hastings 1999). In light of the lack of correlations between VELB presence and patch and landscape level variables, population level studies of VELB indicate that they exist as metapopulations among watersheds (Collinge and others 2001). Under this population structure, the VELB are believed to occupy several patchy populations that exhibit a high turnover rate between extinction and recolonization, and the survival of the overall population is somewhat dependent on dispersal between populations (Collinge and others 2001; Talley 2007). Therefore, large expanses of suitable habitat, within several VELB population patches could turnover, is likely needed for persistence of the overall population.

Due to the Federal status of the VELB, activities that result in disruption or destruction of VELB habitat – elderberry shrubs – must be mitigated for either through enhancement and protection of existing VELB habitat or by acquiring land to create new VELB habitat (USFWS 1999). Mitigation for VELB habitat consists of planting elderberry transplants, elderberry seedlings, and associated native riparian plants for every elderberry shrub impacted, as well as protection of the site into perpetuity (USFWS 1999). Mitigation for VELB requires monitoring of the sites over time for plant survival and beetle occupation rates, but Holyoak and others (2009) showed that a large proportion of the expected reports were missing.

Mitigation sites vary in size and are frequently located far from local VELB populations and consequently natural colonization takes an average of seven years (Talley and others 2006). Occupied transplanted elderberry shrubs, however, do appear to be a successful at introducing VELB populations into mitigation sites (Holyoak and others 2009). Though only a sample of mitigation reports were available, data indicated only a slight loss of the overall VELB population between pre-take (47% VELB occupation) and post-mitigation levels (43% VELB occupation) (Holyoak and others 2009). Similarly to the results of studies in natural systems, VELB in mitigation sites seem to be more abundant in older and moderately stressed elderberry shrubs (Holyoak and Koch-Munz 2008).

Mitigation and restoration of VELB habitat contribute to substantial increases in potential VELB habitat concurrent with continued take of habitat – a ratio of 3.5 seedlings must be planted for every one-inch diameter stem taken, and over 130,000 elderberry shrubs have been planted in restoration sites throughout the Central Valley (Talley and others 2006). Recently, the VELB was proposed for delisting, and once the beetle loses protection, elderberry plantings will likely decrease while take will increase. It is therefore important to understand the best planting practices for elderberry shrubs in restoration sites, as these may become increasingly important for VELB persistence.

# CHAPTER III

# METHODS

## Study Area

The study sites were located in the Sacramento River National Wildlife Refuge (the Refuge) within the 100-year meander zone of the Middle Sacramento River in northern California along a 100-mile stretch from Red Bluff (40.8º N, 122.9º W) to Colusa (39.º3 N, 122º W) (Figures 1 and 2). Red Bluff, at an elevation of 106 m, receives an average rainfall of 61cm, and Colusa, at an elevation of 15 m, receives an average rainfall of 43 cm (California Department of Water Resources 2007).

The headwaters of the Sacramento River are in northern California near the Oregon border in Shasta and Siskiyou counties. Shasta Dam stores water and regulates downstream flows. From Shasta to Red Bluff the river flows through a steep canyon, but then the Middle Sacramento River, from Red Bluff to Colusa, meanders through a broad alluvial floodplain which is mostly developed with farmland. South of Colusa, the river is completely confined by bank stabilization into a narrow channel.

The Refuge was established in 1989 for the conservation of endangered and threatened species, migratory birds, anadromous fish, native riparian/floodplain plants, and their habitats (USFWS 2005). Through various partnerships, the Refuge has been acquiring riparian habitat and associated croplands and orchards on the adjacent

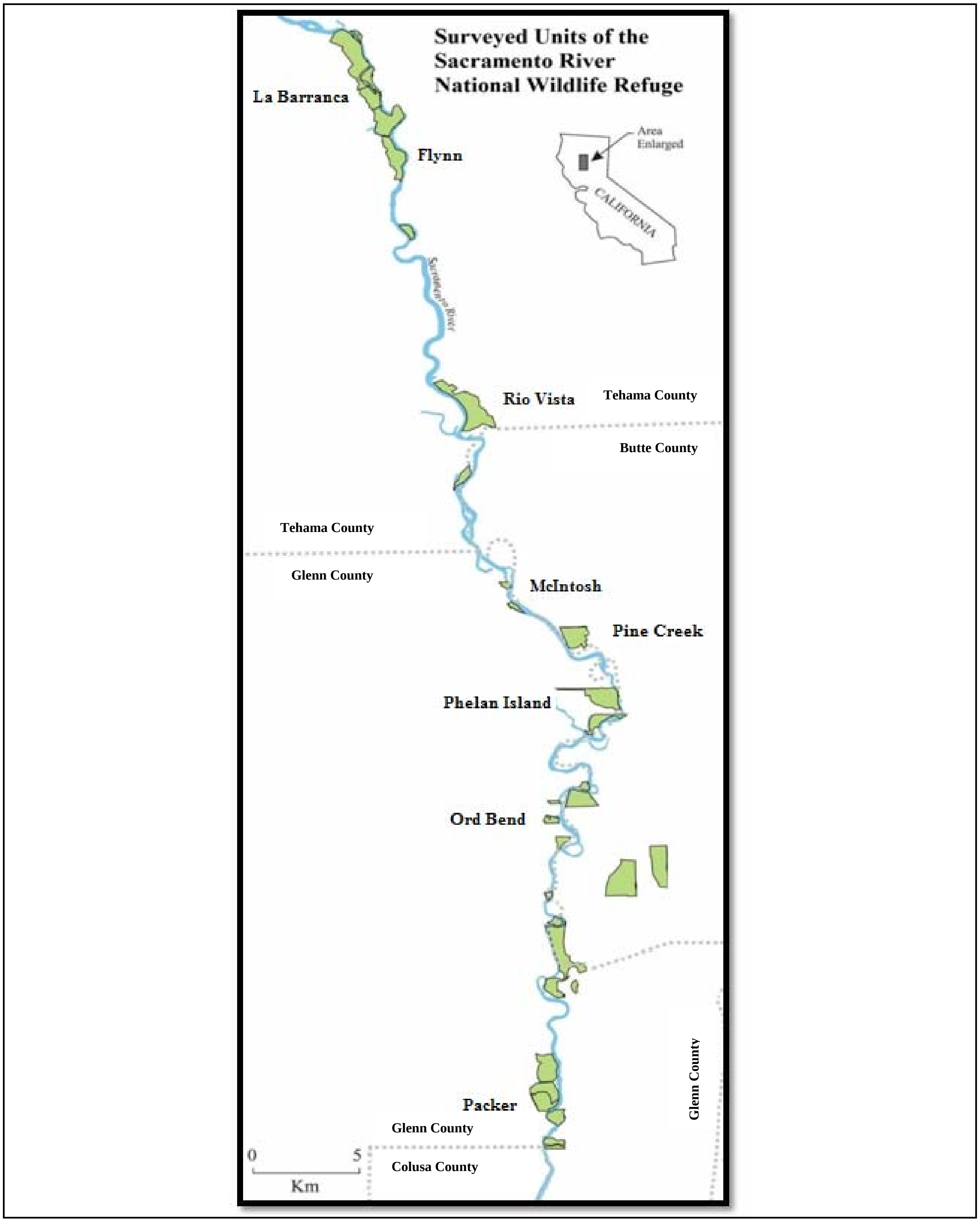



**Fig 2** Refuge units are shown in green and the units surveyed in this study are listed

Source: Adapted from US Fish and Wildlife Service (USFWS) (2005) Sacramento River National Wildlife Refuge Final Comprehensive Conservation Plan. June 2005. US Fish and Wildlife Service, California/Nevada Refuge Planning Office, Sacramento, CA and Sacramento National Wildlife Refuge Complex, Willows, CA floodplain for the last twenty years, to restore them to native riparian and floodplain vegetation and habitats. Each unit of the Refuge either contains or is adjacent to native riparian vegetation. Currently, the Refuge consists of 10,141acres of riparian floodplain habitats and floodplain agricultural lands (USFWS 2008). The agricultural lands cover about 900 acres including walnut orchards and row crops (primarily safflower); in addition, there are over 800 acres of fallowed agricultural lands (USFWS 2008).

All study sites were within the 100-yr floodplain and flood in high rainfall years. Rainfall was high (117% of average) in the winter of 2005/2006, during which time these sites experienced extensive flooding. The two years of this study were below average rainfall years (2007: 45% of average; 2008: 70% of average) (California Department of Water Resources 2007).

## Sampling Design

Data were collected from March through July in 2007 and 2008. For the purposes of this thesis, I focus on the 2008 data since trends and data interpretation were essentially the same for both years and the 2008 data included collection of additional variables based on the 2007 data. For reference, the 2007 data is included in Appendix A. I limited surveys to restored Refuge fields where VELB colonization was previously recorded (River Partners 2004; personal observations) to ensure the shrubs searched were within the beetle's colonization range. I stratified the sampling design by restoration age of field (young and old) and amount of cover by associated vegetation (closed and open, as defined below). Young fields were planted between 1999 and 2004, and old fields were planted between 1993 and 1998. Cover can vary within a field depending on several factors such as planting design, local hydrology and soils. Therefore, cover was determined at each point cluster, which consisted of a central elderberry shrub and its five nearest elderberry shrubs. A point cluster was considered closed if the central elderberry shrub had greater than 25% canopy and/or shrub cover *or* if the nearest woody neighbors to the center elderberry were on average less than 5 m away. A point cluster was considered open if shrub and canopy cover were less than 25% at the central elderberry shrub *and* the woody neighbors were on average greater than 5 m away from the center elderberry shrub. The 25% level of cover was chosen based on observations across different planting designs where cover greater than 25% began to affect the growth form of elderberry. I selected point clusters by locating randomly selected GPS coordinates in each of the following four age and cover classes: young closed, young open, old closed and old open. To ensure a balanced sampling design, I randomly selected GPS points until all classes were filled. I sampled 432 planted elderberry shrubs across 72-point clusters for VELB in restoration field distributed across eight units of the Refuge (Figure 2, Table 1). This sampling provided 18 replicates within each treatment.

Data Collection

For each point cluster I recorded the GPS location of the center elderberry shrub (GARMIN GPS 60, NAD 83 Zone 10, accuracy <15m). All elderberry shrubs were flagged and given a metal tag with an individual shrub ID. For each of the six elderberry shrubs at a point cluster I recorded elderberry shrub height, maximum length, maximum stem diameter (the diameter of the largest stem at ground level), the number of main stems (all stems greater than 2.5cm in diameter that branched below 20 cm) and a visual

**Table 1** Surveyed restoration fields of the Sacramento River NWR

| Field | Unit | River mile | Age of Field* | Field area (ha) | Distance to remnant (m)** |
|---|---|---|---|---|---|
| ryan 2 | La Barranca | 240 | 5 | 45.9 | 152 |
| ryan rest 1 | La Barranca | 240 | 11 | 14.7 | 340 |
| ryan rest 2 | La Barranca | 240 | 7 | 33.8 | 625 |
| flynn 2 | Flynn | 233 | 12 | 21.2 | 142 |
| flynn 5 | Flynn | 233 | 8 | 14.1 | 166 |
| flynn 4 | Flynn | 231 | 10 | 64.8 | 204 |
| rio 4 | Rio Vista | 218 | 12 | 49.1 | 285 |
| rio 5 | Rio Vista | 217 | 11 | 55.8 | 166 |
| rio 6 | Rio Vista | 217 | 10 | 53.2 | 334 |
| rio 8.1 | Rio Vista | 217 | 8 | 16.3 | 150 |
| rio 7 | Rio Vista | 216.5 | 9 | 82.4 | 296 |
| rio 1 | Rio Vista | 216 | 15 | 9.6 | 200 |
| rio 2 | Rio Vista | 216 | 14 | 44.4 | 251 |
| rio 3 | Rio Vista | 216 | 13 | 49.7 | 283 |
| mc annex | McIntosh | 202 | 7 | 5.7 | 106 |
| pc 2 | Pine Creek | 198.5 | 10 | 32.1 | 399 |
| pc 3 | Pine Creek | 198.5 | 9 | 79.4 | 277 |
| pc 4 | Pine Creek | 198.5 | 4 | 3.4 | 377 |
| ord1 | Ord Bend | 184 | 9 | 7.9 | 169 |
| ord3 | Ord Bend | 184 | 9 | 4.4 | 226 |
| ord4 | Ord Bend | 184 | 9 | 2.6 | 171 |
| ord6 | Ord Bend | 184 | 9 | 3.1 | 319 |

*At time of survey
**Average distance of points in field to nearest patch of remnant riparian habitat

estimation of the overall percentage of elderberry shrub dead biomass. To measure cover of each elderberry shrub by associated woody vegetation, I imagined a cylinder created by the drip line of each elderberry that extended from the forest floor to the height of the surrounding tree canopy. Canopy cover was then estimated as the percent of the top of the elderberry cylinder that was covered, and shrub cover was the percent of the cylinder that was filled with other woody species. Distance to the base, height and species of the five nearest woody neighbors of each elderberry shrub were recorded.

I observed that elderberry shrubs varied considerably in their growth form; some shrubs had a few large stems that were sparsely branched, and other shrubs had several highly branched stems. Main stem counts did not accurately represent these differences because main stem counts were made at less than 20 cm above ground, and much of the branching occurred above this height. To capture this difference in growth form, I measured elderberry foliar biomass using a modified foliage height density method. One person stood parallel to the longest breadth of the shrub and held a 0.5m square grid composed of 0.05m squares 3m from the base of the shrub, while an observer stood on the opposite side of the shrub 5m from the shrub base. The grid was held in the center of the shrub at three heights (0.5m, 1.5m and 2.5 m) and 1 m to each side of the center shrub at a height of 1.5m. The observer took a picture of the grid at each location. Later the pictures were analyzed and the number of open squares was counted to determine shrub foliar biomass.

Tissue samples from each elderberry shrub were collected to be analyzed for total nitrogen. I selected live stems that were young but hardened, 2- 4 cm in diameter, and I cut two 15-25 cm sections. I then removed the soft pithy tissue from inside the stems by drilling or scraping. From the same cut branches I removed 10 to 20 green and uninjured leaves. All samples were dried in an oven at 50$^{o}$C for three days and then ground to pass through a 40 mesh sieve (40 openings per 2.5 cm). Leaf and pith samples were tested for percent nitrogen using the Kjeldahl Total-Nitrogen determination (Brookside Laboratories, New Knoxville, Ohio).

Nitrogen is mobile in plants and is known to vary greatly in plant tissues depending on external and internal factors affecting the plant, such as age, season, temperature, competition with neighboring plants, and herbivory (Mattson 1980). I attempted to quantify the potential variation in percent total nitrogen within my study to provide context for interpreting the nitrogen results. I collected additional pith and leaf tissue from a subsample of elderberry shrubs in March and again in July 2008 to test for variability within the season. I tested for variability within individual shrubs by collecting samples from three different branches of nine randomly selected individual elderberry shrubs.

To sample for VELB presence, I searched the shrubs for exit holes and recorded the number of holes and age of each. Recent VELB occupation is indicated by the presence of new exit holes (current season or last season) as determined by the presence of frass (wood shavings and VELB droppings) and a lining of fresh, light-colored wood, whereas the wood inside old holes (two seasons or older) appeared gray and showed evidence of healing, such as re-growth beginning inside the hole. In analyses and throughout the text, occupied shrubs and shrubs with any aged holes both indicate the shrub had at least one exit hole, this could be old or new.

VELB are believed to be relatively poor dispersers (Talley 2007) so restored fields closer to remnant riparian habitat could have higher chances of colonization by VELB. In ArcMap, I measured the distance of the GPS location of each point cluster to the closest edge of remnant riparian habitat. The GIS layer of remnant riparian habitat along the

Sacramento River was based on 2007 aerial photography taken (Sacramento River Monitoring Assessment Program 2008). I did not have information about VELB colonization in the remnant habitat patches.

Analysis

I examined data for individual shrubs as well as sampling point clusters. In general, the patterns and trends for the individual shrubs were similar to the point cluster data (see the discussion for more detail) and there were only a few cases of significance using individual shrubs that were not significant at the point cluster level. Unless otherwise noted, I present point cluster data, consisting of the averaged variables for the six shrubs in each point cluster. However, three tests were performed using individual shrub data due to the way the data were collected to address specific hypotheses. These included analyses testing my study design classes and VELB occupation, using the five nearest woody neighbors to each individual elderberry shrub to examine the neighbor effect on elderberry health and VELB colonization, and investigating why some shrubs that contain old exit holes lost current occupation while others remain actively occupied.

To examine trends in elderberry health and VELB occupation, I grouped variables into three categories: site variables include measured environmental and landscape conditions of each point cluster; elderberry structure variables include the physical measurements of each elderberry shrub, and were averaged for each point cluster; and the nutrient variables include pith and leaf tissue total nitrogen values (Table 2). Data were log-transformed when necessary to meet the assumptions of normality and percentage

**Table 2** Variable sets

| Variable Set | Measured variables |
|---|---|
| Study design classes | Age = young or old, Cover = closed or open |
| Site variables | Distance to remnant (m), Age of field (years), Canopy cover (%), Shrub cover (%), Neighbor distance (m), Neighbor height (m) |
| Elderberry Structure variables | Height (m), Length (m), Maximum stem diameter (cm), Number of main stems, Dead biomass (%), Foliar biomass (%) |
| Nutrient variables | Pith nitrogen (%), Leaf nitrogen (%) |

and proportional data were arcsine transformed. I conducted all analyses using JMP version 7 (SAS Institute Inc. 2007).

Elderberry Shrub Health

To determine how age of a field and amount of vegetation cover affect elderberry structure, health and nutrient levels, I used MANOVAs. If the overall MANOVA model was significant, I ran ANOVAs on the individual variables, and used Tukey-Kramer honestly significant difference tests to identify differences among means in significant ANOVAs.

I used multiple regressions to determine which site variables best predicted dead biomass, foliar biomass and nutrient levels. Multicollinearity among the predictor variables in each multiple regression model was evaluated by calculating condition numbers of predictor variable sets prior to running the regressions, and by examining the

Variance Inflation Factors (VIF) of the coefficient estimates once each model was tested (McGarigal and others 2000). I used Akaike's Information Criterion (AIC) for model selection and present the top three models. Because my sample size was small, I used AICc. I compared the top candidate models in each regression by calculating ΔAIC, which is the difference between a contender model's AIC and the AIC of the best model. ΔAIC < 2 indicates strong support for the model relative to the other models. I presented all models with ΔAIC less than two. I present *wi* which calculates the weight of evidence that model *i* is the best approximating model, given the data and set of candidate models (Burnham and Anderson 2001).

I used ANOVAs to examine the relationship of elderberry dead biomass based on the presence or absence of a particular species of woody neighbor. These analyses were done using individual shrub data because of the way data for neighboring plants were collected.

To estimate the amount of variability within my nutrient data, I compared means of percent pith or leaf nitrogen between years and within a season using paired two sample t-tests for unequal variances. To compare variability of percent nitrogen among tissue samples taken from individual shrubs, I used Levene's test of unequal variance.

VELB

I tested variation in VELB presence and absence of new holes and any aged holes across my study design (age and cover) using contingency tables with Pearson's Chi-square test (Gotelli and Ellison 2004). To meet the requirements of at least five data point clusters in each category, individual shrub data was used.

To evaluate whether recent VELB occupation (presence of new holes) was associated with a particular structure, site, or nutrient variable, I used Spearman's rank correlations with sequential Bonferroni corrections. Multiple logistic regressions were then used to further examine the relationships between recent VELB occupation and site, structure and nutrient variables. AIC was used for model selection using the same methods as I used with the multiple regressions for elderberry health.

To determine whether VELB occupation was related to the woody species growing as neighbors to the elderberry shrub, I compared observed and expected numbers of times a woody species was a neighbor when VELB were present and absent (any aged holes) using G-tests and the individual shrub data.

I found many shrubs with old exit holes, but far fewer contained both old and new holes. This potentially indicated that while some shrubs that had old exit holes continued to provide VELB habitat, other shrubs that were once occupied by the beetle no longer represented suitable VELB habitat. I used multiple logistic regression models to test which variables best predicted the presence of previously occupied shrubs with sustained occupation (contained new holes).

# CHAPTER IV

# RESULTS

## Elderberry Shrub Health

### *Age and Cover Effects on Shrub Structure and Nutrient Variables – Point Cluster Data*

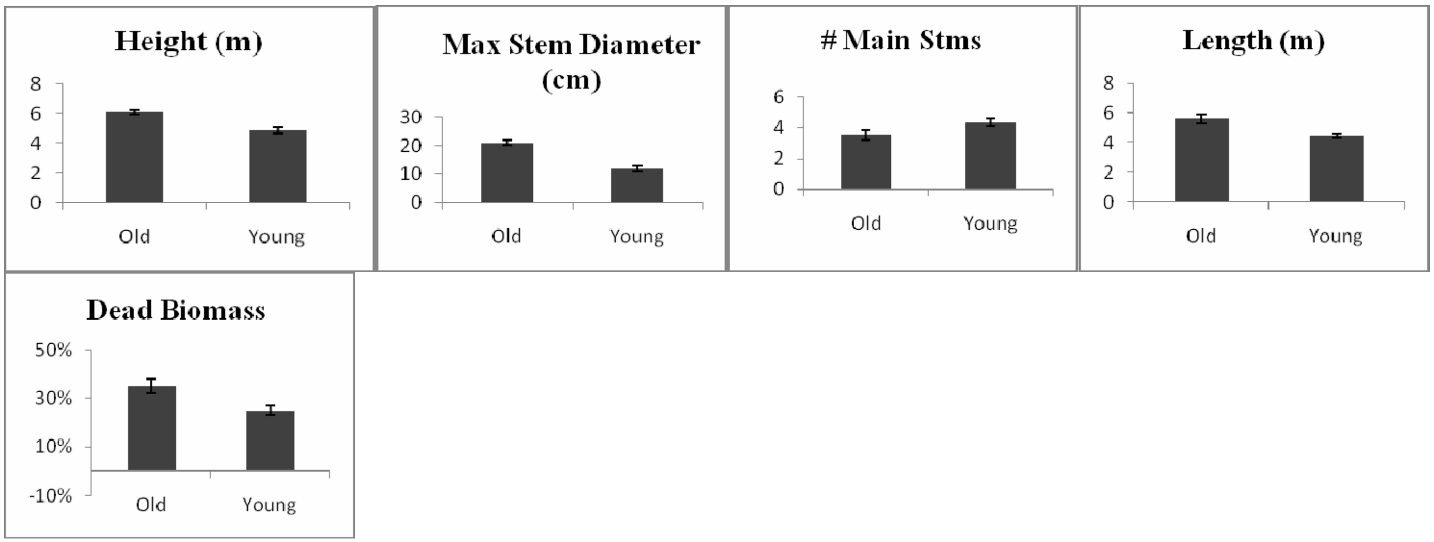
Cover by neighboring plants increased the amount of elderberry dead biomass and affected the shape of the shrubs (Table 3; Figure 3). In closed sites, elderberry shrubs were taller with less overall foliar biomass and fewer main stems than shrubs growing in open conditions. Elderberry shrubs in old sites were larger (taller, greater maximum length, greater maximum stem diameter, more foliar biomass) and had more dead biomass than elderberry shrubs in young sites (Table 3; Figure 3). The significant interaction effects revealed effects of cover on elderberry structure over time (Figure 4). Elderberry shrub maximum length and stem diameter notably increased between young and old sites under open conditions, but remained relatively the same under closed sites. Shrub height also increased with age in both open and closed sites but the relative change in height was greater in open sites compared to closed sites. In contrast, the change in dead biomass and foliar biomass with age was more notable in the closed sites where the extent of dead biomass increased and foliar biomass decreased with age. A MANOVA testing differences in nutrient levels by age and cover was not significant (Wilks' lambda = 0.85, $p = 0.09$).

**Table 3** Summary of ANOVA results testing for differences in elderberry structure variables among the two Age groups (Old and Young) and the two Cover groups (Closed and Open). p-values are given for the main effects and the interaction between them

| Elderberry Structure Variable | SS | MS | SSE | MSE | $F_{3,68}$ | *p* Age | *p* Cover | *p* Age X Cover |
|---|---|---|---|---|---|---|---|---|
| Height | 42.09 | 14.03 | 54.51 | 0.80 | 17.50 | <.0001 | <.0001 | 0.02 |
| Length | 46.12 | 15.37 | 133.54 | 1.96 | 7.83 | <.0001 | 0.343 | 0.002 |
| Maximum stem diameter | 2000.44 | 666.81 | 2939.68 | 43.23 | 15.42 | <.0001 | 0.575 | <.0001 |
| Number of main stems | 0.23 | 0.08 | 0.99 | 0.01 | 5.33 | 0.003 | 0.014 | 0.535 |
| Dead biomass | 0.85 | 0.28 | 1.28 | 0.02 | 15.07 | 0.001 | <.0001 | 0.027 |
| Foliar biomass | 0.70 | 0.23 | 1.84 | 0.03 | 8.58 | 0.612 | <.0001 | 0.001 |

Wilks' lambda = 0.287, $p < 0.0001$, ANOVAs $df = 68$

A. Age Class




B. Cover Class

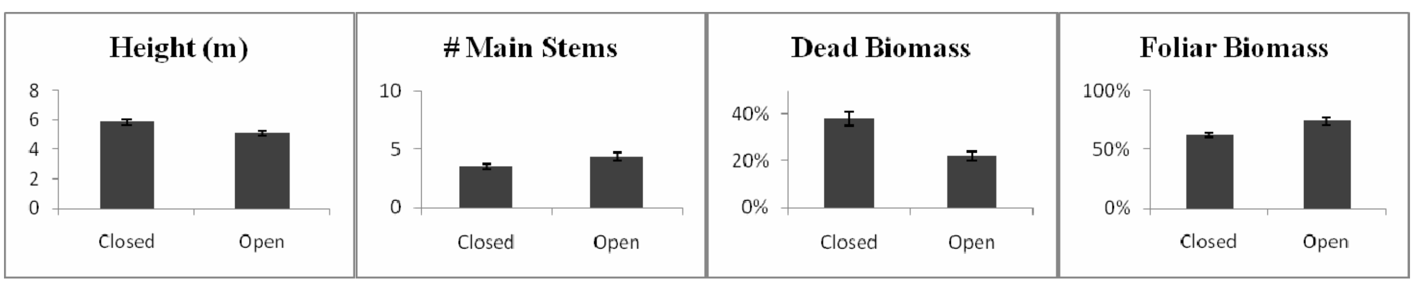



**Fig. 3** Comparisons of mean (±SE) elderberry structure variables for (A) Age and (B) Cover classes. Only significantly different pairs of variables are shown

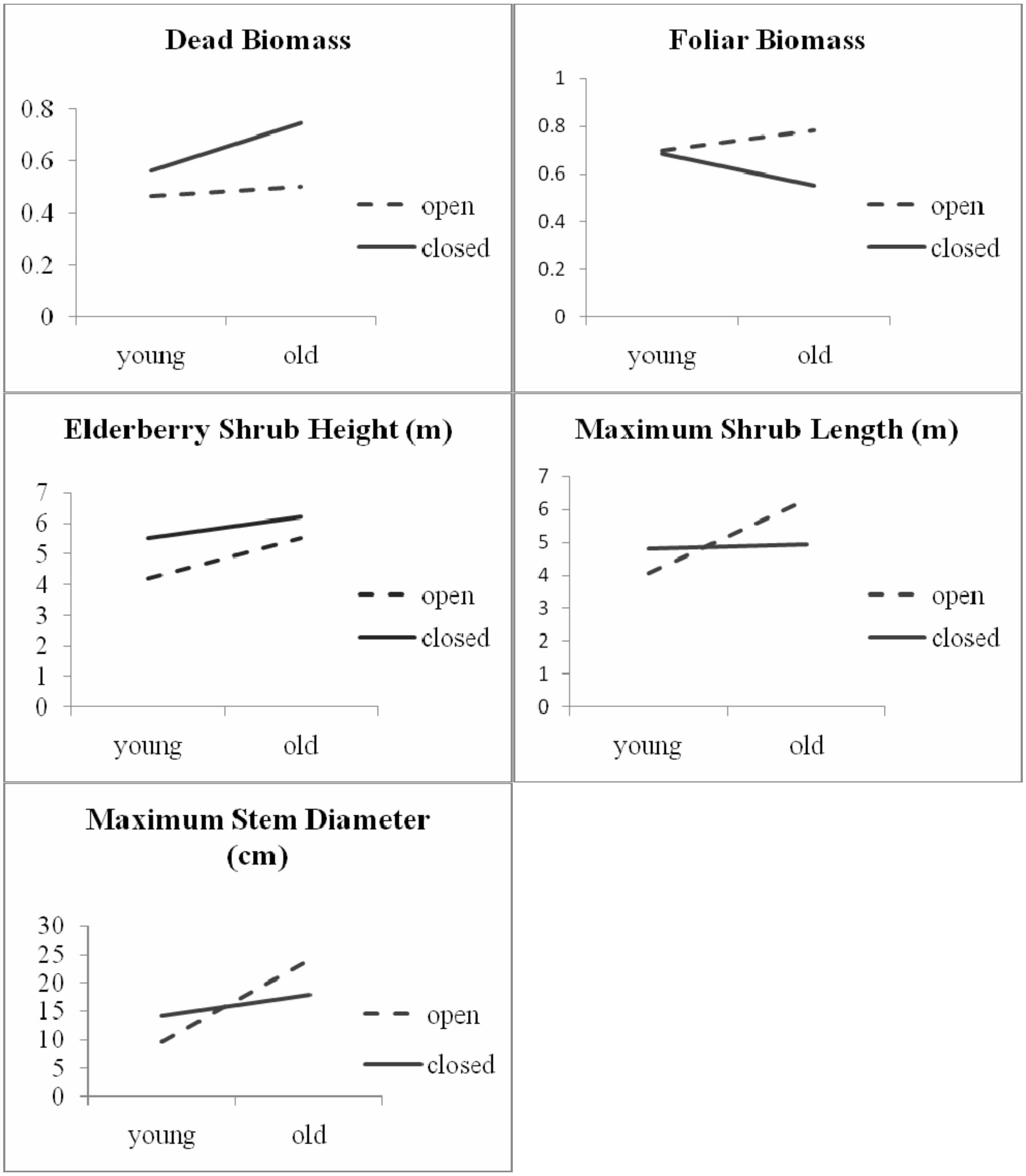



**Fig. 4** Significant interaction effects of age and cover on structure variables.

*Site Effects on Dead Biomass, Foliar Biomass and Nutrient Levels – Point Cluster Data*

Multiple regression models revealed site variables that explained 70% of the variation in elderberry dead biomass (Table 4). Increases in age, canopy cover and shrub cover

**Table 4** Information-theoretic statistics and coefficients (SE) of site variables for the top three multiple regression models explaining elderberry dead biomass. AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using *wi*.Values in parentheses indicate SE. "—" indicate the variable was not included in the model. All variables tested were included in at least one top model.

| Model No. | $r^2$ | AICc | *wi* | Intercept | Age of field | Canopy cover | Shrub cover | Neighbor distance | Neighbor height |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 70% | -330.4829 | 42% | 0.334(0.048) | 0.017(0.005) | 0.805(0.130) | 0.292(0.111) | — | 0.013(0.008) |
| 2 | 71% | -330.008 | 34% | 0.306(0.880) | 0.013(0.004) | 0.636(0.079) | 0.278(0.112) | — | — |
| 3 | 69% | -328.9247 | 20% | 0.342(0.050) | 0.019(0.005) | 0.777(0.134) | 0.256(0.119) | -0.005(0.005) | 0.012(0.008) |
| null | 0% | -238.8109 | 0% | 0.569(0.020) | — | — | — | — | — |

contributed to increases in dead biomass in all top models. The neighbor heights and distances provide more detailed descriptions of the nature of cover that affects elderberry dead biomass. With the increasing height of neighboring trees or shrubs, the amount of elderberry dead biomass increased. Though only present in the weakest model, neighbor distance indicated that elderberry dead biomass increased when these woody species were planted closer to the elderberry shrubs.

Approximately 50% of the variation in the amount of elderberry foliar biomass was explained primarily by cover (Table 5). Foliar biomass decreased when canopy cover was high. The weakest model indicated that foliar biomass decreased with site age. This trend is likely driven by the interaction between age and cover as discussed above (Figure 4); foliar biomass decreased in closed sites over time but increased in open sites over time. Foliar biomass increased however in the sites where shrub cover was high, but also increased when the woody neighbors were planted at farther distances. The weakest model indicated that foliar biomass increased in sites with taller neighbors.

Multiple regression models were able to explain some of the variation in both pith and leaf nitrogen levels (Tables 6 and 7). Several variables were included in the top models and a few were shared for both pith and leaf tissues. In both tissues, nitrogen increased with canopy cover and dead biomass, which point to higher nitrogen levels in closed sites. However, nitrogen levels also increased in shorter shrubs. Shrub height and the remaining variables included in the model are more indicative of open sites. This contradiction may be because in all models the amount of variation explained was low and the coefficients of variables were small relative to their standard errors, which suggests these variables were not strongly affecting nitrogen levels. Alternatively, these

**Table 5** Information-theoretic statistics and coefficients of site variables for the top three multiple regression models explaining elderberry foliar biomass. AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using *wi*. Values in parentheses indicate SE. "—" indicate the variable was not included in the model. All variables tested were included in at least one top model

| Model No. | $r^2$ | AICc | *wi* | Intercept | Age of field | Canopy cover | Shrub cover | Neighbor distance | Neighbor height |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 49% | -281.61 | 43% | 0.85(0.051) | — | -0.555(0.113) | 0.23(0.162) | 0.0311(0.007) | — |
| 2 | 48% | -281.39 | 39% | 0.891(0.046) | — | -0.477(0.101) | — | 0.027(0.006) | — |
| 3 | 52% | -279.80 | 18% | 0.85(0.072) | -0.009(0.007) | -0.75(0.184) | 0.22(0.169) | 0.032(0.007) | 0.017(0.011) |
| null | 0% | -238.81 | 0% | — | — | — | — | — | — |

**Table 6** Information-theoretic statistics and coefficients of site variables for the top three multiple regression models explaining elderberry pith total nitrogen. AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using *wi*. Values in parentheses indicate SE. "—" indicate the variable was not included in the model. Variables tested but not included in either model were age, shrub cover, and neighbor distance

| Model No. | *r2* | AICc | wi | Intercept | Canopy cover | Neighbor height | Height | Length | Maximum stem diameter | # main stems | Dead biomass | Foliar biomass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 22% | -746.38 | 59% | 0.891 (0.046) | 0.002 (0.007) | — | -0.002 (0.00) | — | — | -0.0003 (0.00) | 0.015 (0.008) | 0.022 (0.006) |
| 2 | 35% | -747.11 | 41% | 0.05 (0.006) | 0.013 (0.009) | -0.001 (0.00) | -0.002 (0.001) | 0.003 (0.00) | -0.0003 (0.00) | -0.001 (0.00) | 0.014 (0.008) | 0.017 (0.007) |
| null | 0% | -734.94 | 0% | — | — | — | — | — | — | — | — | — |

**Table 7** Information-theoretic statistics and coefficients (SE) of site and structure variables for the top three models explaining elderberry leaf total nitrogen. AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using *wi*. "—" indicate the variable was not included in the model. Variables tested but not included in the models are age, shrub cover, neighbor distance, neighbor height, maximum stem diameter, # of main stems and foliar biomass

| Model No. | *r2* | AICc | *wi* | Intercept | Canopy cover | Height | Length | Dead biomass |
|---|---|---|---|---|---|---|---|---|
| 1 | 23% | -545.35 | 45% | 0.189(0.014) | 0.033(0.027) | -0.016(0.004) | 0.006(0.003) | 0.035(0.030) |
| 2 | 21% | -544.56 | 30% | 0.181(0.012) | — | -0.014(0.004) | 0.004(0.002) | 0.059(0.020) |
| 3 | 17% | -544.14 | 25% | 0.181(0.013) | — | -0.009(0.002) | — | 0.042(0.018) |
| null | 0% | -534.89 | 0% | — | — | — | — | — |

models could be reflecting the high variability inherent in nitrogen levels and detected in this study.

*Nitrogen Variability*

I found significant variability in nitrogen levels overtime and among individual shrubs, therefore conclusions concerning nutrient data should be interpreted with caution. There were significant differences in pith and leaf nitrogen levels in individual elderberry shrubs over the course of the season (Table 8). Levene’s test of unequal variances indicated equal variance of means of multiple pith nitrogen samples taken from individual shrubs ($F$ = 2.37, $p$ = 0.07), but for leaf nitrogen the variances among samples taken from individual shrubs were not equal ($F$ = 6.86, $p$ = 0.0009).

**Table 8** Variability in percent nitrogen within season: Two-sample t-test assuming unequal variances.

| | *df* | t-critical two tail | *p* |
|---|---|---|---|
| Pith within 2008 season | 27 | 2.052 | 0.005 |
| Leaf within 2008 season | 26 | 2.056 | <0.0001 |

*Woody Neighbor Species Effects on Dead Biomass – Individual Shrub Data*

ANOVAs showed that when certain neighbors were present, elderberry shrubs had significantly higher levels of dead biomass (Table 9). When cottonwoods and willows were neighbors, elderberry dead biomass was higher than when these species were not neighbors, whereas when coyote bushes were neighbors, dead biomass was lower. The presence of box elders as neighbors did not significantly increase elderberry dead

**Table 9** Summary of ANOVA results testing for differences in variables among elderberry shrubs with or without certain woody neighbors for individual shrub data. P-values are given for the main effect. Also given are least squares means (SE). Means with the same letter are not significantly different, as indicated by Tukey's multiple comparison test. All means were back transformed

| | Significance of Effect (*p*-value) | Mean dead biomass when woody neighbor present or absent | |
|---|---|---|---|
| Woody Neighbor | Neighbor present or absent | Dead biomass present | Dead biomass absent |
| Coyote Bush (*Baccharis pilularis*) | <0.0001** | 26(0.4)[a] | 34(0.2)[b] |
| Willow (mixed Salix spp) | <0.0001** | 34(0.4)[a] | 26(0.3)[b] |
| Fremont's Cottonwood (*Populus fremontii*) | 0.0021* | 33(0.6)[a] | 27(0.2)[b] |
| Blue elderberry (*Sambucus mexicana*) | 0.0108* | 27(0.4)[a] | 32(0.3)[b] |
| Box elder (*Acer negundo*) | 0.0364* | 32(0.4)[a] | 28(0.3)[b] |
| California Sycamore (*Platanus racemosa*) | 0.1466 | 28(0.6)[a] | 31(0.2)[a] |
| Valley Oak (*Quercus lobata*) | 0.6297 | 30(0.5)[a] | 29(0.2)[a] |
| California Rose (*Roca californica*) | 0.7211 | 29(0.6)[a] | 30(0.2)[a] |
| Oregon Ash (*Fraxinus latifolia*) | 0.7569 | 29(0.6)[a] | 30(0.2)[a] |

*indicates significance at $p<0.05$

**indicates significance at $p<0.05$ after sequential Bonferroni correction

biomass but there were notable differences in means. Additional elderberry shrubs as neighbors notably decreased elderberry dead biomass, but this was also not significant.

Other tree species such as California sycamore, Valley oak and Oregon ash had no effect on elderberry dead biomass.

## VELB Occupation

### *Summary of Exit Hole Searches*

The summary of exit hole searches is shown in Table 10. A total of 21% of all shrubs searched had new holes, 65% of point clusters had new holes. Almost all shrubs or point

**Table 10** Summary of exit hole surveys

| Category | Percent |
|---|---|
| Recently occupied shrubs (new holes present, old holes present or absent) | 21 |
| Recently occupied points (new holes present, old holes present or absent) | 65 |
| Occupied shrubs (old and/or new holes) | 56 |
| Occupied points (old and/or new holes) | 93 |
| Shrubs with sustained occupation (old and new holes) | 33 |
| Points with sustained occupation (old and new holes) | 69 |

clusters that had new holes were previously occupied (old holes were also present). However, not all shrubs with old exit holes also had new holes. Only 33% of shrubs with old exit holes showed sustained or current occupation (presence of new holes). This indicates that 67% of shrubs that were once being used by the VELB did not have new exit holes during the survey period.

*Influence of Age and Cover Classes on VELB Occupation – Individual Shrub Data*

Age and cover classes did not affect whether or not shrubs were recently occupied (had new holes) ($p$=0.12). When old and new exit holes were considered, there were significantly more occupied shrubs in older sites than in younger sites (Figure 5, $p < 0.0001$) but there were no differences in occupation among open and closed sites.

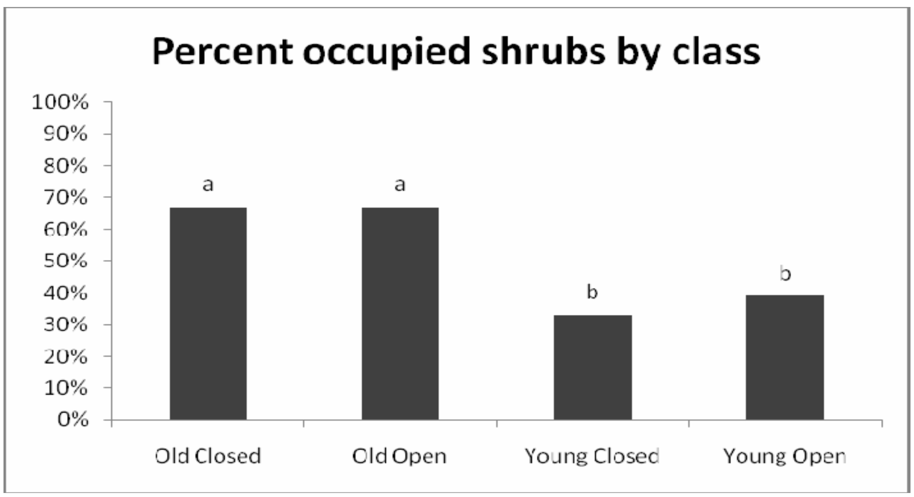



**Figure 5**: Percent of occupied shrubs within each study design class. Letters denote significantly different occupation among classes by contingency tests.

*Structure, Site and Nutrient Variable Effects on VELB Occupation – Point Cluster Data*

Recent occupation (presence of new holes) was significantly correlated with increases in shrub height and dead biomass (Table 11). Though not significant, recent occupation was higher when the point clusters were closer to remnant patches of riparian habitat. Beetles appear to be responding to either or both the age and size of the shrubs, with more recent occupation in point clusters with older, larger shrubs. In addition, recent occupation was higher in point clusters receiving greater shrub cover by neighboring trees and shrubs.

**Table 11** Spearman's rank correlations[a] between recently occupied points and all variables

| Variable | Spearman ρ | *p*-value |
|---|---|---|
| Elderberry shrub height | 0.31 | 0.0076** |
| Dead Biomass | 0.26 | 0.0107** |
| Maximum stem diameter | 0.28 | 0.0175* |
| Age | 0.25 | 0.0345* |
| Distance to remnant habitat | -0.25 | 0.0376* |
| Shrub Cover | 0.24 | 0.0428* |
| Maximum shrub length | 0.22 | 0.0475* |
| Canopy Cover | 0.2 | 0.0979 |
| Average neighbor height | 0.17 | 0.142 |
| # of main stems | -0.09 | 0.4664 |
| Pith Nitrogen | 0.08 | 0.523 |
| Leaf Nitrogen | 0.03 | 0.7743 |
| Foliar Biomass | -0.02 | 0.8377 |
| Average neighbor distance | 0.02 | 0.8331 |

*indicates significance at $p<0.05$
**indicates significance at $p<0.05$ after sequential Bonferroni correction
[a] Sample size: 47 points

The multiple regression models explained some of the variation in recently occupied point clusters (Table 12). The variables included in the top models were somewhat different from the important variables in the Spearman's rank correlations (Table 11). Akaike weights indicated that each of the four top models performed about equal. Like the Spearman's rank correlations, all models indicated greater recent occupation in point clusters closer to remnant habitat, and with taller elderberry shrubs. Unlike the correlations, the multiple regression models also indicated that VELB occupation was

**Table 12** Information-theoretic statistics and coefficients (SE) of site and structure variables for the top three models explaining recent occupation (presence of new holes). AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using wi. "—" indicate the variable was not included in the model. Variables tested but not included in the models were age, canopy cover, shrub cover, length, maximum stem diameter, number of main stems, and neighbor distance

| Model # | *r2* | AICc | wi | Intercept | Distance to remnant | Pith nitrogen | Leaf nitrogen | Shrub height | Dead biomass | Neighbor height |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21% | 80.35 | 30% | -7.42(3.24) | -0.004(0.002) | 997.58(610.64) | 65.49(44.46) | 0.93(0.33) | — | — |
| 2 | 23% | 80.40 | 29% | -8.12(3.29) | -0.004(0.002) | 884.25(610.27) | 77.75(46.9) | 1.33(0.48) | — | 0.2(0.15) |
| 3 | 18% | 80.87 | 23% | -5.47(2.81) | -0.004(0.002) | 1045.86(582.91) | — | 0.82(0.32) | — | — |
| 4 | 25% | 81.48 | 17% | -8.49(3.16) | -0.003(0.002) | 907.05(608.61) | 68.01(47.91) | 1.37(0.48) | 4.52(3.51) | 0.39(0.21) |
| null | 0% | 89.90 | 0% | 0.631(.25) | — | — | — | — | — | — |

higher when both pith and leaf nitrogen levels were higher. The relationship with pith shows slightly more support because it was included in all four top models, whereas leaf nitrogen was present in three of the top four. The weakest model indicated that recent VELB occupation increased with higher levels of elderberry dead biomass. Neighbor height was also included in the weaker model, which shows some evidence that taller neighbors to elderberry shrubs increase the likelihood of VELB occupation.

*VELB Presence/Absence and Woody Neighbors – Individual Shrub Data*

The species of woody neighbor planted in association with the elderberry shrubs affected occupation (the presence of old and/or new holes). VELB were significantly present more often than expected when Valley oaks and California sycamores were neighbors (Table 13). When other elderberry shrubs were neighbors, VELB were also present more often than expected but this was not significant ($p$ = 0.086). When box elders were neighbors to elderberry shrubs, the likelihood of recent VELB occupation was significantly lower than expected.

*VELB Presence/Absence and Woody Neighbors – Individual Shrub Data*

Overall, the presence of occupied shrubs across most restoration fields was high, when both old and new exit holes are considered (Table 14). Yet, not all of the shrubs with old exit holes showed sustained occupation (presence of new holes). For example, Table 14 shows all fields that contained shrubs with old exit holes, and the percentage of these shrubs that showed sustained occupation (also had new exit holes). Certain fields showed high sustained occupation rates, such as Rio 6 (75%) and Ord 1 (67%). Others showed

**Table 13** Frequency of observed and expected values (in parentheses) of neighbor species to elderberry shrubs with VELB present or absent (using any aged exit holes) for 2007 and 2008 individual shrub data

| Woody neighbor species | # times a neighbor | VELB present | VELB absent | G-statistic | *p*-value |
|---|---|---|---|---|---|
| Box elder (*Acer negundo*) | 208 | 88(116) | 120(92) | 15.677 | <0.0001** |
| Valley Oak (*Quercus lobata*) | 340 | 223(190) | 117(150) | 12.973 | <0.0001** |
| California Sycamore (*Platanus racemosa*) | 125 | 75(61) | 50(64) | 6.52 | 0.011** |
| Blue elderberry (*Sambucus mexicana*) | 469 | 281(263) | 188(206) | 2.94 | 0.086 |
| Coyote Bush (*Baccharis pilularis*) | 296 | 153(166) | 143(130) | 2.22 | 0.136 |
| Fremont's Cottonwood (*Populus fremontii*) | 72 | 35(40) | 37(32) | 1.122 | 0.208 |
| Willow (mixed Salix spp) | 388 | 210(217) | 178(171) | 0.553 | 0.457 |
| California wild rose (*Rosa californica*) | 106 | 61(59) | 45(47) | 0.103 | 0.748 |
| Oregon Ash (*Fraxinus latifolia*) | 119 | 58(58) | 61(61) | 0.00078 | 0.978 |

*indicates significance at $p<0.05$
** indicates significance at $p<0.05$ after sequential Bonferroni

**Table 14** Summary of occupation* and site conditions in restoration fields

| Field | # shrubs with old exit holes | Sustained occupation (new holes) | Canopy cover | Dead biomass |
|---|---|---|---|---|
| Field averages | | 33% | 15% | 32% |
| ryan 2 | 7 | 0% | 0% | 11% |
| flynn 4 | 19 | 5% | 44% | 58% |
| rio 7 | 12 | 17% | 44% | 46% |
| ryan rest 2 | 10 | 20% | 6% | 20% |
| ord4 | 8 | 25% | 1% | 32% |
| flynn 2 | 15 | 27% | 21% | 43% |
| ord6 | 10 | 30% | 4% | 18% |
| rio 2 | 23 | 30% | 14% | 31% |
| rio 3 | 19 | 37% | 9% | 25% |
| flynn 5 | 24 | 38% | 14% | 31% |
| rio 4 | 15 | 40% | 4% | 33% |
| rio 5 | 5 | 40% | 18% | 30% |
| pc 3 | 7 | 43% | 4% | 37% |
| rio 1 | 22 | 45% | 3% | 22% |
| mc annex | 4 | 50% | 1% | 22% |
| pc 2 | 6 | 50% | 16% | 26% |
| ryan rest 1 | 8 | 50% | 30% | 40% |
| ord1 | 6 | 67% | 0% | 28% |
| rio 6 | 8 | 75% | 32% | 43% |

*Only fields with more than one occupied elderberry shrub are shown

low rates of sustained occupation, or high rates of lost occupation, such as Ryan 2 (0%) and Flynn 4 (5%).

Multiple regression models explained little of the variation in the ability of these shrubs to sustain VELB occupation (Table 15). In all models, sustained VELB

**Table 15** Information-theoretic statistics and coefficients (SE) of site and structure variables for the top five models explaining sustained occupation (shrubs with old holes and new holes). AICc is corrected for small sample sizes. The weight of an individual model relative to the other candidate models can be compared using wi. "—" indicate the variable was not included in the model. Variables tested but not included in the models are age, height, canopy cover, shrub cover, neighbor distance, neighbor height, and foliar biomass

| Model No. | *r2* | AICc | wi | Intercept | Height | Pith nitrogen | Dead biomass | Neighbor height | Neighbor distance |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 4% | 264.05 | 31% | -1.745(0.631) | 0.290(0.114) | — | — | -0.097(0.052) | |
| 2 | 5% | 264.53 | 24% | -2.331(0.711) | 0.298(0.118) | — | 1.765(0.966) | -0.150(0.064) | 0.044(0.063) |
| 3 | 5% | 264.68 | 23% | -1.860(0.786) | 0.246(0.116) | 96.377(126.961) | — | -0.081(0.053) | — |
| null | 0% | 264.72 | 22% | -0.686(0.139) | — | — | — | — | — |

occupation was associated with taller elderberry shrubs and shorter woody neighbors. These models also showed weak evidence that sustained occupation was higher with both increases in dead biomass and pith nitrogen, as well as with greater neighbor distances.

# CHAPTER V

# DISCUSSION

Though the Valley elderberry longhorn beetle has been a target species of restoration on the Sacramento River for 20 years and thousands of elderberry shrubs have been planted to provide habitat for this rare species, this is the first evaluation of the health of planted elderberry shrubs and the corresponding occupation by the beetle beyond the initial required three year monitoring period. While I specifically selected study sites known to have at least one VELB exit hole based on the River Partners (2004) surveys, my study demonstrates continued and recent use by VELB of the restoration sites.

## VELB Occupation in Relation to Age of the Restoration and Cover by Woody Neighbors

Similar to all investigations of VELB to date, beetle occupation across the restoration sites did not strongly correlate with measured variables, but given the repeated observation that the beetle forms weak relationships with environmental variables, many of the trends from this study merit interpretation.

For example, VELB occupation, both old and recent, in the restoration sites was higher in older and larger shrubs, in terms of height, width and maximum stem diameters, which are variables that correlate with increased occupation in remnant sites as well (Barr 1991; Talley 2005). Indicators of shrub size (height, length and maximum stem diameter) also increase with age, making it difficult to discern whether the beetles are selecting shrubs based on age, size or both. For example, older, larger shrubs may simply have higher occupation rates because they have been available longer for colonization (Talley and others 2007). However, even among young sites VELB occupation was highest in larger shrubs, indicating that shrub size may be an important factor to VELB colonization independent of age. Furthermore, age was a more consistent predictor of old exit holes than of new exit holes. This suggests that while shrubs may accumulate exit holes overtime, age in itself may not be an important attribute of a suitable host plant.

VELB occupation showed a less consistent relationship to cover than age, but there is evidence that the increased cover of certain planting designs increased recent VELB occupation. Recent occupation increased with higher levels of neighbor shrub cover, while the relationship with canopy cover was not significant. However, recent beetle occupation also increased when neighboring trees and shrubs were taller, which is suggestive of increasing canopy cover since neighbor height was correlated with canopy cover ($r^2$ = .7). This discrepancy can be explained by the species of trees and shrubs planted with elderberry that showed significant relationships with VELB occupation. Newly occupied shrubs were present more often than expected when planted with sycamores and oaks. Sycamores and oaks can grow to be tall neighbors, and yet in general they contribute relatively little canopy cover over elderberry shrubs, due to their more sparsely branched growth forms. Box elders, however, are only of average height and yet grow with laterally extended, dense branches that contribute to high amounts of canopy cover over elderberries. When box elders were present, beetle occupation was less than expected.

The association between higher VELB occupancy with increased shrub cover and the lack of a clear relationship detected with canopy cover is interesting when compared to other studies. For example, VELB presence in mitigation sites was more likely under no canopy and less likely under willows, cottonwoods, and oaks (Holyoak and Koch-Munz 2008). These mitigation sites were comparable in age to the restoration sites, so the valley oaks should have exhibited similar growth patterns. In contrast, Talley (2005) found VELB were more common in wooded areas with 25-50% canopy cover than in more sparsely wooded and open areas. In general, it appears that VELB prefer at least moderate amounts of cover, but there are certain canopy producing species that are less likely to increase chances of VELB occupation, in particular box elders, cottonwoods and willows. Planting designs with elderberry that incorporate valley oaks and sycamores in contrast may provide better VELB habitat.

### Elderberry Health in Relation to Age of the Restoration and Cover by Woody Neighbors

The results of this study indicate that planting design significantly influences the health of elderberry shrubs through biotic interactions among the plants over time. Elderberry shrubs in closed sites grew taller, but were more narrow and had fewer stems and less foliar biomass, all of which indicate they allocated their resources towards growth in height instead of girth and volume, possibly to reach light gaps. Additionally, shrubs with greater cover from woody neighbors contained greater amounts of dead biomass. While dead biomass of shrubs increased with age, the correlations with cover were stronger and it was the interaction between age and cover that best explained the increase in dead biomass. In general elderberry shrubs grew larger overtime, but increased cover by neighboring woody species seemed to slow down and redirect shrub growth and simultaneously increase the amount of dead biomass.

The growth form or possibly species of the woody neighbor affected the degree to which elderberry health declined. For example, foliar biomass decreased when canopy cover was high but increased with the height of woody neighbors. Therefore, it was not the height of the species planted near elderberry shrubs that affects the growth form so much as it was the amount of cover that is produced. Similarly, canopy cover over elderberry shrubs resulted in higher dead biomass than cover within the shrub layer of elderberry shrubs. The woody neighbors that contributed to increases in dead biomass - cottonwoods, box elders and willows, are typically mixed riparian forest species that produce a lot of cover over elderberry. More open savanna like species, such as coyote brush and other elderberry shrubs, were associated with less elderberry dead biomass. The effects of cover on elderberry shrubs by woody neighbors over time implicate that more open planting designs with savanna or woodland species would allow elderberry shrubs to remain healthier and bigger for a longer amount of time. This result is in line with previous observations of biotic affects on elderberry health. Hubbell (1997) showed that blue elderberry growth rates declined under competition from alfalfa, and Talley (2005) found that older, larger blue elderberry shrubs were found under open canopy gaps in savannas and woodlands.

The open planting designs that are optimal for producing healthier, bigger elderberry shrubs that are likely to persist as VELB habitat longer, are similar to the cover conditions that appear to be good for VELB occupation. Both healthier shrubs and occupied shrubs increased in restoration sites with higher shrub cover, low canopy cover, and taller neighbor species. However, VELB occupation was also affected by the health of the elderberry shrub as discussed below. These correlations with health indicate that closed planting designs may be important to VELB habitat as well.

VELB Occupation in Relation to Elderberry Health

Consistent with studies of VELB occupation in natural sites and mitigation plantings (Arnold 1984; Collinge and others 2001; Holyoak and Koch-Munz 2008), recent VELB activity in the restoration sites was higher among elderberry shrubs with increased levels of dead biomass. The percent of elderberry dead biomass could increase as the shrubs age (or become larger), in response to high amounts of cover, or because of the presence of VELB exit holes. It is difficult to determine whether the beetles select for shrubs with more dead biomass or cause the increases through occupation overtime. Old exit holes showed a slightly stronger correlation with dead biomass than new exit holes, which could indicate that the beetles cause rather than respond to the increased dead material, because old holes have had a longer time to effect the health of the shrub. In contrast, the observed correlation between beetle presence and dead biomass may simply be because dead biomass of elderberry shrubs increases with age, which this study and others consistently find as a predictor of VELB occupation. My results show a more consistent and stronger trend between occupancy and dead biomass however than between occupancy and age, indicating that dead biomass of the shrub may be an important variable independent of age. Additionally, the dead biomass of elderberry shrubs in this study responded most strongly to increases in cover, regardless of the occupation level of the shrub. This suggests that exit holes may increase the dead biomass of elderberry shrubs but the effect of cover on dead biomass is stronger and independent of VELB occupation.

The dead biomass of plants may confer benefits to VELB which, like other cerambycids, most likely use olfaction to locate host plants and mates, and therefore possibly use the volatiles released from the stressed tissue in elderberry shrubs. Host plant volatiles released by stressed plants, in particular isopreniod compounds, have been well documented as the initial cue used by cerambycid beetles for host plant and mate location (Hanks 1999; Ginzel and Hanks 2004). The chemicals volatize at average temperatures, and because of their low weight they can travel far from the plant. For cerambycid beetles, which are typically not highly vagile and are small relative to the vast landscape in which they must find the appropriate host plant, these volatile chemicals can be used to locate host plants as well as conspecifics (Hanks 1999). In addition to helping VELB locate host plants, the volatile chemicals may also carry information about the quality of the plant as habitat. VELB adults only have a few weeks of life to find mates (Linsley and Chemsak 1972), and as a small insect in a large world, a strong signal for orientation that conveys information about the habitat quality saves time and energy searching for the appropriate habitat and mates. Arnold (1984) intentionally stressed shrubs in four locations through girdling or slashing because he predicted that the chemicals released by stressed tissue helped beetles locate the elderberry shrubs. Arnold supported this idea with the subsequent observation of adults on the damaged shrubs in three of the locations; however, specific observations such as the presence of exit holes on these shrubs were not recorded.

Because of the reoccurring association with higher dead biomass as a measure of stress and a recent indication of higher VELB occupancy with increased nitrogen levels (Talley 2007), some have speculated that beetles select shrubs with increased dead biomass because these shrubs may have higher nitrogen levels that could benefit developing VELB larvae. The effects of stress on plants vary by species and even among plant tissues, but some studies report increases in total nitrogen as stress increases (for a review, see Mattson 1980). VELB larvae grow and develop inside elderberry stems for one to two years as they feed on the internal pith tissue (Linsley and Chemsak 1972), and increased nutritional quality of plant tissue has been linked to increased growth rates of wood boring beetles (Haack and Slansky 1987). Similarly, Talley (2007) found VELB presence could be partially explained by increased pith nitrogen levels. The woody tissues that wood borers feed on are all nutrient limited, but pith tissue is among the most limited (Hanks 1999). The low availability of nutrients as been linked to the slow development time of VELB larvae, and of wood borer larvae in general (Hanks 1999). Many cerambycids intentionally stress host plants or select weakened plants, possibly to compromise the plant’s defense mechanisms or to elevate the nitrogen content (Mattson 1980; Forcella 1982). In fact, every other genus of longhorn beetles within the same subfamily select or cause severely stressed host shrubs (Hanks 1999) while VELB adults are believed to emerge from living shrubs that are only moderately stressed.

The relationship between plant stress (dead biomass), nitrogen, and insect performance fits the trends detected with VELB. Recent occupation has been shown to increase in shrubs that have moderate - as opposed to very low or high - levels of dead biomass (Holyoak and Koch-Munz 2008). Under severe stress, plant nitrogen begins to decline

(Mattson 1980). Nitrogen levels can become depleted under high plant competition over time (Vitousek and Howerth 1991). Shrubs may reach a certain level of dead biomass that causes nitrogen levels to drop too low to support beetles.

My results show inconsistent evidence that VELB occupation increases as pith and leaf nitrogen levels increase. The relationship was significant in multiple regression models but not in pairwise correlations (Tables 11 and 12). Nitrogen results also showed inconsistent trends in relation to the age of restoration and cover by woody neighbors. Nitrogen levels in both leaf and pith tissues increased with canopy cover and dead biomass, but both tissues also increased nitrogen levels when neighboring trees and shrubs were shorter. Similarly, pith nitrogen increased in shrubs with greater foliar biomass, which was highly correlated with open conditions. Therefore, the nitrogen results show conflicting evidence for increases under both open and closed sites. It is possible that the nitrogen levels of elderberry shrubs depended less on the amount of canopy or shrub cover and more so on the particular species. This would be in line with the results for both elderberry shrub and beetle response to cover, which indicated that the particular species of woody neighbor was important. This may be due to the structural differences and growth forms of the neighbors. For example, both increased VELB occupation and healthier shrubs were associated with either shrubby, shorter species or with slow growing trees that tend towards a narrow growth form. Species more associated with greater canopy cover - broader and more branched - were correlated with decreases in both beetle occupation and shrub health. Perhaps species that produce a lot of cover, but that are not particularly tall, create conditions that allow the amount of nitrogen in elderberry shrubs to increase, possibly because of species specific differences in competition for nitrogen. All the variables correlated with increased nitrogen levels were also correlated with age, though age was not correlated with nitrogen levels. Furthermore, nitrogen in plant tissue is generally high in younger actively growing tissue and declines as the plant ages (Mattson 1980) so it would be unusual for nitrogen to increase as the sites aged.

Nitrogen is highly variable in plant tissue over time, depending on the stress level of the plant, the season, the age of the plant, the climate, and availability of nutrients within the soil (Mattson 1980). Similarly, my nitrogen samples showed high variability throughout the season and within individual shrubs. Additionally, my results indicate that the connection between nitrogen levels, VELB occupation and elderberry health is not clear. Furthermore, the connection between plant stress and nitrogen is highly debated (Larson 1989). Therefore, despite the evidence supporting a connection between dead biomass, nitrogen, and VELB occupation, nitrogen levels may be too costly and unreliable as a variable to assess quality of VELB habitat.

VELB Patterns of Occupation in the Restoration Sites

Previous VELB occupation (old holes) was the most correlated variable to recent occupation (new holes), as 87% of shrubs with new holes contained old exit holes. The tendency of VELB to reoccupy shrubs has been noted in several studies (Barr 1991, Collinge and others 2001) and Talley (2005) found that 74% of recently occupied shrubs were also previously occupied. Studies of VELB commonly find occupation to be higher where shrubs are clustered and where connectivity among shrubs is high (Collinge and others 2001; Talley 2005, 2007). Observations of adult VELB and closely related beetles show that VELB are limited in the distances they can disperse (Talley and others 2006; personal observation) and this may explain why individual shrubs are often repeatedly occupied over time.

If VELB dispersal is limited, planted elderberry shrubs should show higher occupation in sites closer to remnant riparian habitat, where there is potential for source populations. This trend was not observed in planted elderberry in mitigation sites (Holyoak and Koch-Munz 2008) but it was observed in the restoration fields in this study. Recent occupation increased in sites that were closer to remnant habitat. The Refuge specifically selects sites to be restored that are adjacent to remnant habitat, to increase connectivity and enhance existing riparian vegetation. The results from this study suggest the strategy works for the VELB.

Occupation by the beetle across the restoration fields was widespread, 65% of all point clusters contained recent exit holes. However, at the more local level of individual shrubs, recent occupation was 21%. This pattern of widespread but locally small populations of VELB has been detected in other studies. For example, 64% of all polygons searched across 183 river miles of surveys contained evidence of beetles (Lang and others 1989), and 46% of sites throughout 8 counties contained occupied shrubs (Collinge and others 1991), but within sites, occupied shrubs range from 3 to 9% (Collinge and others 2001; Talley 2007). River Partners (2004) conducted the only prior survey of VELB use throughout the Refuge restoration sites and also detected this pattern, with evidence of VELB occupation in 100% of units surveyed and 83% of fields that comprise the units- but in only 4% of individual shrubs. Such a distribution may reflect an uneven quality of habitat across the landscape that results in patchy, small beetle populations or it may speak to the biology of the species and its limited flying ability. The distribution also fits with the evidence supporting a metapopulation structure of VELB, such as the weak correlations detected between VELB presence and measured environmental variables (Talley 2007).

I also detected widespread occupation at the point cluster level but lower occupation of individual shrubs. One reason is because within points only one shrub had to have new and/or old holes to be considered occupied. The range of variability within a point (i.e. the number of bushes occupied) ranged from 0 to 100%. Further, in terms of recent occupation within a point there were shrubs with old holes that were not recently occupied, as well as shrubs with old holes that were currently occupied. Only 33% of shrubs that were at one time occupied continued to be actively used by VELB. The multiple regression models to evaluate whether there were differences between shrubs with only past occupation and shrubs with current occupation were only able to explain very low amounts of variability. The weakness of the models can be explained in part by the high variability of measured variables of shrubs that sustained occupation. For example, the two fields with the lowest rates of sustained occupation, Flynn 4 and Ryan 2, had 44% and 0% canopy cover, respectively, while the two fields with the highest rates of sustained occupation, Rio 6 and Ord 1 had 0% and 32% canopy cover. Flynn 4, with 44% canopy cover had the highest amount of canopy cover than any other field, and also had shrubs with the highest levels of dead biomass. In this field alone, it seems logical to assume that the effect of cover over time created levels of dead biomass that were too high to support VELB larvae. In contrast, Ryan 2 was only 5 years old, had no canopy cover and the second lowest rate of elderberry dead biomass. This result lends support to the theory that VELB are associated with moderate levels of dead biomass. The shrubs surveyed in Ryan 2 were among the closest to remnant habitat, so it is possible they were colonized due to their proximity but could not support subsequent generations. The two fields with the highest levels of sustained occupation both had moderate levels of dead biomass, despite the large differences in canopy cover. These trends suggests that there may be two very different reactions by both elderberry shrubs and VELB to high and low cover, and that by lumping both classes into one analysis, the differences are averaged out and no clear effect was observed on what variables are important for supporting current occupation versus previous occupation.

## Restoration Implications

The results of this study suggest that open, low cover planting designs can allow elderberry to develop into larger, more robust shrubs that are likely to reach maturity. These designs would likely support VELB populations based on the positive associations between shrub size, age and VELB occupation. Additionally, open planting designs will allow elderberry shrubs to increase in foliar biomass and therefore provide greater structure and resources for other wildlife. However, VELB occupation may also increase in planting designs that include denser plantings of shrubby species, high densities of elderberry shrubs, and tall trees such as sycamores and oaks that produce relatively moderate amounts of canopy cover. Additionally, because of the strong relationship between canopy cover and elderberry dead biomass, and the consistent trend of increased VELB occupation with moderate levels of dead biomass, the incorporation of plantings with broad structured trees that produce higher cover over elderberry, such as box elder and willow, may also provide important habitat to beetle populations.

A diversity of planting designs is important for the beetle in light of successional changes that will take place in the planted fields over time. The closed canopy planting designs may be important habitat for VELB for a period of time when they produce moderate levels of elderberry dead biomass. The dead biomass may be beneficial to the VELB because of increased nitrogen levels, or these shrubs could release strong chemical signals that allow the beetles to locate the habitat as well as each other. Perhaps these signals are also effective means of allowing beetles in remnant sites to colonize the restoration sites. With time however, the high canopy planting designs will eventually cause the shrubs to become too stressed to support viable VELB habitat, at which point VELB may have to locate more suitable shrubs, such as shrubs in a more open planting design. Designs that incorporate multiple plant communities within restoration and mitigation sites are probably the best management option to increase the habitat diversity for VELB and other wildlife.

Recent studies indicate that elderberries in restoration plantings may be critical to sustaining VELB habitat, since natural recruitment of elderberry is low and invasive species competition with elderberries in remnant forests is high (Vaghti and others 2009). Vaghti and others (2009) also found that remnant forests with elderberry shrubs were rapidly becoming dominated by box elder and black walnut. My results indicate that elderberry planted with high numbers of box elder have particularly high amounts of dead biomass. While studies indicate that physical site conditions such as the hydrologic regime and soil texture exhibit strong controls on elderberry distribution (Vaghti and others 2009;  Fremier and Talley 2009) my results show that the associated community can also influence the long term health of the shrubs, placing importance on planting design.

Conservation Strategies

Due to the beetle's strong association with riparian habitat, itself a complex habitat mosaic, it is no surprise that the VELB is adapted to elderberry shrubs that grow in a diversity of plant communities (Talley and others 2007). Before extensive regulation of rivers, the frequent and large flood events on the Sacramento River floodplains would scour away vegetation, creating a mix of senescing and establishing patches (Rood and others 2003). In addition to increasing diversity of plant communities, floods can also decrease populations of rodents like voles that girdle elderberry stems (Silveira pers comm.), as well as deposit fresh sediment, which may increase the availability of nutrients to the plants (Valett and others 2005). Flood events occur with much less frequency and duration on the Sacramento River floodplains to the detriment of the many riparian plants that are dependent upon these events; thus restoration faces huge challenges in sustaining planted riparian habitat with the reduction in magnitude and duration of these natural river processes (Poff and others 1997).

Restoration plantings of elderberry shrubs will become increasingly important in the near future, since VELB have been proposed for delisting. Once delisted, mitigation for take of elderberry shrubs will no longer be required, and current VELB habitat may lose legal protection. In light of the importance of these restoration sites, and the truncated hydrologic regime that reduces natural river processes, monitoring both elderberry health and VELB occupation over time is especially important. These surveys were conducted in sites 16 years or younger, and already there were severely stressed elderberry shrubs and a high proportion of shrubs that lost occupation. Monitoring of VELB populations in restoration should be stratified by planting design and age. Permanent plots would allow both VELB occupation and elderberry health to be monitored as both abiotic and biotic factors influence elderberry over time. Restoration strategies should use an adaptive management approach, with the flexibility to change VELB habitat planting designs as it becomes better understood through population and habitat monitoring.

The limited dispersal abilities of the beetle and their metapopulation structure highlight the importance of large habitat patches and high connectivity. Restoration plantings along the Refuge are among some of the largest patches of VELB habitat in the Central Valley. The current, active beetle populations are evidence that the plantings are succeeding in both connection and expansion of VELB habitat. For the beetle and other targeted wildlife, these restoration sites are experimental in light of the altered river processes to which these plants are adapted; our future designs can be improved through continued monitoring.

## Limitations of This Study

An evaluation of the health of planted elderberry shrubs across the restoration sites was a logical follow-up to the thousands of shrubs planted to create VELB habitat. A larger survey encompassing more points could more thoroughly sample the restoration sites and better test the full range of site conditions. Much of the variation in shrub health is due to the variation in site conditions because of variables untested in this study, such as soil texture, stratification, depth to occlusion, depth to the water table and the frequency and duration of flood events. Therefore, to more accurately test the effects of planting design on shrub health, studies should evaluate these site conditions.

This research reconfirmed trends detected by previous VELB studies, especially that VELB more often occupy larger shrubs with moderate levels of dead biomass. I was however unable to clearly show why dead biomass is an important variable, or whether or not nitrogen content is an important clue to understanding VELB occupation. Because of the high amount of variability in nitrogen temporally and physiologically, much more intensive sampling would be required to explain trends with confidence.

The VELB has proven to be a difficult species to effectively show that measured variables can explain patterns of occupation. VELB show very little association with the location of shrubs on the floodplain, the plant community surrounding the shrubs, or the physical structure of the shrub (except for area and height). The biology of VELB themselves remain very much unknown. From limited observations of adults and comparisons with related cerambycids, VELB are believed to be poor dispersers. As a result, VELB are most common in previously occupied shrubs or within close proximity to occupied shrubs. Across the landscape VELB populations appear patchy and clustered within watersheds (Collinge and others 2001) again suggestive of a metapopulation structure.

While it is encouraging that VELB are broadly present throughout the Refuge restoration sites, we still do not fully understand when habitat is no longer suitable, or why a patch may go extinct. For this reason, the restoration designs should incorporate elderberry shrubs in multiple plant communities and beetle populations on these sites must periodically be surveyed.

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# APPENDIX A

## 2007 FIELD SEASON

A VELB survey in restored habitat on the USFWS Sacramento Wildlife Refuge was conducted in 2007. It was the initial year of the overall project and results from that study provided the basis for the sampling effort in 2008 where the research questions were refined. The 2007 season was designed to evaluate current VELB status on the Sacramento River NWR restoration units previously surveyed for VELB in 2003 (River Partners' 2004). The River Partners searched 7600 elderberry shrubs for VELB use or 10% of the planted shrubs on the Refuge at the time of the survey. The River Partners selected 24 restored fields within 5 units based on the density of planted elderberry shrubs within each field. The percentage of shrubs searched with exit holes in the River Partner's survey ranged across fields from 0 to 21.1%. I stratified the surveyed fields into 3 groups (occupation groups) based on the percentage of occupied shrubs and chose my sampling points from high fields (>9%) medium fields (2.4 – 5.2%) and fields where no VELB exit holes were found. I randomly chose 10 sample points within each group; each point consisted of a center elderberry shrub and the 5 nearest elderberry shrubs. In total I surveyed 180 shrubs throughout 10 fields within 5 restoration units in season one (Table A-1). Data for 2007 was collected from 23 April to 15 August.

**Table A-1**: Surveyed restoration fields of the Sacramento River NWR

| Field | Unit | River mile | Age of Field* | Field area (ha) | Distance to remnant (m)** |
|---|---|---|---|---|---|
| flynn 4 | Flynn | 231 | 9 | 64.8 | 197 |
| rio 4 | Rio Vista | 218 | 11 | 49.1 | 285 |
| rio 5 | Rio Vista | 217 | 10 | 55.8 | 166 |
| rio 6 | Rio Vista | 217 | 9 | 53.2 | 334 |
| rio 7 | Rio Vista | 216.5 | 8 | 82.4 | 296 |
| rio 1 | Rio Vista | 216 | 14 | 9.6 | 200 |
| rio 2 | Rio Vista | 216 | 13 | 44.4 | 251 |
| phelan 4 | Phelan Island | 191 | 9 | 8.6 | 64 |
| phelan 6 | Phelan Island | 191 | 6 | 8.9 | 139 |
| ord1 | Ord Bend | 184 | 8 | 7.9 | 425 |
| ord2 | Ord Bend | 184 | 8 | 2.6 | 173 |
| packer 2 | Packer | 167.5 | 7 | 33.5 | 230 |

*At time of survey

**Average distance of points in field to nearest patch of remnant riparian habitat

## Results

### Elderberry Shrub Health

#### *Age and Cover Effects on Structural Variables*

MANOVAs in 2007 showed a consistent effect of age on elderberry structure variables; elderberry shrubs in old sites were larger (taller, greater maximum length, greater maximum stem diameter, more foliar biomass) and less healthy (more dead biomass) than elderberry shrubs in young sites (individual ANOVAs are shown in Table A-2). The effects of cover on elderberry structure, including the interactions between age and cover

**Table A-2.** Summary of ANOVA results testing for differences in elderberry structure variables among the two Age groups (Old and Young) and the two Cover groups (Closed and Open). p-values are given for the main effects and the interaction between them. Means with the same letter are not significantly different, as indicated by Tukey's multiple comparison test. All means were back transformed.

| Elderberry Structure Variable | SS | MS | SSE | MSE | $F_{3,26}$ | *p* Age | *p* Cover | *p* Age X Cover | Mean Old | Mean Young | Mean Closed | Mean Open |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilks' lambda = 0.24, p = 0.0027, ANOVAs df = 3,26 | | | | | | | | | | | | |
| Height | 14.94 | 4.98 | 25.56 | 0.98 | 5.0656 | 0.001 | 0.317 | 0.424 | $6.70^{a}$ | $5.21^{b}$ | $6.16^{a}$ | $5.75^{a}$ |
| Length | 0.07 | 0.02 | 0.12 | 0.00 | 4.6984 | 0.009 | 0.418 | 0.348 | $5.12^{a}$ | $4.02^{b}$ | $4.41^{a}$ | $4.74^{a}$ |
| Maximum stem diameter | 0.40 | 0.13 | 0.42 | 0.02 | 8.1283 | 0.000 | 0.912 | 0.546 | $1.21^{a}$ | $0.99^{b}$ | $1.11^{a}$ | $1.10^{a}$ |
| Number of main stems | 0.34 | 0.11 | 0.52 | 0.02 | 4.8702 | 0.084 | 0.017 | 0.353 | $6.60^{a}$ | $4.72^{a}$ | $4.32^{a}$ | $7.00^{b}$ |
| Dead biomass | 0.16 | 0.05 | 0.82 | 0.03 | 1.734 | 0.054 | 0.790 | 0.109 | $0.63^{a}$ | $0.49^{a}$ | $0.57^{a}$ | $0.55^{a}$ |

were not as consistent as the effects of age. Shrubs were larger overall in open sites; they had significantly more main stems.

### *Site Variable Effects on Dead Biomass*

The top three multiple regression models all included canopy cover with a positive coefficient, but shrub cover was only in the third top model, with a small coefficient and large standard error, or otherwise showing no directional effect. Average neighbor distance was included in the second best model, but also had a small coefficient with a large standard error (Table A-3).

### *Elderberry Shrub Nutrient Relationships*

I used MANOVAs to examine effects of the age and cover study design on nutrient levels of elderberry shrubs, but they were not significant for 2007 (Wilks' lambda = 0.54, $p$ = 0.1293).

## VELB Occupation

### *Summary of Exit Hole Searches*

The summary of exit hole searches is shown in Table A-4. The percent of VELB occupation varies greatly between individual data and point data, because in many cases only one of the six shrubs in a point contained exit holes, but points in these cases were considered occupied.

**Table A-3.** Information-theoretic statistics and coefficients of site variables for the top 3 models explaining elderberry dead biomass. "—" indicate the variable was not used included in the model.

| 2007 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Model # | r2 | wi | Intercept | Age of field | Canopy Cover | Shrub Cover | Avg neighbor distance | Avg neighbor height |
| 1 | 40% | 0.54 | 0.446(0.037) | — | 0.466(0.106) | — | — | — |
| 2 | 42% | 0.23 | 0.355(0.12) | — | 0.483(0.11) | — | 0.014(0.017) | — |
| 3 | 42% | 0.22 | 0.527(0.16) | — | 0.558(0.16) | -0.272(0.35) | — | — |
| null | | 0 | 0.560(0.033) | — | — | — | — | — |

**Table A-4**. Summary of exit hole surveys.

| Category | Percent |
|---|---|
| Recently occupied shrubs (new holes present, old holes present or absent) | 13 |
| Recently occupied points (new holes present, old holes present or absent) | 50 |
| Occupied shrubs (old and/or new holes) | 34 |
| Occupied points (old and/or new holes) | 67 |

*VELB Occupation and Site, Structure, and Nutrient Variables*

The study design effects of age and cover significantly affected presence and absence of VELB exit holes. Age was significant, there were more occupied shrubs in old groups than in young groups ($p$ = 0.0013) but there were no significant differences among cover groups. Among presence and absence of new VELB holes by point data, in 2007 old groups had more occupied shrubs than young groups ($p$ = 0.001) there were no significant differences among age and cover groups. Spearman's rank correlations between all variables and recently occupied shrubs are shown in Table A-5. After Bonferroni corrections, the significant correlations for 2007 for new holes were positive with age and maximum stem diameter.

*VELB Presence/Absence and Woody Neighbors*

In both 2007, when Valley oaks were neighbors to elderberry shrubs, VELB were present more often than expected and absent less often than expected (Table A-6).

**Summary**

In general the trends for 2007 were similar to 2008 in terms of both elderberry health and VELB occupation. The most notable difference was a lack of significant effect of cover on both elderberry health and VELB occupation. The sample design in 2008 was set up specifically to look for differences in closed and open sites. In 2007, the sample design did not capture differences among cover as well.

**Table A-5.** Spearman's rank correlations[a] between recently occupied points and all variables.

| Variable | Spearman ρ | *p*-value |
|---|---|---|
| Age | 0.68 | <0.0001** |
| Maximum stem diameter | 0.64 | 0.0017** |
| Maximum shrub length | 0.42 | 0.0039** |
| Average neighbor height | 0.04 | 0.0138* |
| Average neighbor distance | 0.37 | 0.0432* |
| Elderberry shrub height | 0.27 | 0.0954 |
| Canopy Cover | 0.15 | 0.2919 |
| # of main stems | 0.34 | 0.3019 |
| Dead Biomass | -0.08 | 0.4912 |
| Shrub Cover | 0.12 | 0.6491 |

*indicates significance at $p<0.05$

**indicates significance at $p<0.05$ after sequential Bonferroni correction

[a]Sample size: 15 points

**Table A-6.** Frequency of observed and expected values (in parentheses) of neighbor species to elderberry shrubs with VELB present or absent (using any aged exit holes) for 2007 and 2008 individual shrub data.

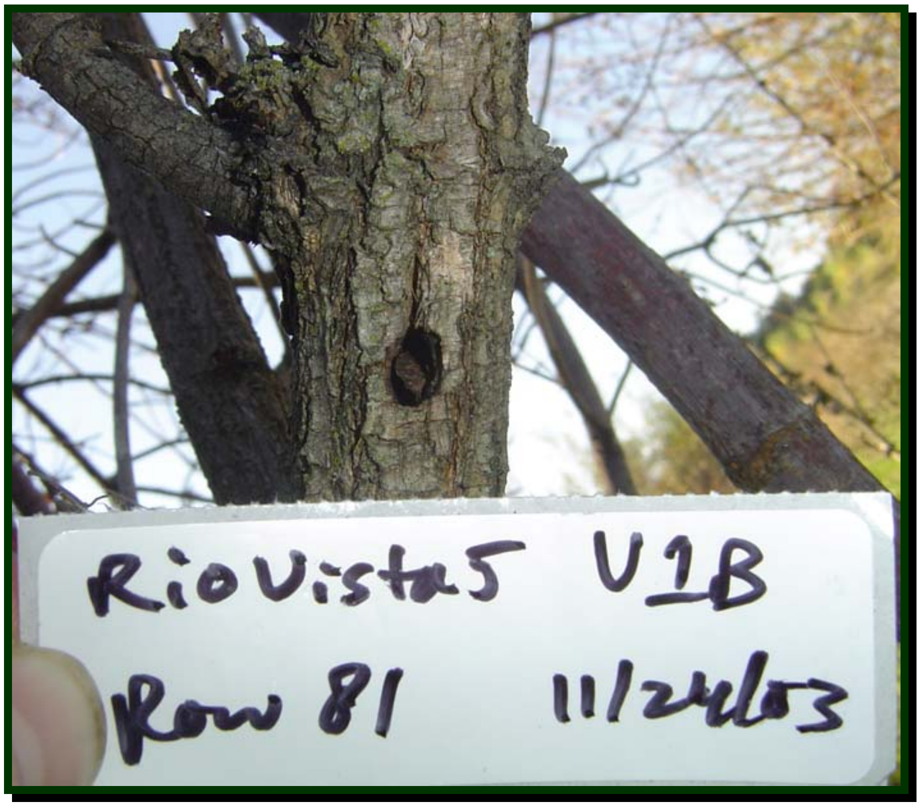
| 2007 data | | | | | |
|---|---|---|---|---|---|
| Woody neighbor species | # times a neighbor | VELB present | VELB absent | G-statistic | *p*-value(2-tailed) |
| Box elder (*Acer negundo*) | 78 | 24(27) | 54(51) | 0.369 | 0.544 |
| Coyote Bush (*Baccharis pilularis*) | 156 | 40(53) | 116(103) | 5.09 | 0.024* |
| Fremont's Cottonwood (*Populus fremontii*) | 58 | 20(20) | 38(38) | 0.006 | 0.938 |
| California Sycamore (*Platanus racemosa*) | 53 | 17(18) | 36(35) | 0.088 | 0.766 |
| Valley Oak (*Quercus lobata*) | 126 | 68(43) | 58(83) | 21.039 | <0.0001** |
| California wild rose (*Rosa californica*) | 43 | 10(15) | 33(28) | 2.358 | 0.125 |
| Blue elderberry (*Sambucus mexicana*) | 178 | 69(61) | 109(117) | 1.764 | 0.184 |
| Willow (mixed Salix spp) | 188 | 56(64) | 132(124) | 1.52 | 0.218 |

*indicates significance at $p<0.05$

**indicates significance at $p<0.05$ after sequential Bonferroni correction

# Survey of Planted Elderberry on Sacramento River National Wildlife Refuge Riparian Restoration Sites for Use by Valley Elderberry Longhorn Beetles

February 23, 2004

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River Partners. 2004. Survey of Planted Elderberry on Sacramento River National Wildlife Refuge Riparian Restoration Sites for Use by Valley Elderberry Longhorn Beetles. Tehama, Butte and Glenn County, California. Helen Swagerty and Scott Chamberlain. Chico, California.

**Survey of Planted Elderberry on Sacramento River National Wildlife Refuge Riparian Restoration Sites for Use by Valley Elderberry Longhorn Beetles**

## I. INTRODUCTION

In 1980, the US Fish and Wildlife Service designated the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) (VELB) as a threatened species under the Endangered Species Act. Elderberry shrubs (*Sambucus mexicana*) are the only host plant for the VELB. Declining VELB populations is attributed to habitat fragmentation and recent observations suggest that the Argentine ant *(Linepithema humile*) have impacted populations of VELB (Huxel 2000).

### A. Project Overview

In September 2003, River Partners signed a contract with the US Fish and Wildlife Service (USFWS) to survey planted elderberry on Sacramento River National Wildlife Refuge (Refuge) riparian restoration sites to determine use by VELB.

To date, 76,000 elderberry plants have been planted on the Sacramento River National Wildlife Refuge since 1989. Although the survivorship of planted elderberry on restoration site exceeds 80 percent, no formal surveys have ever been carried out to document their use by VELB. Anecdotal accounts speak of seeing VELB exit holes in elderberries in restoration plantings, but only as fortuitous observations.

Project goals were to examine10 percent (7,600) of the planted elderberry shrubs at several Sacramento River National Wildlife Refuge units for presence or absence of VELB exit holes and in addition, the presence and absence of Argentine ants. Refuge units surveyed lie along 66 miles of the Sacramento River (between RM 167 and RM 233), encompassing Tehama, Butte and Glenn Counties:

- Flynn Unit, Tehama County, River Mile 230.5-233
- Rio Vista Unit, Tehama and Butte Counties, River Mile 215.5-218
- Phelan Island Unit, Glenn County, River Mile 190.5-191.5
- Ord Bend Unit, Glenn County, River Mile 183.7-184, and
- Packer Unit, Glenn County, River Mile 167-168.

### B. Purpose of Report

This report documents the results of the VELB survey conducted October 31, 2003 to December 18, 2003 and provides recommendations for additional VELB research.

## II. SURVEY METHODOLOGY

### A. General Protocol

To determine the sampling size at each of the selected refuge units to meet the project goal, we utilized planting records, which noted differing densities of elderberry shrubs in various fields. Surveyors walked down rows and searched for exit holes in elderberry shrubs with stems greater than 1 inch in diameter. Each shrub, regardless of exit holes, was noted on data sheets as dead or alive. When exit holes were found, the number of holes was marked on the data sheet. Flagging to indicate the row number was attached to a stem of the shrub.

Data collected on each shrub with VELB holes includes: field number, row number, status (dead/alive), number of VELB holes, GPS number, distance from ground (inches), stem width (cm), hole dimensions (cm x cm), presence of ants (Y/N) and any comments (Appendix I).

Examination for the presence or absence of Argentine ants was searched for on only shrubs with holes. All ants were collected in aspirators and drawn into vials. Ants were then put into a kill jar (potassium cyanide) with the unit, field, row, date, and GPS number on the jar. Later, ants were pinned back at the lab (CSU, Chico) with each receiving a data label and then put into a Schmitt box containing paradichlorobenzene to prevent dermestid infestation.

Ant identification was done using several resources (Holldobler and Wilson 1990; Gregg 1963; Haney et al. 1993; Smith 1947). The following website was helpful in formicid identification as well: (http://www.antweb.org/california.jsp; and http://www.utep.edu/leb/antgenera.html). Ant specimens will be deposited at California State University, Chico, Chico, California in the entomology collection (Holt Hall Room 235).

### B. VELB Monitoring Data

Tables 1-5 summarize the monitoring data collected during the survey. Raw data may be found in Appendix I. Elderberry survivorship was high with only less than 1% dead. However, dead elderberry shrubs counted were individuals that were still present in the field. Therefore, we were not accounting for mortality that occurred before the last flood across these units.

Most fields contained elderberry shrubs with VELB exit holes, with some shrubs containing multiple exit holes. A total of 449 exit holes in 299 shrubs were observed in the selected refuge units.

**Table 1. Summary of VELB monitoring data collected at the Ord Bend Unit, Sacramento River National Wildlife Refuge.**

| Field Number | Year Planted | Total Shrubs Surveyed | Number of Exit Holes | Number of Shrubs with Holes | % Shrubs with Exit Holes |
|---|---|---|---|---|---|
| 1 | 1999 | 102 | 4 | 4 | 3.9 |
| 2 | 1999 | 33 | 1 | 1 | 3.0 |
| 3 | 1999 | 77 | 4 | 4 | 5.2 |
| 4 | 1999 | 23 | 2 | 1 | 4.3 |
| 7 | 1999 | 31 | 2 | 2 | 6.5 |
| 8 | 1999 | 30 | 0 | 0 | 0.0 |
| **Totals** | | **296** | **13** | **12** | **4.1** |

**Table 2. Summary of VELB monitoring data collected at the Flynn Unit, Sacramento River National Wildlife Refuge.**

| Field Number | Year Planted | Total Shrubs Surveyed | Number of Exit Holes | Number of Shrubs with Holes | % Shrubs with Exit Holes |
|---|---|---|---|---|---|
| 5 | 2000 | 139 | 15 | 10 | 7.2 |
| 2A | 1996 | 181 | 5 | 4 | 2.2 |
| 4A | 1998 | 339 | 85 | 48 | 14.2 |
| 4B | 1998 | 152 | 3 | 2 | 1.3 |
| **Totals** | | **811** | **108** | **64** | **7.9** |

**Table 3. Summary of VELB monitoring data collected at the Rio Vista Unit, Sacramento River National Wildlife Refuge.**

| Field Number | Year Planted | Total Shrubs Surveyed | Number of Exit Holes | Number of Shrubs with Holes | % Shrubs with Exit Holes |
|---|---|---|---|---|---|
| 1 | 1993 | 81 | 18 | 13 | 16.0 |
| 2 | 1994 | 889 | 132 | 87 | 9.8 |
| 3 | 1995 | 251 | 85 | 53 | 21.1 |
| 4 | 1996 | 361 | 21 | 16 | 4.4 |
| 5 | 1997 | 1146 | 35 | 28 | 2.4 |
| 6 | 1998 | 930 | 30 | 20 | 2.2 |
| 7.1 | 1999 | 381 | 0 | 0 | 0.0 |
| 8.1 | 2000 | 556 | 2 | 1 | 0.2 |
| **Totals** | | **4595** | **323** | **218** | **4.7** |

**Table 4. Summary of VELB monitoring data collected at the Phelan Island Unit, Sacramento River National Wildlife Refuge.**

| Field Number | Year Planted | Total Shrubs Surveyed | Number of Exit Holes | Number of Shrubs with Holes | % Shrubs with Exit Holes |
|---|---|---|---|---|---|
| 3 | 1997 | 75 | 1 | 1 | 1.3 |
| 4 | 1998 | 22 | 2 | 2 | 9.1 |
| 5 | 1999 | 219 | 1 | 1 | 0.5 |
| 6 | 2001 | 359 | 0 | 0 | 0.0 |
| **Totals** | | **675** | **4** | **4** | **0.6** |

**Table 5. Summary of VELB monitoring data collected at the Packer Unit, Sacramento River National Wildlife Refuge.**

| Field Number | Year Planted | Total Shrubs Surveyed | Number of Exit Holes | Number of Shrubs with Holes | % Shrubs with Exit Holes |
|---|---|---|---|---|---|
| 2.1 VE | 2000 | 1185 | 1 | 1 | <0.1 |
| 2.1 VW | 2000 | 231 | 0 | 0 | 0.0 |
| **Totals** | | **1416** | **1** | **1** | **<0.1** |

As expected, older sites had more VELB exit holes than younger sites (Figure 1), which may be a function of stem width (Figure 2). However, younger sites, such as Field 4 (planted 1998) and Field 5 (planted in 2000) of the Flynn Unit had a relatively high percentage of shrubs with exit holes. This phenomenon may be more of a function of geographical location, as these fields were adjacent to existing riparian vegetation along Elder and Oat Creek. The mean stem width in which exit holes were found was 5.2 ± 2.5 centimeters (Figure 2), which supports the observation of older units having more exit holes. The mean height above ground was 22.3 ± 12.5 inches (Figure 3).

**Figure 1. Occurrence of VELB exit holes in relation to the year elderberry shrubs were planted.**

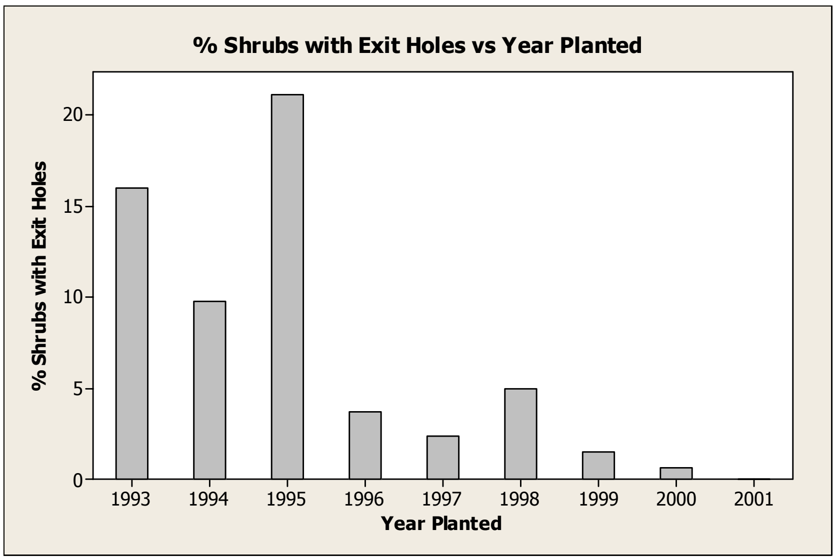



**Figure 2. Occurrence of VELB exit holes in relation to stem width.**

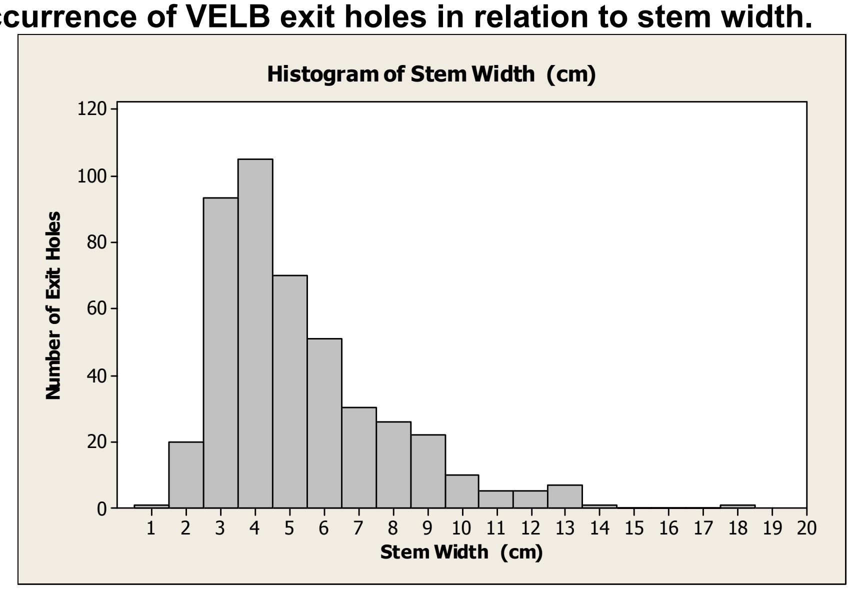
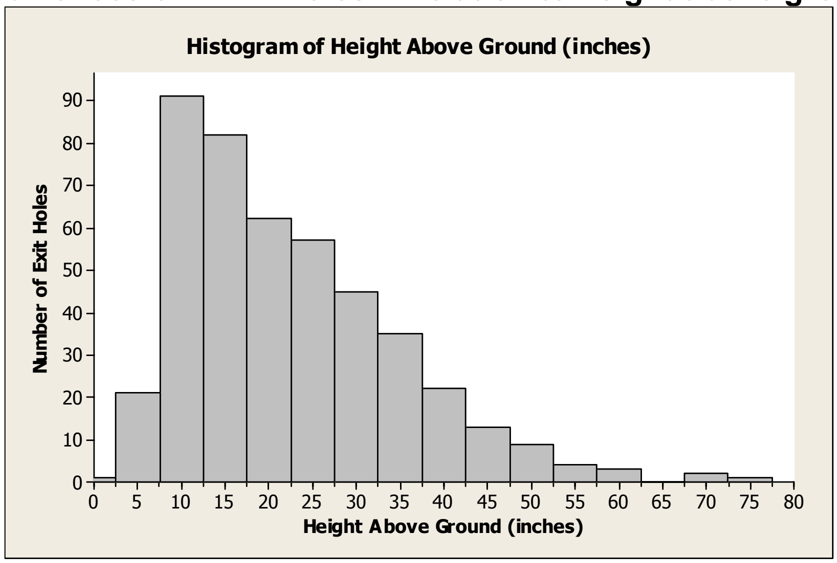


**Figure 3. Occurrences of VELB holes in relation to height above ground.**




Patterns emerged when locations of shrubs with exit holes were plotted, illustrating VELB colonization within the restoration sites (Appendix II). Greater evidence of colonization was observed in areas adjacent to existing riparian vegetation. At the Flynn Unit, Field 5, which abuts native vegetation along Elder Creek, and Field 4, which is bordered by remnant vegetation along Oat Creek, exhibited an exceptional amount of exit holes.

### C. Argentine Ants Observations

Ants were most likely to be found at the base of the shrub. Deep bark furrows near the base of shrubs probably provided a draw for ants (a young elderberry shrub with relatively smooth bark or young shoots on an old shrub does not provide any refuge for an ant). Typically during the survey, ants have only been found in small numbers, but on December 8, 2003, a relatively large colony of *Prenolepis imparis* was found on a shrub with VELB holes at Rio Vista Field 2. The presence of VELB holes in elderberry shrubs may facilitate the use of the shrub by ants. As beetles make exit holes, a cavity is provided for ants, as well as other taxa.

It is not likely that Argentine ants *(Linepithema humile*) occurred in any of the fields surveyed during the course of this study. However, field observations took place in late fall, in which cooler temperatures may have inhibited ant activity.

## III. CONCLUSIONS

This study has shown the effectiveness of restoration of riparian habitat with a goal of increasing VELB habitat. Our survey revealed evidence of VELB exit holes, indicating successful colonization in the selected refuge units. In the future, it would be interesting to determine if colonization is a factor of shrub age or stem width.

## IV. RECOMMENDATIONS

The following are recommendations for further study:

- A follow up examination in the spring to monitor the presence of any new exit holes to compare with last season's exit holes to determine their age.
- Measure the distances from shrubs with existing VELB exit holes to the nearest source of remnant riparian vegetation containing elderberry shrubs.
- Survey other restoration units on both USFWS and non-USFWS refuges along the Sacramento River.
- Assess flooding frequency at restoration sites relative to abundance of VELB exit holes.
- Examine along tributaries to determine extent of VELB occurrence.

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## Appendix I

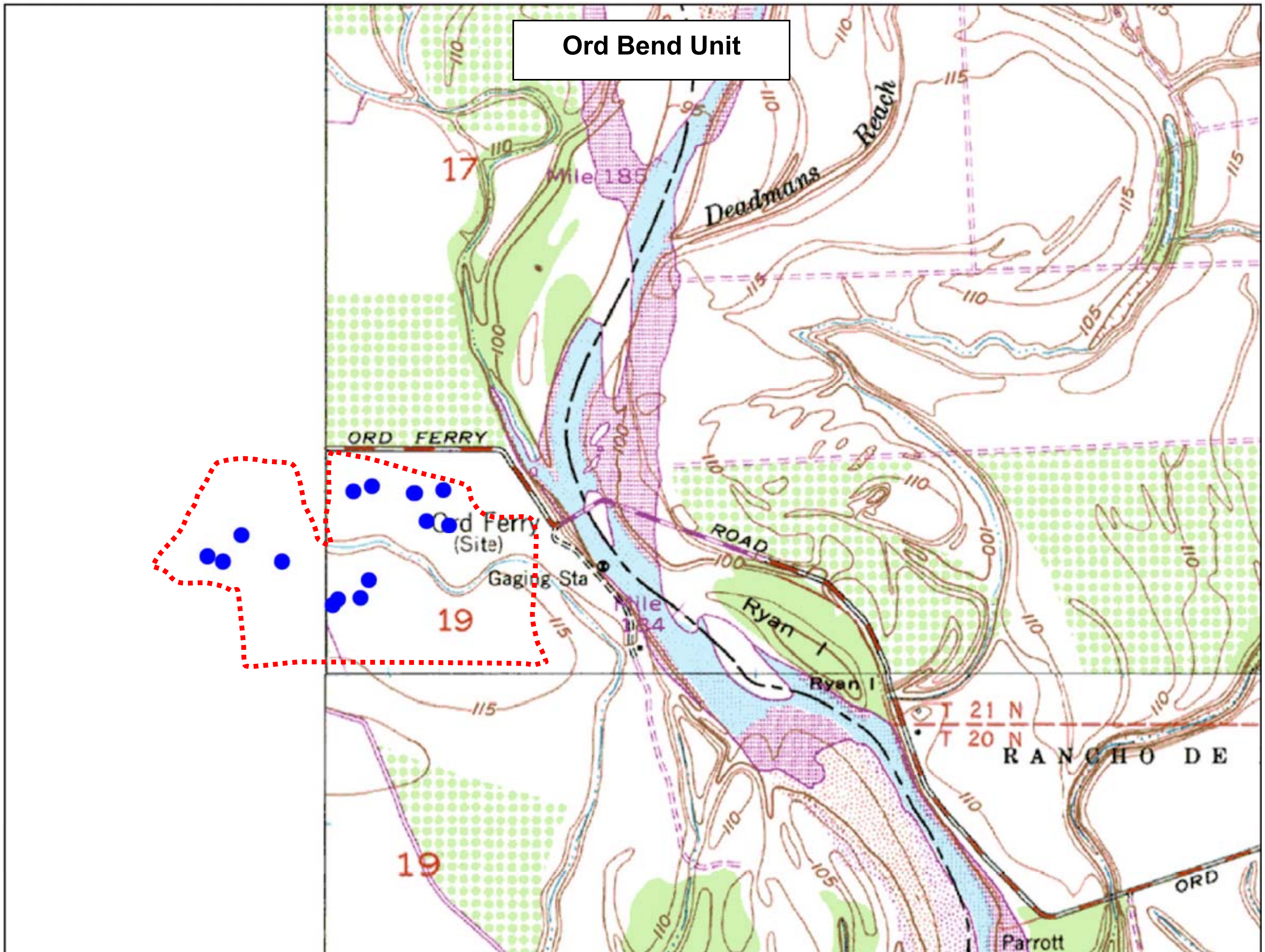
**Raw VELB monitoring data collected between October 31,20003 and December 18, 2003**

**Photographs of VELB exit holes found at the Ord bend, Flynn, Rio Vista, Phelan Island and Packer Units of the Sacramento River National Wildlife Refuge.**

# Appendix II

## GPS locations of VELB exit holes found at the Ord Bend, Flynn, Rio Vista, and Phelan Island Units of the Sacramento River National Wildlife Refuge

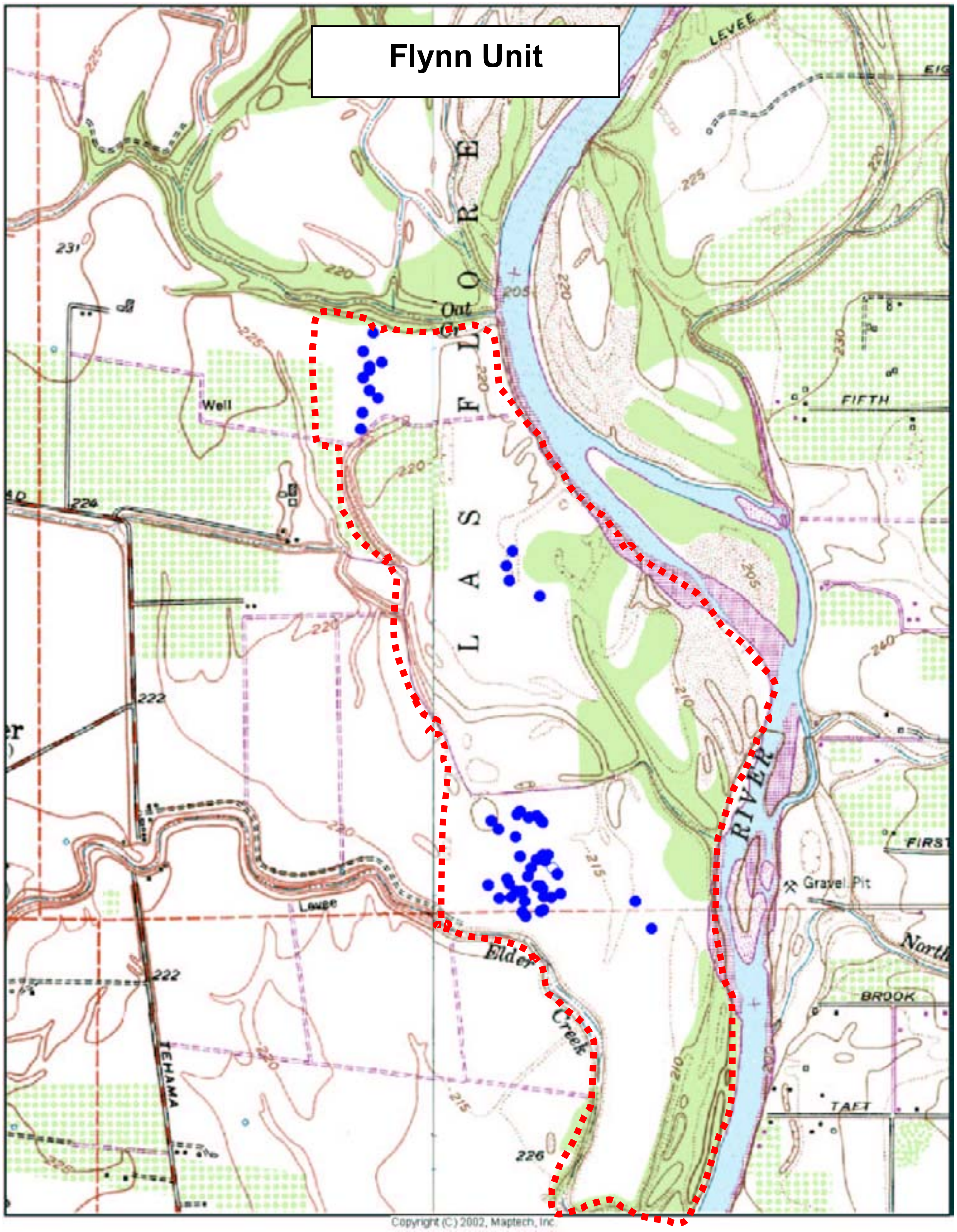
**Note: The Packer Unit was excluded from mapping because a GPS point was not taken at the location of the VELB exit hole.**



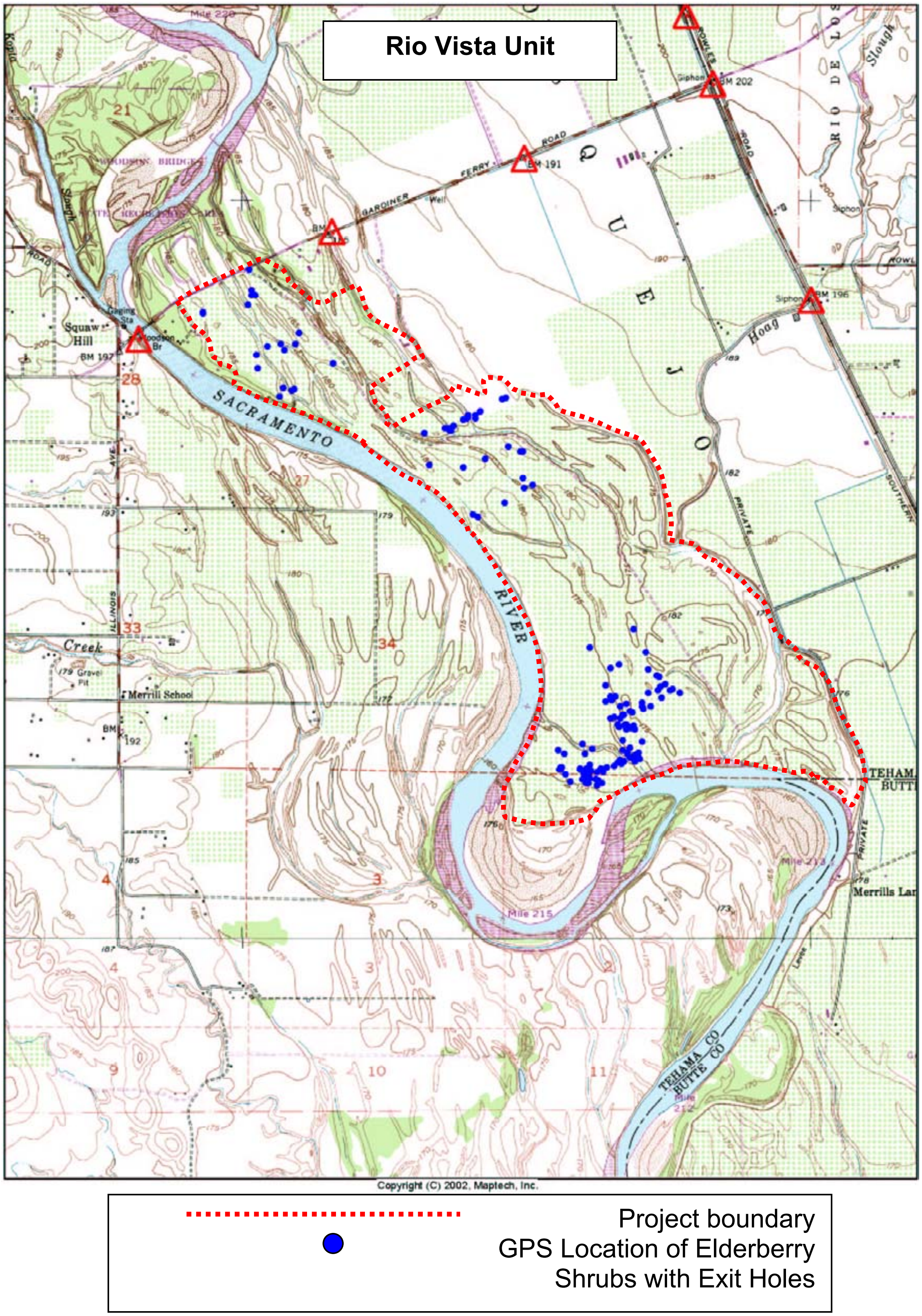



Approximate Field Boundary

GPS Location of Elderberry Shrubs with Exit Holes




Project boundary
GPS Location of Elderberry Shrubs with Exit Holes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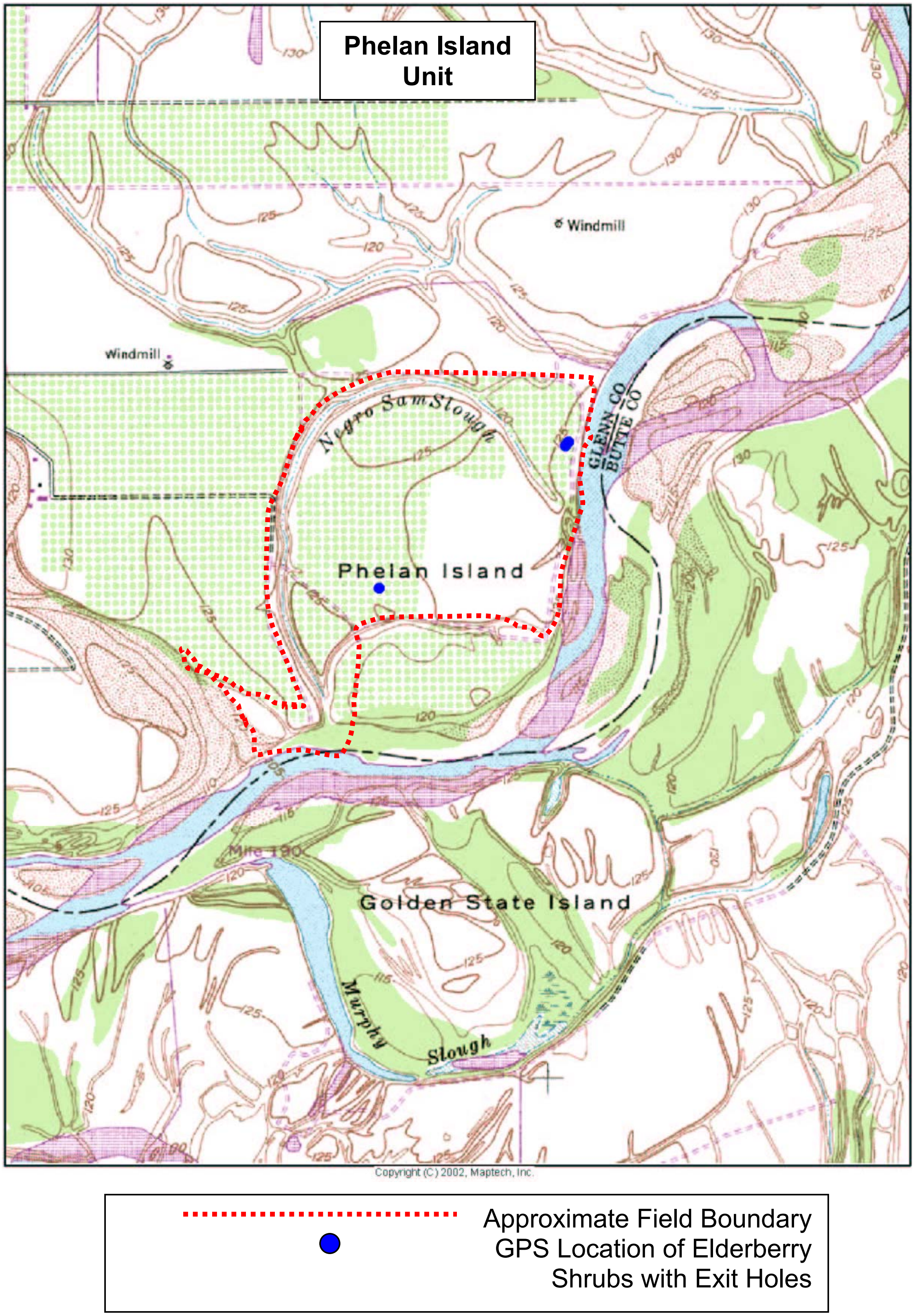
SACRAMENTO
RIVER
Squaw Hill
BM 197
Woodson Br
GARDINER
FERRY
ROAD
BM 191
BM 202
BM 196
Siphon
Hoag
Creek
Merrill School
Gravel Pit
ILLINOIS
AVE
Mile 215
Mile 212
TEHAMA CO
BUTTE CO
Merrills Lan
PRIVATE
Copyright (C) 2002, Maptech, Inc.
Project boundary
GPS Location of Elderberry Shrubs with Exit Holes



Phelan Island Unit
Windmill
Windmill
Negro Sam Slough
GLENN CO
BUTTE CO
Phelan Island
Mile 190
Golden State Island
Murphy
Slough
Copyright (C) 2002, Maptech, Inc.
Approximate Field Boundary
GPS Location of Elderberry Shrubs with Exit Holes

# 2018 Valley Elderberry Longhorn Beetle and Blue Elderberry Surveys

## Afton Cell 2 Restoration, Afton Cell 1 Remnant Riparian, RD 1004 Remnant Riparian

**<u>January 31, 2019</u>**

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## Section 1. Introduction

This report summarizes the results of the 2018 valley elderberry longhorn beetle (*Desmocerus californicus* ssp. *dimorphus*) (VELB) and blue elderberry shrub [*Sambucus nigra* ssp. *caerulea* (syn. *Sambucus mexicana*)] monitoring conducted at the Afton Unit Cell 2 Restoration ("Afton 2 Restoration"), Afton Unit Cell 1 Remnant Riparian ("Afton 1 Remnant Riparian"), and RD 1004 Remnant Riparian sites in Glenn County, California (Figure 1). The Afton 2 Restoration, Afton 1 Remnant Riparian, and RD 1004 Remnant Riparian sites are part of the U.S. Fish and Wildlife Service's (USFWS) Sacramento River National Wildlife Refuge (SRNWR). The Afton 2 Restoration and Afton 1 Remnant Riparian sites comprise the Afton Unit of the SRNWR and are located along River Miles 166–167 on the east bank of the Sacramento River. The RD 1004 Remnant Riparian site, part of the SRNWR Drumheller Slough Unit, is located approximately 1.2 miles south of the Afton Unit, on the south side of Road 67. The Nature Conservancy (TNC) planted the Afton 2 Restoration site in 2009. Monitoring surveys were conducted at the two remnant sites in 2008 (Gilbart 2008) and at the planted site in 2010, 2012, 2014, and 2016 by staff currently working at the Northern California Regional Land Trust (NCRLT).

The VELB monitoring is required by the Afton Tri-Party Agreement between TNC, USFWS, and Pacific Gas and Electric Company (PG&E). The purpose of the monitoring is to provide information to assist in the evaluation of the success of restoration efforts in providing VELB habitat and promoting species recovery. Additionally, the monitoring data provides information about the growth and survival characteristics of the VELB host plant, blue elderberry at the survey sites.

## Section 2. Survey Methods

NCRLT staff [Paul Kirk (Biologist), John Hunt (Biologist), Malia Pearl (Biological Technician), and Ian Calunga (Biological Technician)], conducted surveys between November 26, 2018 and December 10, 2018. Two teams of two personnel were deployed each field day in order to complete the surveys. A random sample of shrubs to survey was selected from shrubs previously surveyed within the Afton 2 Restoration site (Hunt et. al., 2010, 2012, 2014, 2016), as well as the Afton 1 and RD 1004 Remnant Riparian sites (Gilbart 2008). Locations of sampled shrubs were recorded using Collector for ArcGIS and are shown in Figure 2.

Sampling within the RD 1004 Remnant Riparian site was hampered by dense thickets of Himalayan blackberry and poison oak, limiting observations and data collection to a subset of shrubs within this site. Additionally, on January 23, 2014 a fire burned a large portion of riparian habitat within the easterly portion of RD 1004 (Figure 2; Joe Silveira, pers. comm. January 29, 2019). It appeared that elderberry shrubs within this portion of RD 1004 were either newly recruited, younger shrubs and/or derived from suckers of previously burned shrubs.

Field data collection followed the same methods as used in previous surveys of these sites. All sampled shrubs were examined for VELB exit holes and assessed for multiple morphological characteristics. The morphological characteristics for which data was recorded included:

- Shrub status (i.e., alive or dead);

- Shrub height (meters);
- Maximum basal stem diameter (centimeters);
- Number of all live stems ≥ 2.5 centimeters in diameter branching within 1 meter of the ground ("live stems ≥ 2.5 centimeters");
- Number of live stems in each of three size classes (2.5–7.5 cm, 7.6–12.5 cm, and ≥12.5 cm);

For shrubs that had VELB exit holes, data collected included:

- Number of exit holes present on each shrub;
- Diameter of exit holes in centimeters (cm);
- Diameter of stems with exit holes (cm);
- Age class of exit holes: ≤2 yrs. old ("new"); >2 yrs. old ("old") and, in some cases, "undecided";
- Height above ground for each exit hole (cm);

All new VELB exit holes were measured and records were made of whether they had clean margins, were healed over, or were warped. In addition to documenting VELB exit holes, the following information was collected for shrubs containing new exit holes: (1) relative cover (visual estimate) of each woody species within 5 meters and (2) visual estimate of herbaceous cover vs. bare ground.

## Section 3. Results

A general summary of shrub data collected from each site is provided in Table 1, below.

**Table 1. Total number of blue elderberry (*Sambucus nigra* ssp. *caerulea*) shrubs sampled during 2018 valley elderberry longhorn beetle (*Desmocerus californicus* ssp. *dimorphus*) (VELB) surveys and total excluded from analysis**

| Sample Site | Live Shrubs | Dead Shrubs | Total | [1] Excluded from analysis |
|---|---|---|---|---|
| **Afton 2 Restoration Site** | 301 | 1 | 302 | |
| **Afton 1 Remnant Riparian** | 177 | 8 | 185 | 3 |
| **RD 1004 Remnant Riparian** | 35 | 1 | 36 | 8 |
| **Total** | **513** | **10** | **523** | **11** |

***[1]A total of 11"Live" shrubs in remnant riparian sites were excluded from analysis. Three (3) shrubs within the Afton 1 Remnant Riparian and 8 shrubs within RD 1004 Remnant Riparian site were excluded due to dense stands of poison oak and blackberry precluding physical access and data collection. An additional 15 shrubs at the RD 1004 Remnant Riparian site were burned by a fire in 2014 (Figure 2) and are discussed further in summary analyses.***

Data was collected from 523 elderberry shrubs distributed amongst three sampling locations: Afton 2 Restoration site (302 shrubs), Afton 1 Remnant Riparian site (185 shrubs), and RD 1004 Remnant Riparian site (36 shrubs).

Three (3) shrubs within the Afton 1 Remnant Riparian and 8 shrubs within RD 1004 Remnant Riparian site were excluded due to dense stands of poison oak and blackberry precluding physical access and data collection. An additional 15 shrubs at the RD 1004 Remnant Riparian site were burned in the 2014 fire.

After exclusion of these shrubs, final "Live" shrub sample size at Afton 1 Remnant Riparian site was 174 shrubs.

The RD 1004 Remnant Riparian site presented two notable sampling problems: physical access and the 2014 fire that burned the easterly portion of RD 1004 Remnant Riparian site. Because the majority of data (collected from the majority of shrubs observed at this site was either incomplete [due to accessibility issues (n=8; appr. 23% of live shrubs observed at this site)] and/or suspect [due to effects of the 2014 fire on shrubs (n=15; appr. 43% of live shrubs observed at this site)], data collected from the RD 1004 Remnant Riparian site is problematic and discussed separately.

## 3.1 Afton 2 Restoration Site: 2018 versus 2016

### Characteristics of surveyed elderberry shrubs and VELB exit holes

A total of 302 elderberry shrubs were sampled within the Afton 2 Restoration Site during the 2018 monitoring. All shrubs observed were located within restoration planting rows and appeared to be planted.

- Following previous pattern of survivorship within the Afton 2 Restoration Site, only 1 (less than 0.2 percent; n=1) of elderberry shrubs randomly sampled were dead;
- All living elderberry shrubs (n=301) surveyed within the Afton 2 Restoration Site had at least one live stem $\geq$ 2.5 cm in diameter;
- VELB exit holes were documented in 150 live planted elderberry shrubs [49.8 percent of the living elderberry shrubs sampled (n=301)];
- A total of 374 VELB exit holes were observed on live stems. Number of VELB exit holes per occupied shrub ranged from 1 to 11 (mean=2.5; s.d. = 1.9).
- Height above ground for VELB exit holes ranged from 7 to 228 cm (mean = 69.8 cm; s.d. = 48.3)
- Diameter of stems with VELB exit holes ranged from 2.5 to 20 cm (mean = 48.3 cm; s.d. = 7.2)
- Similar to previous field observations, the majority of VELB exit holes exhibited healing to a greater or lesser degree, likely due to ongoing vigorous growth of shrubs within the planting. 119 exit holes exhibited relatively clean margins, 118 exit holes exhibited healing, but were still open, and 137 exit holes were closed at the time of the survey. Similar to previous surveys, the bark on healed and healing holes typically retained the distinctive clean-margined 0.4-1.0 cm diameter hole characteristic of VELB and scar in the healed wood underneath.
- Approximately 2,000 elderberry shrubs were planted in 2009. Cumulative survivorship of elderberry shrubs since initial planting was approximately 80% in 2016 (total live shrubs in 2016 = 1,600). Less than 0.2% of sampled shrubs were dead during the 2018 survey. These observations were comparably to shrub mortality (less than 0.4%) documented during the

2016 census and overall stabilization of shrub mortality following restoration planting and cessation of irrigation. The majority of documented shrub mortality occurred by 2012, with documented survivorship during the 2010 census. As a result of replanting efforts between 2010-2012, total number of "live shrubs" increased and then subsequently declined back toward cumulative 80% survivorship.

- The percent of elderberry shrubs with VELB exit holes sampled during 2018 surveys increased to 49.8% from 29.8% of shrubs observed during the 2016 census.

- Clustering of shrubs with VELB exit holes appears less apparent, but distribution of sampled shrubs with VELB exit holes generally reflects that observed during 2016 census. A comparative map of live elderberry shrubs with VELB exit holes observed during 2018 sample survey and previous post-restoration census surveys (Hunt 2012; Hunt and Kirk 2014, and Hunt and Kirk 2016) is provided in Figure 3.

### Shrub height

Mean live shrub height was 4.3 meters (s.d. = 0.9), with a range of 1.7–8.0 meters. 99.7 percent of shrubs (n=301) were at least 2 meters in height. Since the 2010 monitoring, there was an increase of 2.3 meters (approximately 210 percent) of the mean height of live shrubs.

Height of live shrubs with VELB exit holes ranged from 3.0–7.5 meters (mean = 4.6 meters; s.d. = 0.9).

### Maximum basal stem diameter and summary of live stems > 2.5 cm diameter

Mean maximum basal stem diameter of live shrubs was 17.3 centimeters (s.d. = 7.0) with a range of 2.0 cm – 47.0 cm. In 2016, mean maximum basal stem diameter for all live shrubs was 12.6 centimeters (s.d. = 4.3).

Maximum basal stem diameter of shrubs with VELB exit holes ranged from 5.0–47.0 cm (mean = 19.3 cm; s.d. = 7.1). In 2016, mean maximum basal stem diameter for all live shrubs with exit holes was 13.6 centimeters (s.d. = 4.4).

Similar to the 2016 survey, all live shrubs had at least one live stem ≥ 2.5 cm in diameter [per shrub range of stems ≥ 2.5 cm diameter = 1-36; per shrub mean of live stems ≥ 2.5 cm diameter = 8.1 (s.d. =5.5)]. There was an approximately 15% overall reduction in the mean number of live stems ≥ 2.5cm in diameter for all live shrubs sampled.

For shrubs with VELB exit holes, the range of live stems ≥ 2.5 cm diameter was 1-33 stems (mean = 11.6; s.d. = 6.4). There was an approximately 20% overall reduction in the mean number of live stems ≥ 2.5cm in diameter for all shrubs with VELB exit holes sampled.

A comparative summary of selected attributes for data collected during the 2018 and 2016 Afton 2 Restoration Site surveys is provided in Table 2.

**Table 2. Comparison of selected attributes for blue elderberry (*Sambucus nigra* ssp. *caerulea*) shrubs surveyed for signs of occupancy by valley elderberry longhorn beetles (*Desmocerus californicus* ssp. *dimorphus*) (VELB) during the 2016 and 2018 Afton 2 Unit Restoration Site surveys.**

| Attribute | 2018 | | | 2016 | | | Net Change | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | n= | Mean | S.D. | n= | Mean | S.D. | n= |
| Height (m) Live Shrubs | 4.3 | 0.9 | 301 | 4.2 | 0.9 | 1592 | 0.2 | 0.0 | -1291 |
| Height (m) Shrubs with Exit Holes | 4.6 | 0.9 | 150 | 4.3 | 0.9 | 475 | 0.3 | 0.0 | -325 |
| Max. Basal Diam. (cm) Live Shrubs | 17.3 | 7.0 | 301 | 12.6 | 4.3 | 1592 | 4.7 | 2.7 | -1291 |
| Max. Basal Diam. (cm) Shrubs with Exit Holes | 19.3 | 7.1 | 150 | 13.6 | 4.4 | 475 | 5.7 | 2.7 | -325 |
| # Live Stems > 2.5 cm Live Shrubs | 8.1 | 5.5 | 301 | 9.6 | 6.0 | 1592 | -1.5 | -0.5 | -1291 |
| # Live Stems > 2.5 cm Shrubs with Exit Holes | 9.2 | 5.4 | 150 | 11.6 | 6.4 | 475 | -2.4 | -1.0 | -325 |
| Mean # Exit Holes/Occupied shrub | 2.5 | 1.9 | 150 | 2.0 | 1.9 | 475 | 0.5 | 0.0 | -325 |
| Exit Hole Height (cm) | 69.8 | 48.3 | 374 | 58.8 | 42.0 | 959 | 11.0 | 6.3 | -585 |
| Exit Hole Stem Diam. (cm) | 7.2 | 2.8 | 374 | 6.7 | 2.7 | 959 | 0.5 | 0.1 | -585 |

## 3.2 Restoration Site versus Remnant Riparian Sites

### Characteristics of surveyed elderberry shrubs and VELB exit holes

Morphological data was collected from 502 live elderberry shrubs across all sampling sites. Eleven "live" shrubs in remnant riparian sites were excluded from analysis due to dense stands of poison oak and blackberry precluding physical access and corresponding collection of morphological data.

### RD 1004 Remnant Riparian Site: Impacts of 2014 Fire on Data

The RD 1004 Remnant Riparian site presented two notable sampling problems: physical access and the 2014 fire that burned the easterly portion of RD 1004 Remnant Riparian site. The majority of data collected from live shrubs observed at this site was incomplete or suspect due to accessibility issues (appr. 23%; n=8) or effects of the 2014 fire on shrub morphology (appr. 43%; n=15). As a result, this data was excluded from comparative analysis (i.e., "Restoration versus Remnant Riparian) and is discussed separately here. Following are summary comments regarding data collected within RD 1004 and the 2014 fire:

- Though all of the observable shrubs within the RD 1004 Remnant Riparian Site were surveyed, relatively few live shrubs (n=35) were observed across the entirety of this sampling site. Approximately 43% (n=15) of these shrubs were located within the footprint of the fire and demonstrated morphology affected by fire (e.g., younger "leggy" plants with smaller maximum basal diameters).

- Previous stands of mature elderberry, including locations with VELB exit holes documented by Gilbart (Gilbart 2008) have been burned. Regrowth of elderberry shrubs in this area are evidenced by the presence of stands of smaller shrubs. It was not determined whether these area new plants, regrowth from burned plants, or a combination of both;

- Morphological data collected from shrubs (e.g., maximum basal diameter and number of live stems ≥ 2.5 cm in diameter) may be skewed by regrowth within the burn zone;

- Similar to some morphological data, VELB exit hole data is also likely skewed by the fire, due to loss of previously documented habitat (i.e., mature elderberry shrubs). Observed occupancy at RD 1004 was relatively low (<7%) as compared with the Afton 2 Restoration (49.8%) and Remnant Riparian (20.6%) sites; however, due to the paucity of data for occupied shrubs at this site (n=2), these results may not be truly representative of conditions at this site;

- Shrub height data does not appear to be skewed by shrubs within the fire, possibly because vertical growth of even small-diameter elderberry shrubs appears to be rapid in suitable conditions.

### Afton 2 Restoration versus Afton 1 Remnant Riparian

Following is a summary comparison between data collected at the Afton 2 Restoration and Afton 1 Remnant Riparian sites. As discussed above, data collected at the RD 1004 Remnant Riparian site was excluded from this summary comparison due to substantial impacts of the 2104 fire on the relatively small sample size (Figure 2).

- All living elderberry shrubs surveyed within both Afton 2 Restoration and Afton 1 Remnant Riparian sites had at least one live stem ≥ 2.5 cm in diameter;

- At the Afton 2 Restoration Site, VELB exit holes were documented in shrubs at more than two times the rate ([49.8% of living elderberry shrubs sampled (n=301)] of the Afton 1 Remnant Riparian Site [(20.8% of living elderberry shrubs sampled (n=174)].

- Similar to VELB occupancy rates (number of live shrubs with exit holes), the mean number of exit holes per occupied shrub within the Afton 2 Restoration Site (mean=2.5; s.d. = 1.9; n=150) was more than 1.5 times the mean number of exit holes per occupied shrub within the Afton 1 Remnant Riparian Site (mean=1.6; s.d. = 0.9; n=36).

- At the Afton 2 Restoration Site, average height above ground for VELB exit holes [ranged from 7 to 228 cm (average = 69.8 cm; s.d. = 48.3)] was less than two-thirds (59.1%) the average height above ground for VELB exit holes at Afton 1 Remnant Riparian site [ranged from 38 to 290 cm (average = 118.2 cm; s.d. = 55.6)].

- There was no notable difference in total number of live stems ≥ 2.5 cm between the Afton 2 Restoration Site (average = 8.1 cm; s.d. = 5.5) and the Afton 1 Remnant Riparian (average 7.1; s.d. = 8.6). Similarly, there was no notable difference in total number of stems ≥ 2.5 cm for shrubs with VELB exit holes between the Afton 2 Restoration Site (average = 9.2 cm; s.d. = 5.4) and the Afton 1 Remnant Riparian (average 10.0; s.d.= 12.8).

### Shrub height

There was no notable difference in height of all live shrubs between the Afton 2 Restoration Site (average = 4.3 m; s.d. = 0.9) and the Afton 1 Remnant Riparian (average 4.6 m; s.d. = 1.1). Similarly, there was no notable difference in height of live shrubs with VELB exit holes between the Afton 2

Restoration Site (average = 4.6 m; s.d. = 1.9) and the Afton 1 Remnant Riparian (average 5.0 m; s.d. = 0.9).

### Maximum basal stem diameter and summary of live stems > 2.5 cm diameter

There was no notable difference in maximum basal stem diameter of all live shrubs between the Afton 2 Restoration Site (average = 17.3 cm; s.d. = 7.0) and the Afton 1 Remnant Riparian (average 17.2 cm; s.d. = 7.5). Similarly, there was no notable difference maximum basal stem diameter of live shrubs with VELB exit holes between the Afton 2 Restoration Site (average = 19.3 cm; s.d. = 7.1) and the Afton 1 Remnant Riparian (average 19.8 cm; s.d. = 7.7). Mean maximum basal diameter was greater for VELB occupied shrubs than all live shrubs (occupied and unoccupied) at both Afton 2 Restoration Site and Afton 1 Remnant Riparian Site.

There was no notable difference in number of live stems ≥ 2.5 cm for all live shrubs between the Afton 2 Restoration Site (average = 8.1 cm; s.d. = 5.5) and the Afton 1 Remnant Riparian (average 7.1; s.d. = 8.6). Similarly, there was no notable difference in number of live stems ≥ 2.5 cm for live shrubs with VELB exit holes between the Afton 2 Restoration Site (average = 9.2 cm; s.d. = 5.4) and the Afton 1 Remnant Riparian (average 10.0; s.d.= 12.8). Similar to maximum basal diameter, average number of live stems ≥ 2.5 cm was greater for VELB occupied shrubs than all live shrubs (occupied and unoccupied) at both Afton 2 Restoration Site and Afton 1 Remnant Riparian Site

A summary of selected attributes for data collected across all sampling sites (Afton 2 Restoration Site, Afton 1 Remnant Riparian Site, and RD 1004 Remnant Riparian Site) during the 2018 surveys is provide in Table 3.

**Table 3. Summary of Selected Attributes for Data Collected Across All Sites Sampled During 2018 Afton VELB Surveys**

| Attribute | Afton 2 Restoration | | | [1]Afton 1 Remnant Riparian | | | [1,2]RD 1004 Remnant Riparian | | | All 2018 Sampling Sites | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | n= | Mean | S.D. | n= | Mean | S.D. | n= | Mean | S.D. | n= |
| Height (m) Live Shrubs | 4.3 | 0.9 | 301 | 4.6 | 1.1 | 174 | 4.2 | 2.1 | 27 | 4.4 | 1.1 | 502 |
| Height (m) Shrubs with Exit Holes | 4.6 | 1.9 | 150 | 5.0 | 0.9 | 36 | 7.1 | 1.5 | 2 | 4.7 | 1.0 | 188 |
| Max. Basal Diam. (cm) Live Shrubs | 17.3 | 7.0 | 301 | 17.2 | 7.5 | 174 | 13.1 | 12.4 | 27 | 17.1 | 7.6 | 502 |
| Max. Basal Diam. (cm) Shrubs with Exit Holes | 19.3 | 7.1 | 150 | 19.8 | 7.7 | 36 | 28.5 | 6.4 | 2 | 19.5 | 7.2 | 188 |
| # Stems >= 2.5 cm Live Shrubs | 8.1 | 5.5 | 301 | 7.1 | 8.6 | 174 | 6.4 | 9.2 | 27 | 7.7 | 6.9 | 502 |
| # Stems >= 2.5 cm Shrubs with Exit Holes | 9.2 | 5.4 | 150 | 10.0 | 12.8 | 36 | 4.0 | 4.2 | 2 | 9.3 | 7.4 | 188 |
| Mean # Exit Holes/Occupied shrub | 2.5 | 1.9 | 150 | 1.6 | 0.9 | 36 | 1.5 | 0.7 | 2 | 2.3 | 1.8 | 188 |
| Exit Hole Height (cm) | 69.8 | 48.3 | 374 | 118.2 | 55.6 | 56 | 235.0 | 75.0 | 3 | 77.2 | 53.6 | 433 |
| Exit Hole Stem Diam. (cm) | 7.2 | 2.8 | 374 | 8.9 | 4.5 | 56 | 7.2 | 2.5 | 3 | 7.5 | 3.1 | 433 |

***[1]A total of 11"Live" shrubs in remnant riparian sites were excluded from analysis. Three (3) shrubs within the Afton 1 Remnant Riparian and 8 shrubs within RD 1004 Remnant Riparian site were excluded due to dense stands of poison oak and blackberry precluding physical access and data collection. An additional 15 shrubs at the RD 1004 Remnant Riparian site were burned by a fire in 2014 (Figure 2) and are discussed further in summary analyses.***

# Section 4. Discussion

## 4.1 Afton 2 Restoration Site: 2018 versus 2016

Approximately 2,000 elderberry shrubs were planted at the Afton 2 Restoration site in 2009. Based on monitoring data collected during in 2016 and 2018, cumulative survivorship of planted elderberry was approximately 80 percent. As observed during previous surveys, overall vigor of live elderberry shrubs is excellent. Vertical growth appears to have stabilized as mean shrub height (both live and occupied) is comparable to 2016 observations. Comparable to data collected in 2016, the site exhibits a 208 percent increase in mean shrub height since 2010 monitoring.

Mean maximum basal diameter continues to increase across the site for all live shrubs and live shrubs with exit holes, reflecting overall growth of approximately 37% and 42%, respectively, since 2016. Since the 2010 monitoring, this was an increase of 13.5 cm (more than 400 percent) in mean maximum basal stem diameter and the largest basal diameter was 47.0 cm, as compared to 17 cm in 2010.

Overall reduction in mean number live stems ≥ 2.5 cm in diameter since 2016 may reflect a shift in morphology of planted shrubs from highly branched toward fewer larger branches as the shrubs mature. Anecdotally, a large number of shrubs within the Afton 2 Restoration site harbored a large number of dead branches within 1 meter of the ground. Additionally, natural recruitment (either through seeding or suckering) was not readily apparent within the Afton 2 Restoration site, which might further limit recruitment of live stems ≥ 2.5 cm in diameter within 1-meter of the ground. Anecdotally, elderberry suckering and recruitment may be more evident in areas recently cleared of vegetation and/or exposed soils, such as burns, newly constructed berms, and staging areas. SNWR Wildlife Refuge Manager Joe Silveira noted similar observations regarding elderberry recruitment on sediment deposits in higher landscape positions away from scour and flooding that favors cottonwood and willows (Joe Silveira pers. comm.). Natural recruitment was documented within the Afton 2 Restoration site during fall 2010 surveys [approximately 1.5% (n=23) of shrubs surveyed] following initial restoration (Hunt 2010), but was not observed in subsequent surveys. This may be due to the success of both woody and herbaceous restoration efforts and resultant dense native vegetation.

It was noted that by 2016, in contrast with previous years, other native woody species, [e.g., coyote bush (*Baccharis pilularis*), Goodding's black willow (*Salix gooddingii*), arroyo willow (*S. lasiolepis)*, planted at the restoration site became increasingly dense between elderberry shrubs. During 2018 surveys, woody species, particularly coyote bush had become so dense as to make simply walking between planted elderberry shrubs extremely difficult over large portions of the site. Additionally, Himalayan blackberry (*Rubus armeniacus*) has begun to colonize pockets of the restoration site. Planted native perennial grasses, especially creeping wild rye (*Elymus triticoides*), have successfully established across much of the site, which may affect recruitment of elderberry seedlings.

Similar to the 2012, 2014, and 2016 surveys, no discernible "natural recruitment" between rows was observed during this survey (planted shrubs often evidenced by in-row position and remnants of milk-carton plant protectors and/or flagging). As discussed in previous reports, recruitment may have occurred within the planting rows, but may have not been discernible due to maturing structure of the restoration site. Indications of natural recruitment between rows may have declined because of native grass planting at the site. Similar to 2016, growth characteristics related to past irrigation practices (e.g., many small and lanky stems) was less pronounced. A large portion of the shrubs continue to exhibit extensive colonization of lichens on trunks and stems, likely reflecting high mean atmospheric moisture at the Afton 2 Restoration site.

The percent of elderberry shrubs with VELB exit holes sampled during 2018 surveys increased to 49.8% from 29.8% of shrubs observed during the 2016 survey. Clustering of shrubs with VELB exit holes was less apparent, but distribution of sampled shrubs with VELB exit holes generally reflects that observed during 2016 and surveys. A comparative map of live elderberry shrubs with VELB exit holes observed during 2018 sampling and previous post-restoration surveys (Hunt 2012; Hunt and Kirk 2014, and Hunt and Kirk 2016) is provided in Figure 3.

## 4.2 Restoration Site versus Remnant Riparian Sites

Differences in both VELB occupancy rates and the mean number of exit holes per occupied shrub between the Afton 2 Restoration and Afton 1 Remnant Riparian site might be attributed to a number of characteristics of the restoration site, including the:

- Large number and density of elderberry shrubs planted within the site;

- Relative openness across the site and between shrubs (“habitat permeability”) during the first 6 years of restoration maintenance, and;

- Rapid growth rate of shrubs across the site (particularly during irrigation years).

Similar to observations during the 2012, 2014, and 2016 surveys, few of VELB exit holes exhibited clear signs of freshly exposed wood (i.e., light colored wood) or frass. As in previous surveys, lack of freshly exposed wood and frass may be associated with the timing of the surveys (late fall). Classification of hole age was often difficult to determine, as weathering, damage, discoloration, and fungal colonization of exit holes in the relative soft wood of elderberry stems appeared to occur rapidly; however, a number of exit holes were judged to have clean margins, while the majority was determined to be clearly older than 2 years. As in previous years, even the oldest holes commonly retained the distinctive clean-margined 0.5-1.0 cm diameter hole characteristic of VELB holes.

The lower mean height above ground for VELB exit holes within the Afton 2 Restoration site, as compared to the Afton 1 Remnant Riparian site, generally reflects a larger number of VELB exit holes detected toward the base of occupied shrubs in the restoration site. The difference in vertical distribution of holes between sites may reflect higher initial occupancy at this height in newly planted elderberry shrubs or a greater proportion of healed and undetectable exit hole scars on generally older shrubs within the remnant riparian.

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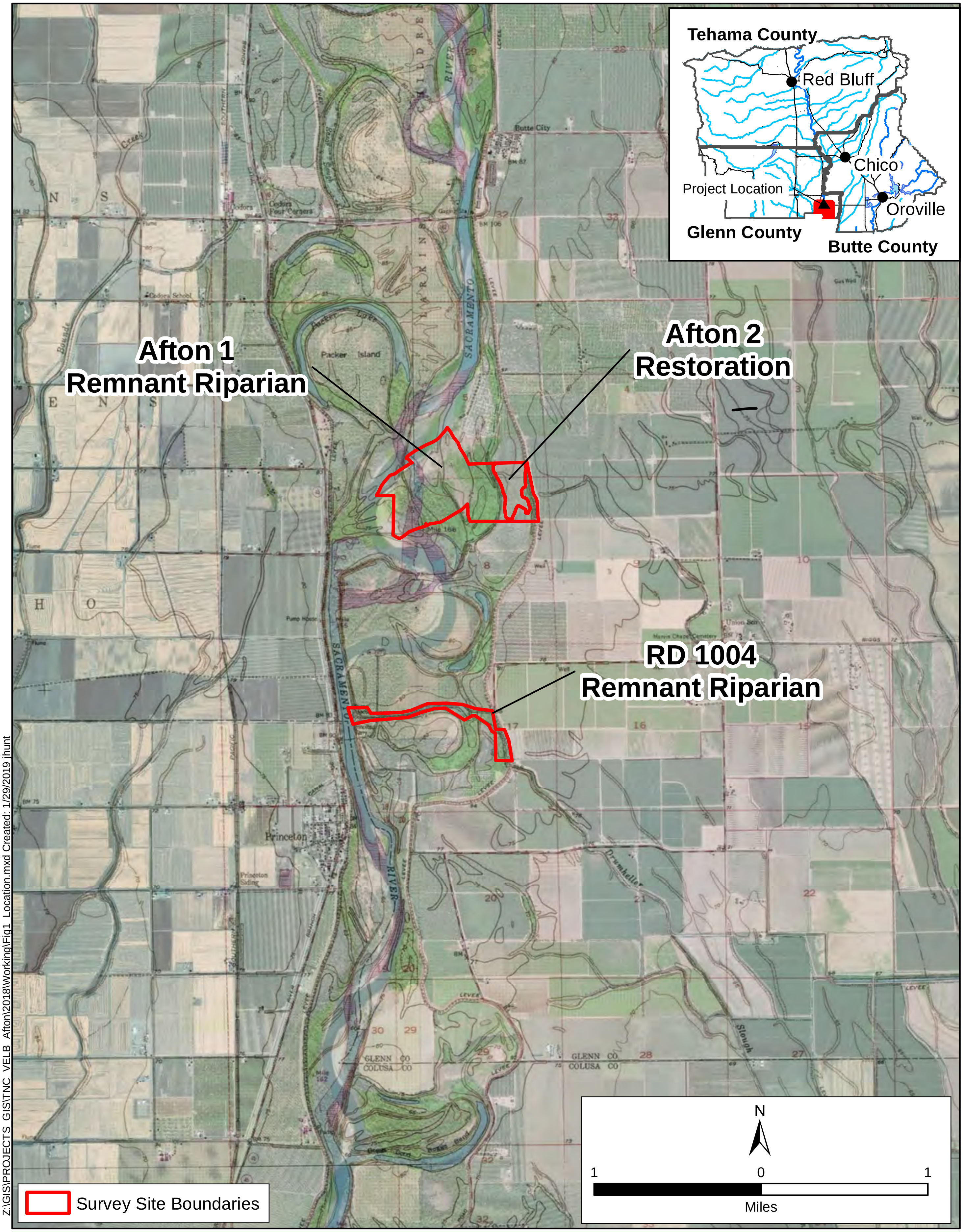


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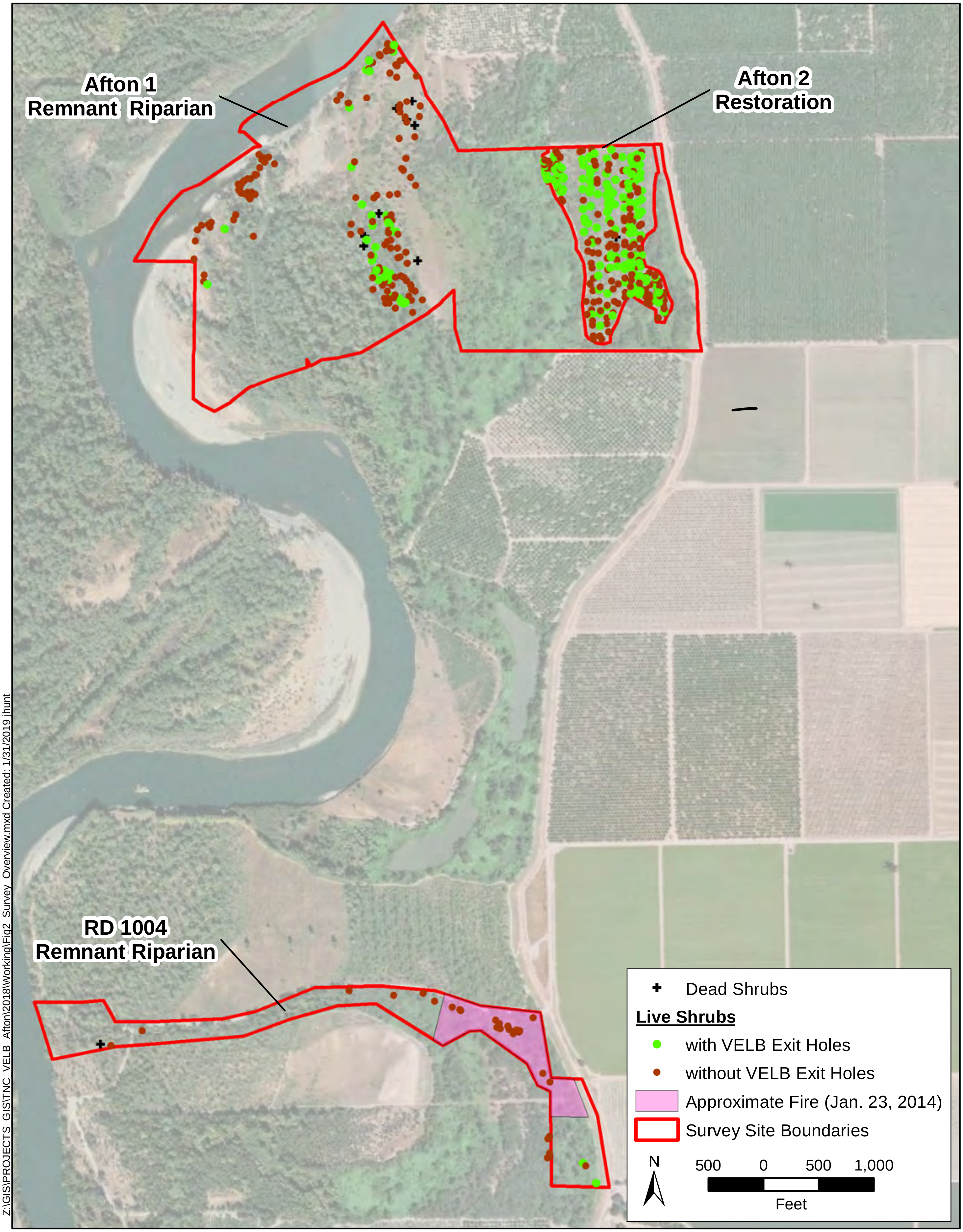
NORTHERN CALIFORNIA
REGIONAL LAND TRUST

*TNC VELB Survey, Glenn County, California*

**Figure 1. Project Location and Vicinity Map**

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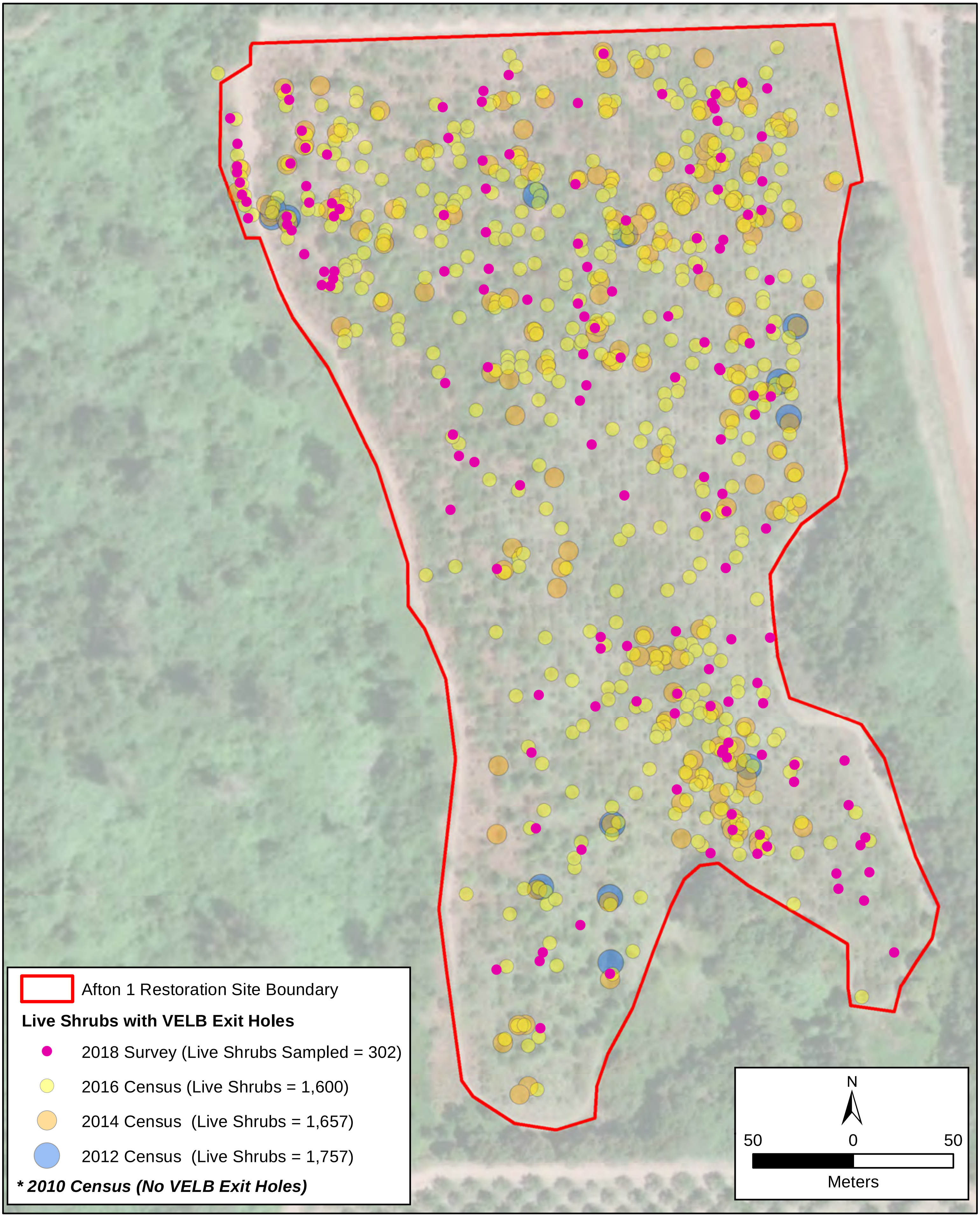
NORTHERN CALIFORNIA REGIONAL LAND TRUST

*TNC VELB Survey, Glenn County, California*

**Figure 2. Field Survey Overview**

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*Afton Unit 2 Restoration Site VELB Survey, Glenn County, California*

**Figure 3. Comparative Map of VELB Exit Holes**

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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# Wildlife Response to Riparian Restoration on the Sacramento River

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## ABSTRACT

Studies that assess the success of riparian restoration projects seldom focus on wildlife. More generally, vegetation characteristics are studied, with the assumption that animal populations will recover once adequate habitats are established. On the Sacramento River, millions of dollars have been spent on habitat restoration, yet few studies of wildlife response have been published. Here we present the major findings of a suite of studies that assessed responses of four taxonomic groups (insects, birds, bats, and rodents). Study designs fell primarily into two broad categories: comparisons of restoration sites of different ages, and comparisons of restoration sites with agricultural and remnant riparian sites.

Older restoration sites showed increased abundances of many species of landbirds and bats relative to younger sites, and the same trend was observed for the Valley elderberry longhorn beetle *(Desmocerus californicus dimorphus)*, a federally threatened species. Species richness of landbirds and ground-dwelling beetles appeared to increase as restoration sites matured. Young restoration sites provided benefits to species that utilize early successional riparian habitats, and after about 10 years, the sites appeared to provide many of the complex structural habitat elements that are characteristic of remnant forest patches. Eleven-year old sites were occupied by both cavity-nesting birds and special-status crevice-roosting bats. Restored sites also supported a wide diversity of bee species, and had richness similar to remnant sites. Remnant sites had species compositions of beetles and rodents more similar to older sites than to younger sites.

Because study durations were short for all but landbirds, results should be viewed as preliminary. Nonetheless, in aggregate, they provide convincing evidence that restoration along the Sacramento River has been successful in restoring riparian habitats for a broad suite of faunal species. Not only did the restoration projects provide benefits for special-status species, but they also appeared effective in restoring the larger native riparian community. Increases in bird abundance through time were observed both at restoration sites and in remnant habitats, suggesting that restoration efforts may be having positive spillover effects, although observed increases may have been caused by other factors.

Although positive overall, these studies yielded some disconcerting results. The Lazuli Bunting *(Passerina amoena)* declined at restoration sites and remnant habitats alike, and certain exotic invasive species, such as black rats, appeared to increase as restoration sites matured.

## KEYWORDS

Bat, bee, beetle, bird, floodplain, insect, monitoring, restoration, riparian, rodent, Sacramento River, Valley elderberry longhorn beetle.

## SUGGESTED CITATION

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## INTRODUCTION

In recent decades, large-scale ecological restoration projects have become increasingly common (Holl et al. 2003). Yet following implementation, most projects have little or no monitoring associated with them (National Research Council [NRC] 1992; Bernhardt et al. 2005) despite widespread recognition of its importance (Society for Ecological Restoration [SER] 2004; Ruiz-Jaen and Aide 2005). There is typically little documentation of the effectiveness of restoration activities, and little is learned about whether and when target wildlife species respond (Block et al. 2001). When monitoring does take place, quantifiable success criteria are rarely defined. Opportunities to improve restoration practices are thus being lost. Reviews of restoration projects demonstrate that outcomes are highly variable (Kondolf and Micheli 1995), and much could be gained by identifying the factors that determine whether or not project goals are met (Gibbs et al. 1999). Such an understanding is critical, not only for making restoration projects more successful and cost-effective, but also for maintaining public and political support for their continued implementation.

On the Sacramento River, millions of dollars have been invested in floodplain restoration with the goal of revitalizing riparian habitats for native species. Yet there has been minimal published documentation of effectiveness beyond limited information on vegetation response. The vegetation studies examined factors affecting the performance of planted species in the first years following planting (Hujik and Griggs 1995a, 1995b; Griggs and Peterson 1997; Alpert et al. 1999), and over the longer term (Griggs and Golet 2002). Additionally, Holl and Crone (2004) characterized factors that influence the natural recruitment of native understory plant species at restoration sites. It has been assumed that target fauna will recover if suitable habitats are restored, yet this assumption has not been adequately tested on the Sacramento River, or elsewhere (Hilderbrand et al. 2005).

There are surprisingly few peer-reviewed studies on wildlife response to riparian restoration. Rarer still are articles that synthesize studies of restoration response across multiple taxa. Only one published manuscript—on landbirds (Gardali et al. 2006)—and two published notes—on bees (Williams 2007), and rodents (Golet et al. 2007)—have directly measured wildlife response at Sacramento River riparian restoration sites, despite the restoration of thousands of hectares of floodplain habitat since 1989 (see below). Many other studies have been conducted, and reports have been produced, yet prior to this paper, they had not been synthesized and made widely accessible.

Here we present the major findings from studies of four taxonomic groups: insects (Hunt 2004; River Partners 2004; Williams 2007), birds (Gardali et al. 2004; Gardali et al. 2006; Gardali and Nur 2006), bats (Stillwater Sciences et al. 2003), and rodents (Golet et al. 2007; Koenig et al. 2007). For all taxa studied, we both draw information from the above-listed publications and reports, and present new results. In introducing the studies, we discuss the value of the different taxa as indicators of restoration success. Then, we present the results of the individual studies, and offer an initial assessment of how well Sacramento River restoration sites are meeting the habitat needs of the river's native riparian taxa. Recognizing that our assessment needs to be made more rigorous and comprehensive, we close this article with a discussion of future monitoring needs.

## Background of Sacramento River Restoration

The Sacramento River is an important river in California from both an environmental and an economic perspective, but it is severely degraded relative to its historical condition. Prior to European settlement, the river was lined by approximately 324,000 hectares of riparian habitat; however, over 95% of this habitat has been lost to logging, agriculture, urban development, and flood control and power-generation projects (Katibah 1984). The loss and degradation of riparian habitat has diminished the river's ability to support viable wildlife populations, and encouraged the invasion and proliferation of non-native species. At-risk special-status terrestrial taxa in the region include diverse species of birds (e.g., western yellow-billed cuckoo *[Coccyzus americanus occidentalis]*, Swainson's hawk *[Buteo swainsoni]*, and bank swallow *[Riparia riparia]*); mammals (e.g., western mastiff bat *[Eumops perotis]*, Yuma myotis *[Myotis yumanensis]*); and insects (e.g., valley elderberry longhorn beetle *[Desmocerus californicus dimorphus]*) (CALFED 2000a).

In 1986, state and federal agencies and non-government organizations began to implement management programs aimed at improving the health of the river. Senate Bill 1086 was passed by the California legislature, and called for the formation of the Upper Sacramento River Fisheries and Riparian Habitat Council. In 1987, by the authority provided under the Fish and Wildlife Act of 1956, the Endangered Species Act of 1973, and the Emergency Wetlands Resources Act of 1986, the U.S. Congress authorized the establishment of the U.S. Fish and Wildlife Service (USFWS) Sacramento River National Wildlife Refuge (the Refuge). In 1989, the Refuge was established. Its goal is to provide up to 7,284 hectares of habitat for endangered and threatened species, migratory birds, and anadromous fishes (USFWS 2005). As of 2007, the Refuge consisted of 3,837 hectares of riparian and agricultural habitats, owned in fee title, and distributed among 26 individual units. An additional 518 hectares is held by the Refuge as a ranch easement. The other major aggregation of conservation land along the middle river is the California Department of Fish and Game (CDFG) Sacramento River Wildlife Area, which, in 2007, consisted of 1,658 hectares distributed among 13 units.

The Nature Conservancy (TNC), a non-profit environmental organization, launched the Sacramento River Project (the Project) in 1988. Key Project partners include the USFWS, the U.S. Army Corps of Engineers, the CDFG, the California Department of Water Resources, the California Department of Parks and Recreation, the California Wildlife Conservation Board, River Partners, and the Sacramento River Conservation Area Forum. The main goal of the Project is to develop and implement a "single blueprint" for ecosystem restoration and management on the main stem of the Sacramento River, so that different efforts along the river work collaboratively in support of a unified conservation vision.

The Project has focused on restoration along the meandering reach of the Sacramento River, between the towns of Red Bluff and Colusa (~161 river km, Figure 1), because degradation in this reach is largely reversible. Farms (as opposed to cities) have replaced floodplain forests, and levees, where present, are often set back from the river by appreciable distances. In some areas, bank revetment (riprap) is absent, and the natural processes of bank erosion and point bar deposition are still intact (Buer et al. 1989; Singer and Dunne 2001). All of the USFWS Refuge

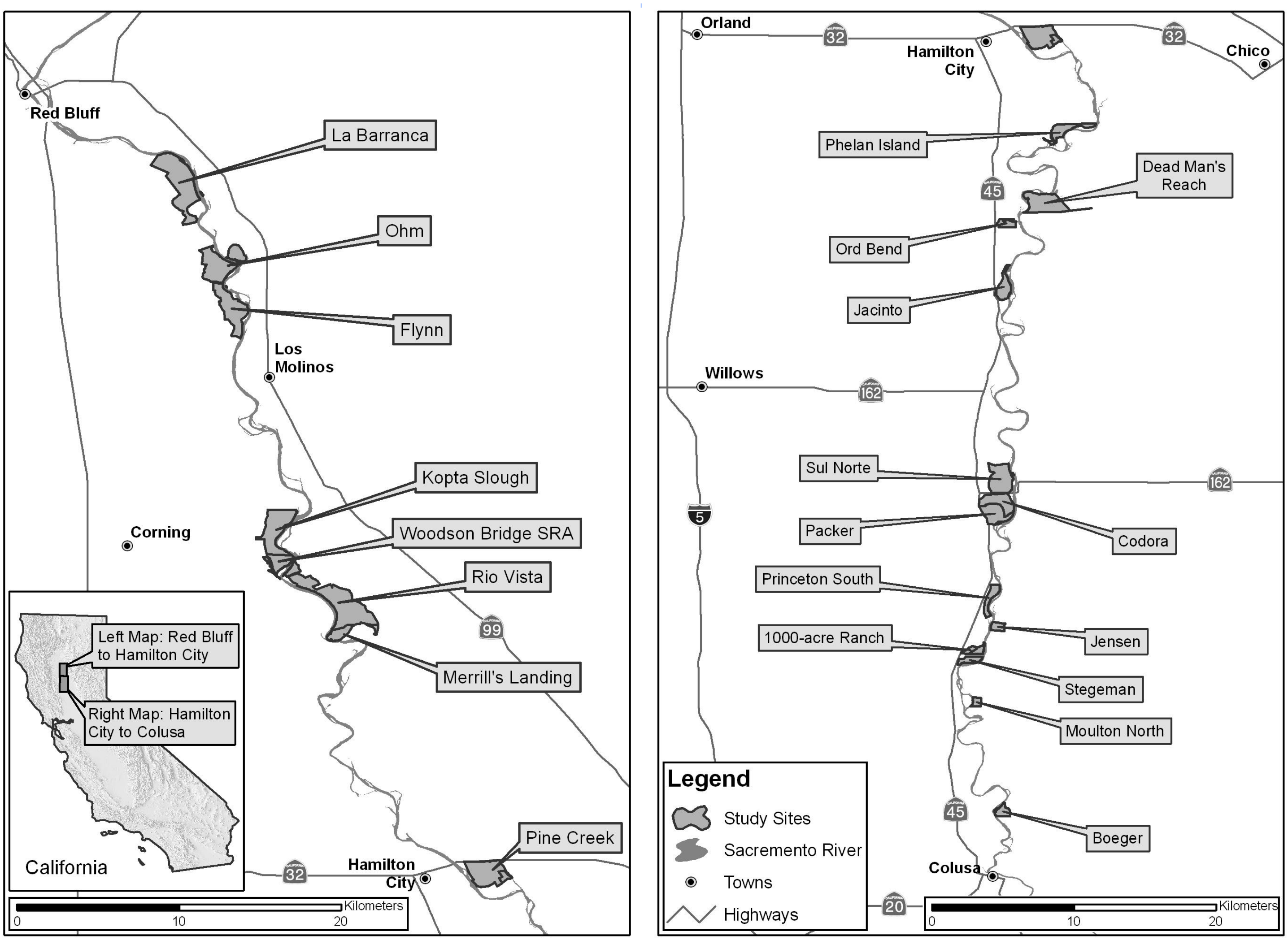


**Figure 1.** Locations of study sites within the 161-river km Sacramento River Project area, California. The left map shows the northern half of the Project area and the right map depicts the southern half.

and the CDFG Sacramento River Wildlife Area are contained within the Red Bluff to Colusa stretch.

The Project's strategies for restoring the Sacramento River include:

1. Conserving flood-prone lands, giving priority to those that contain and/or border remnant riparian habitats (Project partners have acquired ~5,424 ha in fee title since 1988; Figure 2A)
2. Increasing habitat connectivity and patch size by revegetating land with native species (Project partners have planted ~2,337 ha with >1 million trees since 1989; Figure 2B)
3. Restoring natural river processes (e.g., flooding, meander migration, sediment transport) on conservation lands while simultaneously promoting flood damage reduction for agricultural properties and important human infrastructure (e.g., roads and bridges).

## OVERVIEW OF STUDY METHODS

### Study Sites and Sampling Periods

In total, 21 field sampling locations spanned the length of the Project area (Figure 1). All of the restoration sites were previously in agriculture, most commonly as walnut or almond orchards, before being revegetated with local ecotypes of indigenous trees, shrubs, and understory species. For information on revegetation methods and approaches see Griggs and Peterson (1997) and Alpert et al. (1999). Restoration sites are located in low-lying floodplain areas embedded in a landscape matrix of natural remnant habitats, fallow land, and agriculture (see Figure 1 in Holl and Crone 2004); none are in close proximity to urban areas or dense residential settlements. Agriculture consists primarily of orchard, row, and field crops, although a few areas are managed as irrigated pasture for livestock.

Years of study varied, but were between 1993 and 2005 (Table 1). Field sampling for all but the landbird study took place in 1 year or less. Consequently, results from individual studies should be viewed as preliminary; however, the collective weight of evidence they present is considerable.

### Study Designs and Performance Metrics

Several study designs were used. Some studies simply compared restoration sites of different ages (Figure 3) to determine if older sites provide more benefits to wildlife than younger sites. Others compared wildlife use patterns at restoration sites with those at older remnant riparian forests that were never used for agriculture. Some studies also drew comparisons with agricultural sites. Comparisons among different site types (agriculture, restoration, and remnant) are informative because they enable us to determine if wildlife use patterns at restoration sites are more similar to patterns observed at remnant forest sites than at agricultural sites. If so, then this is one measure of restoration success. It should be understood, however, that from an ecological standpoint, conditions in remnant forests are not ideal. All remnant sites are subjected to a highly altered flow regime, and are

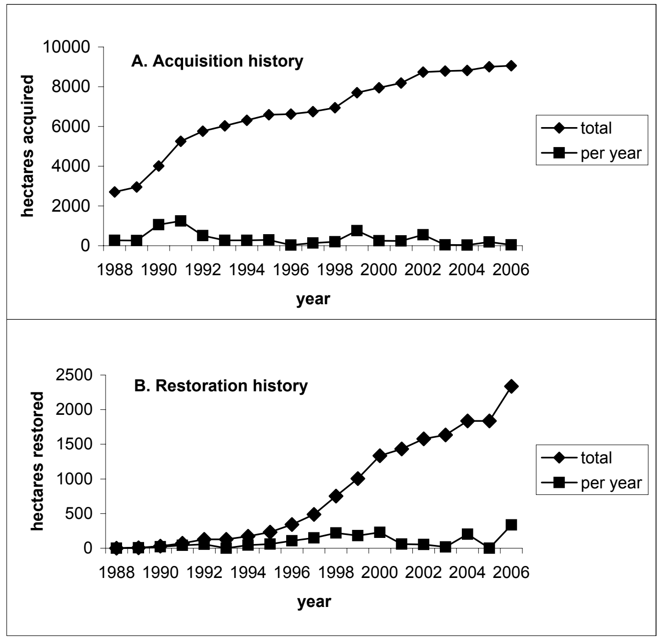


**Figure 2.** Amount of land A) acquired for riparian habitat conservation; and B) planted with native riparian species within the Sacramento River Project area, California.

degraded to varying degrees with invasive species. Most are also highly fragmented.

Various performance metrics were used to assess restoration success in the different studies. Included were assessments of species richness, abundance, percent occupancy, community composition, adult survival, and reproductive success.

## CASE STUDIES

### Insects

Insects have tremendous taxonomic and functional diversity, and play essential roles in ecosystems as pollinators, predators, prey, herbivores, and scavengers. Hence, they are useful focal species for studies that seek to characterize the degree to which ecosystem function is restored in restoration projects (Wilson 1987; Williams 1993). However, in a review of 68 restoration case studies, only 32% measured some component of arthropod diversity (Ruiz-Jaen and Aide 2005). Restoration monitoring programs often exclude insects for several reasons: they are small, innocuous, and generally viewed as non-char-

**Table 1.** Landcover types and taxa studied at each of the field sampling locations for the studies profiled in this paper. Some sites had multiple landcover types present. Many of the restoration sites were composed of sets of fields that were planted over a series of years. The locations of these sites along the Sacramento River are depicted in Figure 1. Sites are listed according to their locations on the river, from north to south.

| Site Name | Landcover Types Sampled (years planted) | Taxa Studied (years sampled) |
|---|---|---|
| La Barranca[a] | Walnut orchard | Bats (2002), birds (1993–2001) |
| | Restoration site (1997–2003) | Bees (2003) |
| | Remnant riparian | Bees (2003), birds (1993–2001) |
| Ohm[a] | Walnut orchard | Birds (1993–2001) |
| | Remnant riparian | Birds (1993–2001) |
| Flynn[a] | Restoration site (1996-2000) | Bees (2003), birds (1998–2003), VELB[d] (2003) |
| | Remnant riparian | Bees (2003), birds (1998–2003) |
| Kopta Slough[b] | Restoration site (1989-1992) | Beetles (2000–2001), birds (1996–2003), rodents (2005) |
| Woodson Bridge SRA | Remnant riparian | Bats (2002), bees (2003), birds (1996–2003), rodents (2005) |
| Rio Vista[a] | Restoration site (1993-2000) | Bees (2003), beetles (2000–2001), birds (1993–2003), VELB (2003) |
| Merrill's Landing[c] | Remnant riparian | Beetles (2000–2001), rodents (2005) |
| Pine Creek[a, c] | Restoration site (1997-1999) | Bees (2003), beetles (2000–2001) |
| | Remnant riparian | Bees (2003), beetles (2000–2001) |
| Phelan Island[a, e] | Restoration site (1991-2002) | Bats (2002), bees (2003), beetles (2000–2001), birds (1994–2003), rodents (2005), VELB (2003) |
| | Remnant riparian | Bats (2002), bees (2003), beetles (2000–2001), birds (1994–2003), rodents (2005) |
| Dead Man's Reach[a] | Walnut orchard | Bats (2002) |
| Ord Bend[a] | Restoration site (1999) | VELB (2003) |
| Jacinto[c] | Restoration site (2001) | Rodents (2005) |
| Sul Norte[a] | Remnant riparian | Birds (1994–2003) |
| Codora[a] | Walnut orchard | Birds (1994–2001) |
| | Restoration site (2000) | Birds (1998–2001) |
| | Remnant riparian | Birds (1994–2001) |
| Packer[a] | Restoration site (2000) | VELB (2003) |
| Princeton South[c] | Restoration site (2001) | Rodents (2005) |
| Jensen[b] | Walnut orchard | Rodents (2005) |
| 1000-acre Ranch[b] | Prune orchard | Rodents (2005) |
| Stegeman[c] | Remnant riparian | Rodents (2005) |
| Moulton North[c] | Restoration site (2002) | Rodents (2005) |
| Boeger[b] | Field crop | Rodents (2005) |

*a Units of the USFWS Sacramento River National Wildlife Refuge Complex*
*b Parcels currently managed (Kopta Slough) or owned (all others) by The Nature Conservancy*
*c Units of the Department of Fish and Game Sacramento River Wildlife Area*
*d Valley elderberry longhorn beetle*
*e Parcel owned by the Sacramento and San Joaquin Drainage District*

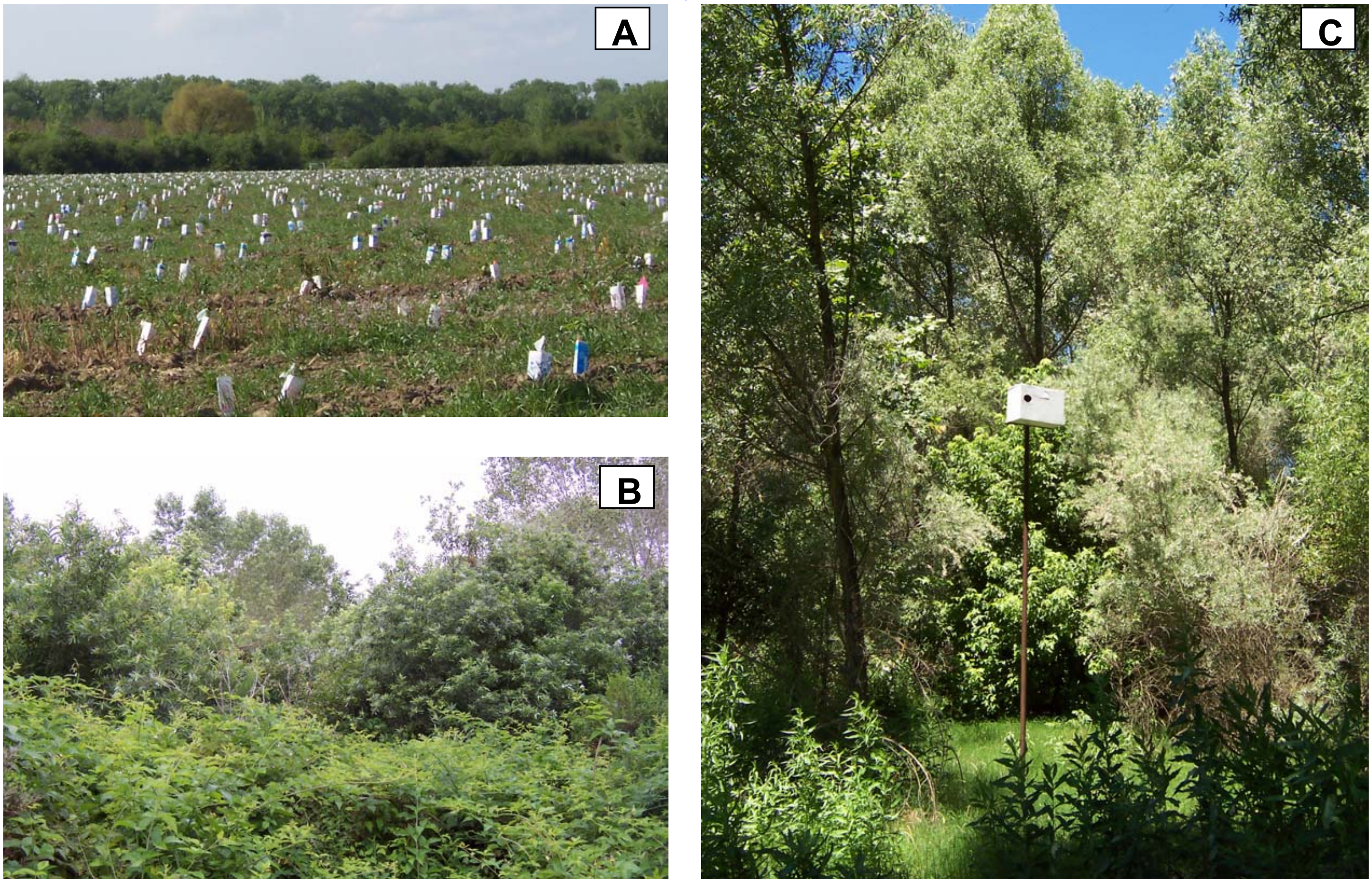


**Figure 3.** Sacramento River riparian restoration sites of varying ages: (A) New mixed riparian forest at USFWS Hartley Island Unit planted by The Nature Conservancy (TNC). Milk cartons are used to protect young plants from herbicides (applied for 3 years to control weeds) and summer sun (photo taken April 2005); (B) Six-year old restoration site at the DFG Beehive Bend Unit, planted by River Partners (photo taken June 2006); and (C) Fifteen-year old restoration site at DWR Phelan Island River Unit, planted by TNC, with barn owl nest box (photo taken June 2006). Photos by G. Golet.

ismatic; the functional roles that individual species play in ecosystem processes are often not well understood; and the sheer diversity of taxa may be overwhelming to the researcher (Williams 2000).

On the Sacramento River, three investigations of terrestrial insect responses to restoration have focused on individual taxa or specific insect orders. These include studies of the federally threatened Valley elderberry longhorn beetle (VELB), ground-dwelling beetles, and bees.

### *Valley Elderberry Longhorn Beetle*

The VELB is a federally threatened endemic species of California's Central Valley that occupies blue elderberry *(Sambucus mexicana)* shrubs during all stages of its life cycle (Barr 1991). We monitored VELB abundance in 2003 to determine the extent to which restoration sites were providing habitat for this species (River Partners 2004).

Surveys were conducted in 24 fields of varying ages (2–10 years post planting, mean 4.8 yrs) at five restoration sites spanning 106 kilometers along the Sacramento River (Table 1, Figure 1). Approximately

10% (7,600) of the elderberry bushes that were planted at these sites were examined for VELB exit holes, which are distinctive and diagnostic of VELB presence (Lang et al. 1989; Barr 1991). VELB pupae inhabit the pith of elderberry branches where they feed and undergo metamorphosis before emerging as adults. Survey starting points were randomly chosen. Surveyors searched for exit holes in elderberry shrubs with stems greater than 1 inch in diameter. When exit holes were found, the status of the elderberry bush was characterized, and distance to the ground, stem width, and hole dimensions were measured.

A total of 449 exit holes were observed in 299 planted elderberry shrubs (4% of those surveyed, River Partners 2004). Older restoration sites had significantly higher levels of VELB occupancy ($F_{1,\ 17}$ = 10.0, $P$ = 0.006, Figure 4), suggesting that VELB colonize and proliferate at restoration sites as the plant community matures. There was no site effect on colonization rate ($F_{4,\ 17}$ = 0.36, $P$ = 0.83), and sites with high rates of colonization did not tend to have more remnant riparian habitat surrounding them than sites with low colonization rates ($F_{1,\ 17}$ = 1.3, $P$ = 0.26). Nor did colonizations within the sites appear to be more frequent at bushes closer to a remnant habitat edge. Collectively, these results suggest that proximity to remnant habitat was not an influencing factor,

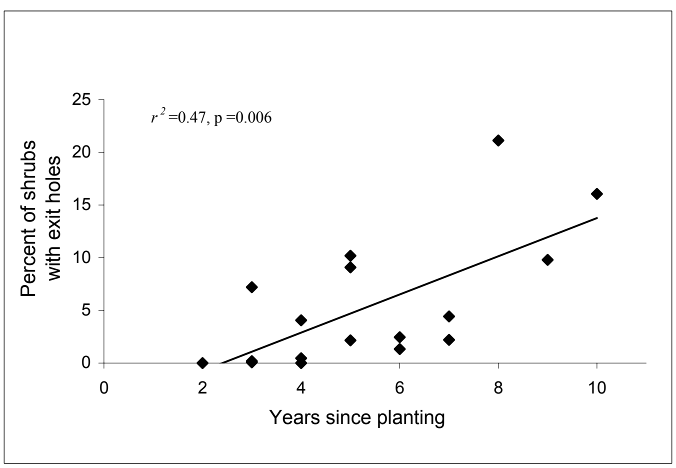


**Figure 4.** Percent of elderberry shrubs with exit holes diagnostic of Valley elderberry longhorn beetle emergence. All shrubs surveyed were within the Sacramento River Project area, California.

and that VELB did not face dispersal distance limitations when colonizing Sacramento River restoration sites. However, on other Central Valley rivers, habitat connectivity has been shown to influence VELB distribution (Talley 2007). The difference in study results may be due to the Sacramento River having relatively more or better-distributed VELB habitat than the other rivers, or it may simply be a function of our study having insufficient statistical power or inadequate design to test for such an effect.

### *Ground-Dwelling Beetles*

In another study conducted to address insect response to restoration, ground-dwelling, surface-active beetle assemblages (Order: *Coleoptera*) were compared among restoration sites of different ages and remnant riparian habitats (Hunt 2004). In contrast to the VELB study, which was conducted to ascertain whether or not restoration efforts were successful in promoting the recovery of a single special-status species, this investigation was initiated to more broadly assess ecosystem response by characterizing the distribution and abundance patterns of a diverse taxonomic group.

Sampling was conducted from December 2000 through November 2001 with pitfall traps at three young riparian restoration sites (1–3 years old), three older riparian restoration sites (6–10 years old), and three remnant riparian forests (>25 years old) along a 31-km stretch of the Sacramento River (Table 1). At each site, 12 traps were placed 15 meters apart in a 3 × 4 grid. Traps were left open for collections for 7 consecutive days each month. Following collection, beetles were identified to the lowest taxonomic level practicable, and then classified as morphospecies (Sensu Oliver and Beattie 1996a; 1996b).

In total, 24,626 individual beetles were collected, representing 188 distinct morphospecies. Mean monthly species richness differed significantly among habitat types ($F_{2,\ 6}$ = 17.9, $P$ = 0.003, Figure 5), with remnant riparian habitats having significantly higher species diversity than either young or older restoration sites (Bonferroni pairwise comparisons probabilities 0.003 and 0.019, respectively). In addition, a Bray-Curtis cluster analysis demonstrated that different habitat

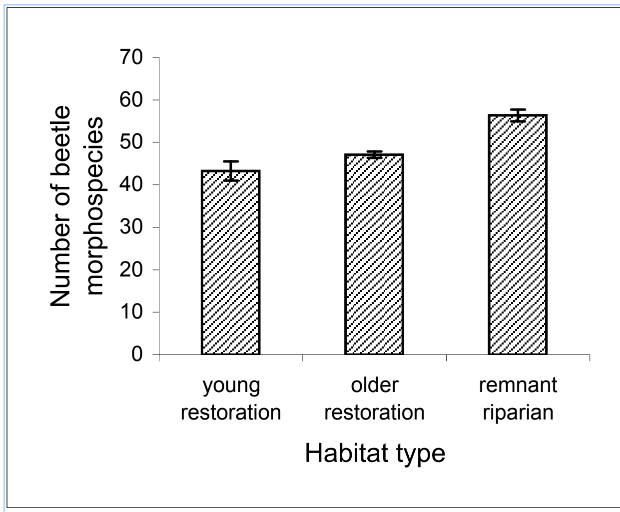


**Figure 5.** Ground-dwelling beetle species richness (mean ± SE) at young restoration sites, older restoration sites, and remnant habitats within the Sacramento River Project area, California.

types contain characteristic groupings (Figure 6). Coleoptera species assemblages appear to transition predictably as a function of forest age such that older restoration sites were more similar to remnant riparian sites than were young restoration sites. Young restoration sites showed greater differences in composition through time than did older restoration sites and remnant riparian forest habitats, and a significant response to forest type was observed among 37 morphospecies (Hunt 2004).

## *Bees*

Bee (Order: *Hymenoptera*) species richness was compared within 1-ha plots at five 8-year-old restoration sites and five remnant riparian forest/scrub habitats geographically paired along 72 river kilometers (Table 1 in Williams 2007). Paired sites were separated by 0.5–3.8 km. Plots were surveyed every 6 weeks from late February through August, 2003 (five sampling periods). At each site, bees were netted at flowering plants and captured in 30 water-filled pan traps spaced regularly along two crossed 100-m transects (see http://online.sfsu.edu/~beeplot/ for details on trapping methods). Abundance of all plant species within the plots was measured with quadrat sampling.

Results suggest that restored sites are providing habitat for a wide diversity of bee species (Williams 2007). Bees of a variety of life-histories were captured: 5% social to some degree, 73% solitary/gregarious, and 13% cleptoparasitic. Mean species richness pooled from netting and pan traps was not statistically different between restored (mean = 39, SE = 6.5) and remnant (mean = 42, SE = 1.6) sites ($t = 0.335$, $df = 4$, $P = 0.78$). Interestingly, the 8-year-old restoration sites contained many different bee species than what were identified at remnant habitats (Sorensen index mean ± SE similarity between paired sites = 0.45 ± 0.022). Bee communities sampled with netting at restored and remnant sites cluster separately, based on non-metric multi-dimensional scaling (Figure 7A), such that only about half of the bee species among paired sites overlapped. Such differences highlight the importance of a mosaic landscape composed of habitat in different successional stages for promoting species diversity. One cause of dissimilarity between bees from restored and remnant sites may be differences in flowering plant communities at these two site types (mean similarity 0.32 ± 0.043, Sorensen index; Figure 7B). However, paired sites with greater similarity of plants did not have more bee species in common with one another (Williams 2007), suggest-

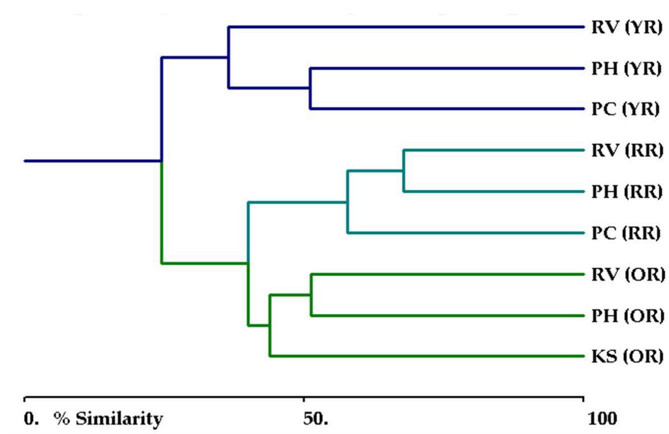


**Figure 6.** Cluster analysis (Group Average Link) of Bray-Curtis values for year-end totals of Coleopteran sample assemblages collected within the Sacramento River Project area, California. Forest types are defined as: YR = Young restoration; OR = Old restoration; RR = Remnant riparian forest. Site locations are as follows: KS = Kopta Slough; RV = Rio Vista; PC = Pine Creek; PH = Phelan Island (reprinted from Hunt [2004] with permission).

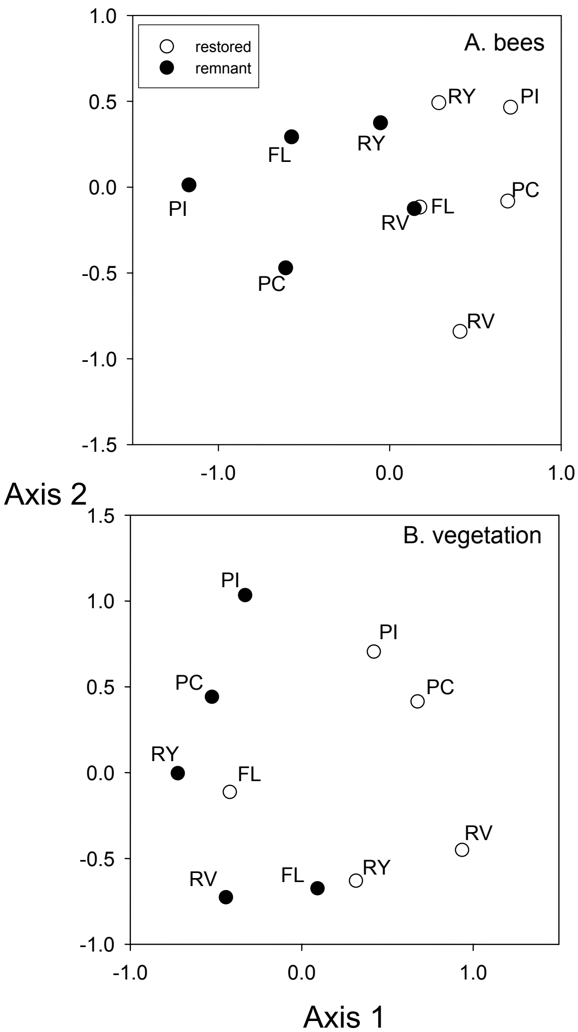


**Figure 7.** Non-metric Multidimensional Scaling (NMDS) plots of bee and vegetation communities at restoration and remnant sites within the Sacramento River Project area, California. Values based on season-long totals using Sorensen-Bray-Curtis dissimilarity values. Sites are FL = Flynn, PI = Phelan Island, PC = Pine Creek, RV = Rio Vista, LA = La Barranca.

ing that other factors also influence the distribution of bees among Sacramento River habitat types.

## Birds

Birds are valuable indicators of ecological integrity (Carignan and Villard 2002). Their communities are often diverse, yet individuals can easily be detected and readily distinguished to species level. Because they have fairly specific habitat requirements, high levels of energy expenditure, and are high on the food chain, they provide useful information about ecosystem function (Sekercioglu 2006). Bird data may be widely comparable due to standardized field (Ralph et al. 1993) and analysis methods (Nur et al. 1999). Also, with many birds it is possible to directly assess vital rates (e.g., fecundity, survival), so factors driving population dynamics may be determined. For all these reasons, birds can be useful indicators of restoration success. Yet, identifying the underlying causes for patterns observed in bird data is not always easy. Birds—especially migratory birds—respond to the environment at multiple spatial and temporal scales (Temple and Wiens 1989), and thus may be strongly influenced by factors outside of any one study area.

The Sacramento River Project area hosts many special-status bird species (Table 2) and is used by many species during all seasons of the year, providing important habitat for breeding, dispersal, migration, and over-wintering (Gaines 1977). Indeed, riparian areas are considered to be the most critical habitats for landbirds in all of California (Manley and Davidson 1993; DeSante and George 1994).

### *Landbirds*

In 1993, PRBO Conservation Science (PRBO) initiated systematic studies of landbirds (passerines and near-passerines) in the Sacramento River Project area. Since then, landbird monitoring has been ongoing, at various levels of intensity, in both restored and remnant riparian habitats (Table 1). Monitoring efforts have focused most consistently on estimating bird abundance and community composition by conducting point counts (Ralph et al. 1993), and relating these parameters to site-specific habitat characteristics (Nur et al. 2004).

To conduct point counts, we established a series of survey stations approximately 200 meters apart (Ralph et al. 1993). Point count stations were surveyed three times during the breeding season from 1993 through 2001, and twice in 2002 and 2003. The duration of each count was 5 minutes, and all birds seen or heard were recorded. We used only those birds noted within 50 meters of the observer, and assumed that detection probabilities were similar within this distance among habitat types and years. Counts began at dawn and continued up to 4 hours past sunrise (see Gardali et al. [2004]; Gardali et al. [2006]; and Gardali and Nur [2006] for additional study details).

To characterize vegetation at each point count station, we used a modified version of the relevé method (Ralph et al. 1993). In brief, vegetation was assessed using a relevé, a plot with a 50-meter radius (0.785 ha) centered on the point count location. Several characteristics of the plots were recorded including maximum tree dbh (diameter breast height), presence of water, and the cover and height of each vegetation stratum. Within each vegetation stratum, species composition was determined, as was species richness and percent cover for trees and shrubs.

Additional monitoring was conducted to estimate reproductive success and adult survival for a subset of species with sufficient sample sizes (Small and Gardali 2004; Gardali and Nur 2006). Nest monitoring allows measures of nest success at specific sites and in specific habitat, and provides information on population health of landbirds (Nur et al. 1999). Nest finding and monitoring followed Breeding Biology Research and Monitoring Database (BBIRD) protocol (Martin et al. 1997) and guidelines outlined in Martin and Geupel (1993). All nests found were checked at least once every 4 days to determine outcome (fledge or fail) and, when appropriate, cause of failure. To minimize human disturbance, visits to nests were brief. Researchers caused very little disturbance to vegetation in the nest area, and did not check nests when predators were detected nearby.

We provide reproductive success estimates by calculating daily nest survival rates using the Mayfield method (Mayfield 1975; Johnson 1979). This method incorporates the number of days that each observed nest remained active (from the find-date) to calculate the daily survival probability. The daily survival probability is raised to the power of the total number of days in the nesting period (laying, incubation, and nestling phases), which differs by species, to obtain the overall nest survival estimate for the entire nest period.

To estimate adult survival rates, we sampled Black-headed Grosbeaks and Spotted Towhees with standardized-effort mist-netting (Monitoring Avian Productivity and Survivorship protocol; DeSante et al. 2000). One 12-meter, 36-millimeter-mesh mist-net was operated at each of 10 net sites for 5 morning hours per day, for 1 day during each of 10 consecutive 10-day periods. Starting dates were in early May, and operation continued through the 10-day period, ending in early August. Nets were opened 45 minutes before sunrise, and kept open for 5 hours. Captured birds were banded with standard USFWS bands, measured, and released immediately.

Results indicate that restoration sites are providing habitat for a diverse community of landbirds. Species richness increased as the sites matured ($\beta = 0.86$, SE = 0.084, 95% CI = 0.69–1.02, adjusted $r^2 = 0.55$, $P < 0.0001$; Figure 8), and the abundance of many species, with diverse life-history requirements, has dramatically increased as the sites have aged (Figure 9; Gardali et al. 2006). An exception is the Lazuli Bunting *(Passerina amoena)*, which has been declining at both restoration sites and in remnant habitats (Gardali et al. 2006). The increase in species richness at restoration sites is apparently due to certain species (e.g., House Wren *[Troglodytes aedon]*) being absent until the structural complexity of the sites increase beyond some threshold amount. Nur et al. (2004) found that the abundance

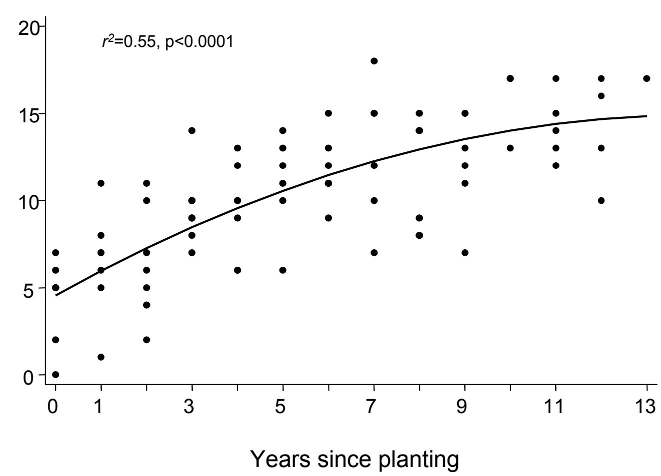


**Figure 8.** Landbird species richness at restoration sites of varying ages within the Sacramento River Project area, California.

**Table 2.** Special-status wildlife and fish species of the Sacramento River Project area, California and their observed patterns of use on restoration sites. Several of the less common and/or more cryptic species have not yet been observed; however, their occurrence is likely based upon established habitat requirements and home ranges. Restoration actions were designed to benefit these and other more common species. Definitions of the acronyms used in this table appear at the end of the table on the following page.

| SPECIES | STATUS | | | DOCUMENTED USES ON RESTORATION SITES |
|---|---|---|---|---|
| | NGO[a] | STATE | FEDERAL | |
| **BIRDS** | | | | |
| American white pelican *(Pelecanus erythrorhynchos)* | – | SSC (1) | – | Foraging in adjacent waterbodies |
| Double–crested cormorant *(Phalacrocorax auritus)* | – | SSC (2) | – | Foraging in adjacent waterbodies |
| Great egret *(Ardea alba)* | – | CDFS | – | Foraging |
| Great blue heron *(Ardea herodias)* | – | CDFS | – | Foraging |
| Snowy egret *(Egretta thula)* | USBCWL | – | – | Foraging |
| Cooper's hawk *(Accipiter cooperii)* | – | SSC (2) | – | Nesting |
| Sharp–shinned hawk *(Accipiter striatus)* | – | SSC (3) | – | Yes |
| Bald eagle *(Haliaeetus leucocephalus)* | – | SE, CDFS, SFP | FT | Nesting, foraging in adjacent waterbodies |
| Golden eagle *(Aquila chrysaetos)* | – | SSC (3), CDFS, SFP | PR, BLMS | Yes |
| Osprey *(Pandion haliaetus)* | – | SSC (2), CDFS | – | Nesting, foraging in adjacent waterbodies |
| Northern harrier *(Circus cyaneus)* | – | SSC (2) | – | Nesting, foraging |
| Swainson's hawk *(Buteo swainsoni)* | USBCWL, AW | ST | FSC, FWSBCC | Foraging |
| White–tailed kite *(Elanus leucurus)* | – | SFP FSC | – | Foraging |
| Peregrine falcon *(Falco peregrinus)* | – | SFP, CDFS | FWSBCC | Yes |
| Merlin *(Falco columbarius)* | – | SSC (1) | – | Yes |
| Caspian tern *(Sterna caspia)* | – | – | FWSBCC | Foraging in adjacent waterbodies |
| Western yellow–billed cuckoo *(Coccyzus americanus occidentalis)* | – | SE FSC, FSS, | FC, FWSBCC | Nesting, foraging |
| Short–eared owl *(Asio flammeus)* | USBCWL, AW | SSC (2) | – | Foraging |
| Long–eared owl *(Asio otus)* | – | SSC (2) | – | Not yet observed |
| Rufous hummingbird *(Selasphorus rufus)* | USBCWL, AW | – | FSC, FWSBCC | Yes |
| Allen's hummingbird *(Selasphorus sasin)* | USBCWL, AW | – | FSC | Not yet observed |
| Nutall's woodpecker *(Picoides nuttallii)* | USBCWL, AW | – | – | Nesting, foraging |
| Olive–sided flycatcher *(Contopus cooperi)* | USBCWL, AW | SSC | FSC, FWSBCC | Foraging |
| Willow flycatcher *(Empidonax traillii)* | USBCWL, AW | SE | FSC, FSS | Foraging |
| Loggerhead shrike *(Lanius ludovicianus)* | – | SSC | FSC, FWSBCC | Foraging |
| Bank swallow *(Riparia riparia)* | – | ST | FSC | Nesting, foraging |
| Yellow warbler *(Dendroica petechia)* | – | SSC (2) | – | Foraging |
| Yellow–breasted chat *(Icteria virens)* | – | SSC (2) | – | Nesting, foraging |

*a Non-governmental organization*
*b Status proposed*
*c Species occurrence documented from museum (historical) record only*

**Table 2.** (continued)

| SPECIES | STATUS | | | DOCUMENTED USES ON RESTORATION SITES |
|---|---|---|---|---|
| | NGO[a] | STATE | FEDERAL | |
| **MAMMALS** | | | | |
| Townsend's big–eared bat[c] *(Corynorhinus townsendii)* | WBWGHP | SSC | FSC, FSS, BLMS | Not yet observed |
| Western mastiff bat *(Eumops perotis)* | WBWGHP | SSC | FSC, BLMS | Foraging |
| Pallid bat *(Antrozous pallidus)* | WBWGHP | SSC | FSS, BLMS | Foraging |
| Western red bat *(Lasiurus blossevillii)* | WBWGHP | SSC[b] | FSS | Roosting, foraging |
| Small–footed myotis[c] *(Myotis ciliolabrum)* | – | – | FSC, BLMS | Not yet observed |
| Long–eared myotis[c] *(Myotis evotis)* | – | – | FSC, BLMS | Not yet observed |
| Fringed myotis[c] *(Myotis thysanodes)* | WBWGHP | SSC[b] | FSC, BLMS | Not yet observed |
| Long–legged myotis[c] *(Myotis volans)* | WBWGHP | SSC[b] | FSC | Not yet observed |
| Yuma myotis *(Myotis yumanensis)* | – | – | FSC, BLMS | Foraging |
| Ringtail *(Bassariscus astutus)* | – | SFP | – | Yes |
| **REPTILES** | | | | |
| Northwestern pond turtle *(Clemmys marmorata marmorata)* | – | SSC (2) | FSC, FSS | Breeding, foraging in adjacent waterbodies |
| **FISHES** | | | | |
| Chinook salmon *(Oncorhynchus tshawytscha)* Central Valley Spring–run | – | ST | FT, FSS | Migrating through adjacent waterbodies |
| Chinook salmon *(Oncorhynchus tshawytscha)* Sac. River Winter–run | – | SE | FE | Migrating through adjacent waterbodies |
| Chinook salmon *(Oncorhynchus tshawytscha)* Central Valley Fall /late Fall–run | – | SSC (2) | FSC, FC, FSS | Migrating through adjacent waterbodies |
| Central Valley steelhead *(Oncorhynchus mykiss)* | – | – | FT | Migrating through adjacent waterbodies |
| Green sturgeon *(Acipenser medirostris)* – Southern District Population | AFSE | SSC (1) | FT | Migrating through adjacent waterbodies |
| Hardhead *(Mylopharodon conocephalus)* | – | SSC (3) | FSS | Occupying adjacent waterbodies |
| River lamprey *(Lampetra ayersi)* | – | SSC (3) | FSC | Migrating through adjacent waterbodies |
| Sacramento splittail *(Pogonichthys macrolepidotus)* | – | SSC (1) | FSC | Migrating through adjacent waterbodies |
| **INVERTEBRATES** | | | | |
| Valley elderberry longhorn beetle *(Desmocerus californicus dimorphus)* | – | – | FT | Breeding, foraging |

STATUS CODE DEFINITIONS

*NGO[a]:*
*AFSE American Fisheries Society Endangered http://www.fisheries.org*
*AW Audubon Watch List http://www.audubon.org/bird/watchlist/index.html.*
*USBCWL United States Bird Conservation Watch List http://www.abcbirds.org/watchlist/index.htm.*
*WBWGHP Western Bat Working Group High Priority http://www.wbwg.org.*

*STATE:*
*CDFS California Department of Forestry Sensitive http://www.fire.ca.gov/ResourceManagement/pdf/FPA200301.pdf*
*SE State Endangered*
*SFP State Fully Protected http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=fgc.*
*SSC State Species of Special Concern, numbers in parentheses refer to ranking (1 = highest) http://www.dfg.ca.gov/hcpb/species/ssc/ssc.shtml.*
*ST State Threatened*

*FEDERAL:*
*BLMS Bureau of Land Management Sensitive http://www.or.blm.gov/Resources/special-status_species/CAIB99-86.htm.*
*FC Federal Candidate (for FE or FT status)*
*FE Federally listed, Endangered*
*FSC Federal Species of Concern http://sacramento.fws.gov/es/spp_lists/animal_sp_concern.cfm*
*FSS Forest Service Sensitive http://www.fs.fed.us/r5/projects/sensitive-species/*
*FT Federally listed, Threatened*
*FWSBCC Fish and Wildlife Service Birds of Conservation Concern http://migratorybirds.fws.gov/reports/bcc2002.pdf.*
*PR Protected under Golden Eagle Protection Act*

of several species (e.g., Ash-throated Flycatcher *[Myiarchus cinerascens]*, Tree Swallow *[Tachycineta bicolor]*) was positively associated with tree height and/or canopy cover, factors that typically increase as restoration sites mature. At about 10 years, restoration sites begin to be occupied by primary cavity-nesting species (e.g., Nuttall's Woodpecker *[Picoides nuttallii]*). Comparisons between restored and remnant forests showed that the abundances of many bird species in older restoration sites approached values observed in remnant habitats. Interestingly, abundances of many species studied were also increasing at remnant forest sites—although usually at a slower rate (Gardali et al. 2006). These results suggest that restoration efforts may be producing positive spill-over effects for bird populations in the larger Sacramento Valley, although other factors (e.g., climate, conditions in wintering areas, etc.) may also be responsible.

With the bird studies, we are fortunate to have additional measures of restoration success besides species richness and abundance. These measures were developed for two species which were sufficiently common to allow sufficient sample sizes of nests to be monitored, and adults to be captured: the Black-headed Grosbeak *(Pheucticus melanocephalus)*, a neotropical migrant; and the Spotted Towhee (*Pipilo maculatus*), a year-round resident.

The Black-headed Grosbeak had survival rates at a restoration site that were slightly lower than what was observed at two remnant sites, and considerably higher than a third grazed remnant site (Figure 10; Gardali and Nur 2006). For the Spotted Towhee, results were less encouraging. Adult annual survival for this species was lower at the restoration site than at two remnant sites, and nearly identical to the grazed remnant site (Figure 10). Reasons for the different survival response of these species remain to be determined; however, it is plausible that the lack of a well-developed native understory layer at the restora-

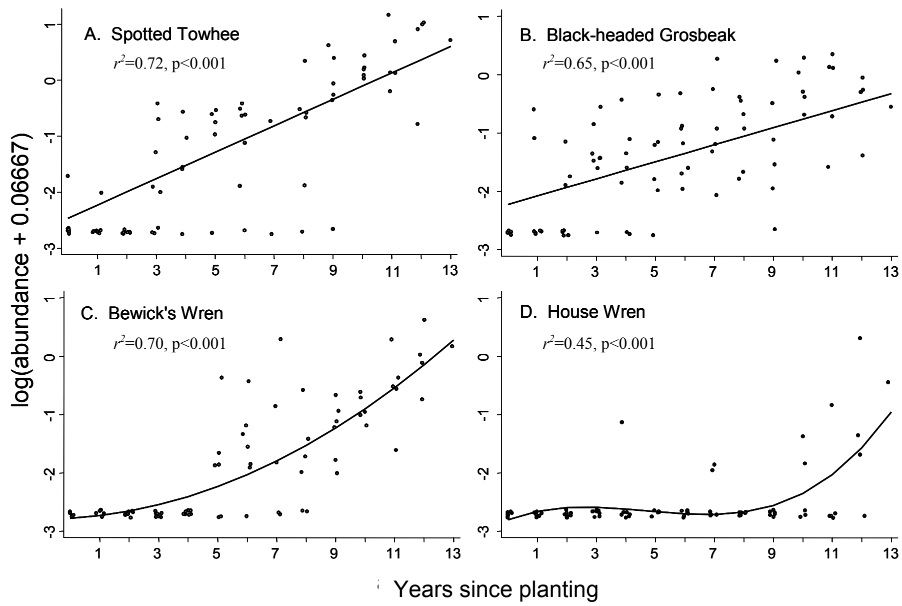


**Figure 9.** Abundance (point count detections) of four landbirds in relation to years since planting at restoration sites within the Sacramento River Project area, California. Lines show values predicted from log-linear regression; quadratic fit for Bewick's Wren and cubic fit for House Wren. Each point represents datum from 1 year for each site (reprinted from Gardali et al. [2006] with permission).

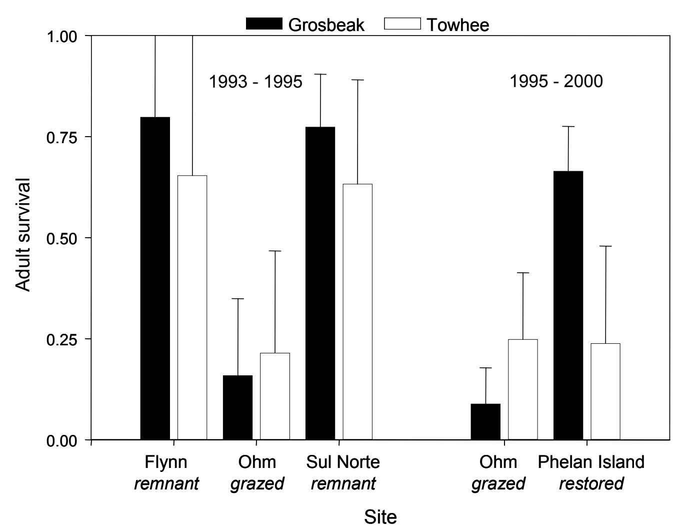


**Figure 10.** Site-specific adult survival of Black-headed Grosbeaks and Spotted Towhees at four sites within the Sacramento River Project area, California. Site types are indicated on the x-axis below the site names (reprinted from Gardali and Nur [2006] with permission).

tion site affected the understory-nesting towhee more than the mid-canopy-breeding grosbeak.

Reproductive success of Black-headed Grosbeaks, as measured by daily survival rates of nests (Mayfield 1975; Johnson 1979) for all years combined, was not statistically different between restored (mean = 0.97, SE = 0.004) and remnant sites (mean = 0.96, SE = 0.009, $t$ = 0.34, $df$ = 2423, $P$ = 0.74, Figure 11A). Rates varied annually, however 95% confidence intervals for restored and remnant sites overlapped in all years. For Spotted Towhees, daily nest survival rates were also not statistically different between restored (mean = 0.94, SE = 0.012) and remnant sites (mean = 0.91, SE = 0.011) over all years combined ($t$ = -1.3, $df$ = 989, $P$ = 0.19).

Daily nest survival rates can also be summarized in terms of overall nest survival for the entire nest period. For Black-headed Grosbeaks, overall nest survival, averaged across all years, was 44% in remnants (CI = 26–63%) and 40% in restored habitat (CI = 36–54%). For Spotted Towhees, the rates were much lower: 9.6% in remnants (CI = 5.0–18%) and 18% in restored sites (CI = 9.1–36%). Towhee daily nest survival rates were thus well below the benchmark value of 42% that is often used in comparative studies of open-cup nesting passerines (Martin 1992).

Analyses of bird habitat relationships in restored and remnant riparian habitats along the Sacramento River and other locations in the Central Valley have confirmed the importance of plant understory and overall structural and compositional diversity. For example, the abundance of several landbird species was strongly related to cover of blackberry (*Rubus* spp.), mugwort *(Artemisia douglasiana)*, and herbs (Nur et al. 2004). Based in part upon these findings and recommendations from Riparian Habitat Joint Venture (RHJV 2003), starting in 1999, an understory component was added to the restoration plantings. Currently, nine native herbaceous species are planted at TNC's restoration sites (Table 3), with the exact number and assortment varying from site to site depending upon local conditions.

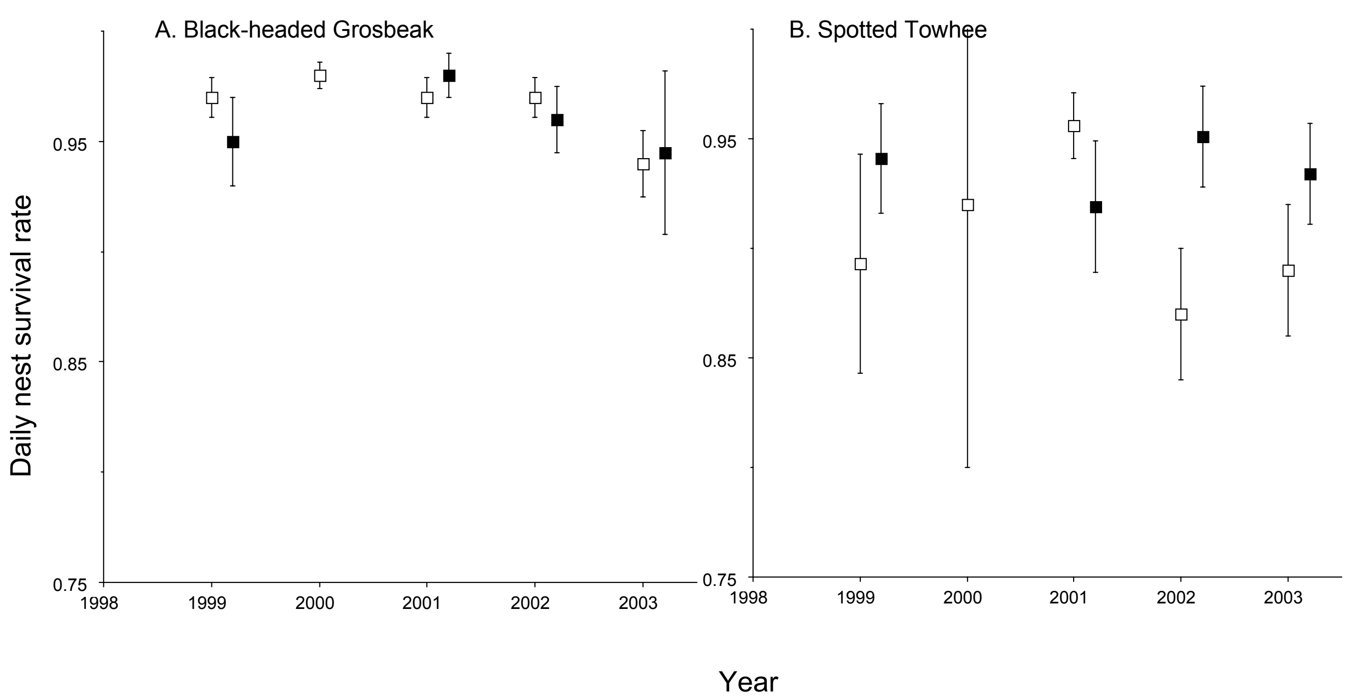


**Figure 11.** Mayfield estimates of nest survival rates for: (A) Black-headed Grosbeak; and (B) Spotted Towhee at restoration and remnant sites within the Sacramento River Project area, California. Solid squares identify restoration sites, and hollow squares indicate remnant sites. Vertical bars indicate 95% confidence intervals.

**Table 3.** Species planted at Sacramento River riparian restoration sites. All species are planted by hand, except seed-propagated species, which are planted with a rangeland drill. Seed-propagated species are planted between rows of hand-planted species, or by themselves in grassland settings. To match Sacramento River ecotypes, all cuttings and seed sources are obtained locally. Nomenclature is based on the Jepson Manual (Hickman 1993). There are no universally accepted standards for common plant names in English. When available, common names correspond to those used in the Jepson Manual (Hickman 1993). Otherwise, they follow Oswald (2002).

| Scientific name | Common name | Growth form | Propagation method |
|---|---|---|---|
| *Acer negundo* var. *californicum* | Box-elder | Tree | Container |
| *Alnus rhombifolia* | White alder | Tree | Container |
| *Aristolochia californica* | California pipevine | Vine | Container |
| *Artemisia douglasiana* | Mugwort | Herb | Container |
| *Baccharis pilularis* | Coyote-brush | Shrub | Container |
| *Baccharis salicifolia* | Mule's-fat | Shrub | Container |
| *Carex barbarae* | Santa Barbara sedge | Sedge | Container |
| *Carex praegracilis* | Clustered field sedge | Sedge | Container |
| *Cephalanthus occidentalis* var. *californicus* | California button-willow | Shrub | Container |
| *Clematis ligusticifolia* | Virgin's-bower | Vine | Container |
| *Elymus glaucus* ssp. *glaucus* | Blue wild-rye | Grass | Container or seed |
| *Fraxinus latifolia* | Oregon ash | Tree | Container |
| *Euthamia occidentalis* | Western goldenrod | Herb | Container |
| *Hordeum brachyantherum* ssp. *branchyanterum* | Meadow barley | Grass | Seed |
| *Leymus triticoides* | Alkali ryegrass | Grass | Container or seed |
| *Lupinus* ssp. | Lupine | Herb | Container |
| *Muhlenbergia rigens* | Deergrass | Bunchgrass | Container |
| *Nassella pulchra* | Purple needlegrass | Bunchgrass | Container or seed |
| *Oenothera elata* ssp. *hirsuitissima* | Hairy evening-primrose | Herb | Container |
| *Quercus lobata* | Valley oak | Tree | Container |
| *Populus fremontii* ssp. *fremontii* | Fremont's cottonwood | Tree | Cutting |
| *Platanus racemosa* | Western sycamore | Tree | Cutting |
| *Rosa californica* | California rose | Shrub | Container |
| *Rubus ursinus* | California blackberry | Shrub/Vine | Container |
| *Salix exigua* | Sandbar willow | Tree/Shrub | Cutting |
| *Salix goodingii* | Goodding's black willow | Tree | Cutting |
| *Salix laevigata* | Red willow | Tree/Shrub | Cutting |
| *Salix lasiolepis* var. *lasiolepis* | Arroyo willow | Tree/Shrub | Cutting |
| *Salix lucida* ssp. *lasiandra* | Yellow willow | Tree/Shrub | Cutting |
| *Sambucus mexicana* | Blue elderberry | Shrub | Container |
| *Toxicodendron diversilobum* | Western poison-oak | Shrub/Vine | Container |
| *Urtica dioica* ssp. *holosericea* | Hoary creek nettle | Herb | Container |
| *Vitis californica* | California wild grape | Vine | Container |

## Small Mammals

Although there are no special-status rodent species in the Sacramento River Project area, much valuable information can be gained by studying this group. In floodplain systems, rodents are an important functional group that has been shown to influence vegetation patterns (Anderson and Cooper 2000). Because they are a primary prey source for many higher trophic-level organisms, their abundance and distribution provides information about food availability. Also, because rodents typically have high reproductive capacity, they may be one of the first resident groups to signal changing habitat conditions (Bock et al. 2002), including those at restoration sites.

In recent years, bats have received increased attention, reflecting a wider recognition of their role in ecosystem function (Wickramasinghe et al. 2003). Although relatively little was known about the bat assemblage in the Central Valley when this study was initiated (Pierson et al. 2000), there were several compelling reasons to think that bats as a group might serve as valuable indicators of restoration success. Because bats are volant, and even the smallest species can travel large distances, they have the potential to respond quickly to changes in habitat quality, disappearing when habitat is lost, and recruiting readily when suitable conditions return. Because bats use echolocation for navigation and foraging, they can be monitored acoustically using relatively inexpensive hardware that records and stores their calls, and that can operate for a number of nights without human attendance (Waldren 2000). Also, because many species rely on both aquatic and terrestrial habitat features, concentrating foraging over lentic or lotic areas, and using tall riparian forests for roosting and breeding, they can be valuable ecological indicators of both aquatic and terrestrial ecosystem health.

### *Rodents*

Rodents are the focus of several management concerns on the Sacramento River. From a biodiversity standpoint, there is a concern that restoration may cause increases in the abundance of undesirable non-native species, such as house mouse *(Mus musculus)* or black rat *(Rattus rattus)*. Another concern, expressed by farmers, is that restoration activities may lead to increases in the abundance of agricultural pest species (e.g., California vole *[Microtus californicus]*, squirrels).

To address these concerns, small mammal distribution and abundance were assessed at agricultural and remnant forest habitats and at young (3–4 years) and older (12–5 years) restoration sites (Table 1). Three replicates of each site type were sampled with Sherman live traps (Wiener and Smith 1972) during spring and fall of 2005. At each site, we sampled for 5 consecutive days using 100 traps arranged in a 10 × 10 trap grid, with traps spaced 10 meters apart. See Koenig et al. (2007) and Golet et al. (2007) for additional study details.

The results of this 1-year study should be viewed as preliminary, given that small mammal abundances are known to be highly variable in riparian settings (Anderson et al. 2000). Nonetheless, our results suggest that rodent distribution and abundance are strongly influenced by changing habitat conditions (species × habitat type interaction, $F_{12, 335} = 10.5$, $P < 0.001$, Figure 12), and that there are clear habitat preferences among species: Deer mouse *(Peromyscus maniculatus)* and house mouse were most common in disturbed agricultural lands; California vole was abundant at young restoration sites where thick thatch layers were often present; western harvest mouse *(Reithrodontomys megalotis)* was common in both the older restoration sites and in remnant habitats with thick herbaceous layers and dense aboveground structure; and black rat was abundant in remnant riparian forest habitats where tightly closed canopies support their arboreal life-style.

A positive outcome of the restoration effort was a decline in the abundance of the non-native house mouse, a species common in human-altered habitats, and a concomitant increase in western harvest mouse, a native species less commonly found around human settlements. A less encouraging outcome was the steady increase in exotic black rat abundance associated with site maturation. This increase may adversely affect area landbirds, as previous research

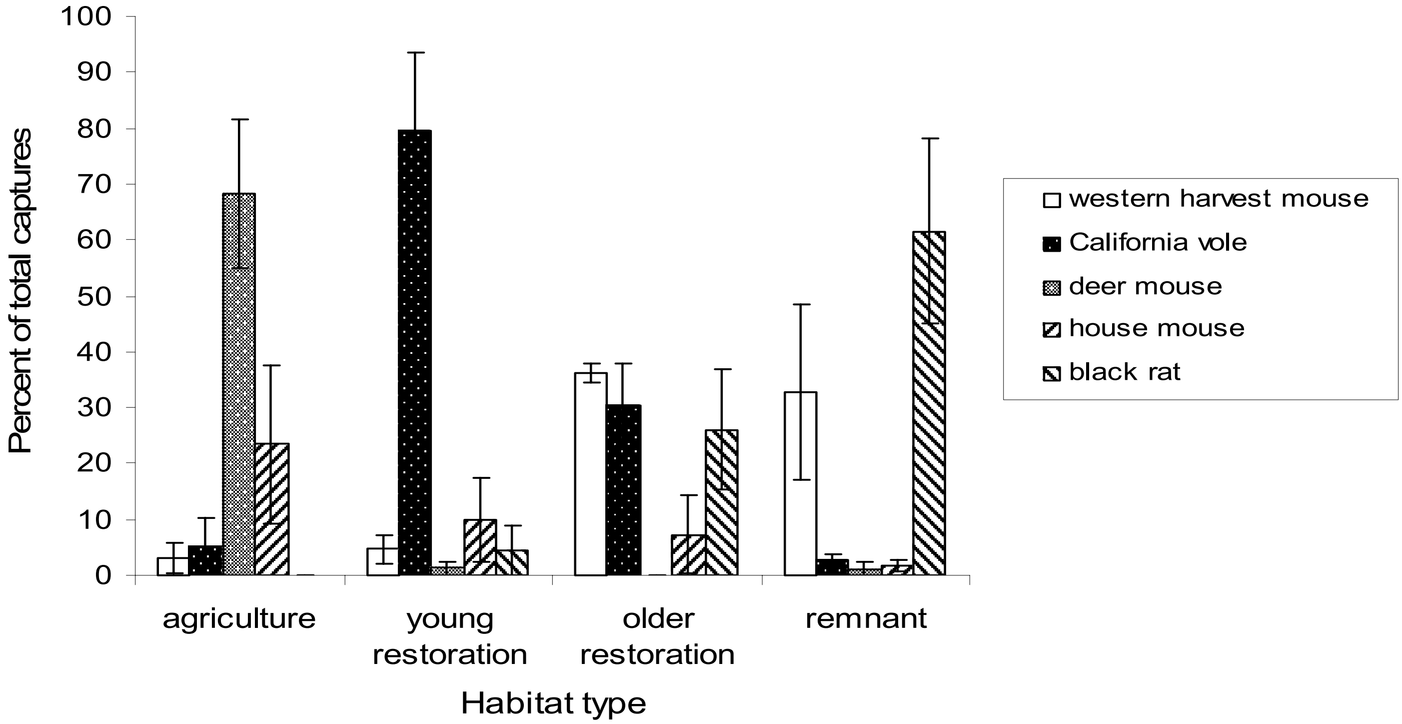


**Figure 12.** Number of animals captured (mean ± SE) in small mammal live traps at four habitat types within the Sacramento River Project area, California.

has demonstrated black rats to be a potentially potent nest predator on the Sacramento River (Small 2005) and in other woodland settings (Brown et al. 1998; VanderWerf 2001). Also, black rats may limit the recovery of bats, of which there are nine special-status species along the river (Table 2), through predation at cavities, crevice roosts, and maternity sites. Bat young are initially flightless and defenseless, and females give birth only once in a year. Although rats have been reported to cause extinctions of both birds (Blackburn et al. 2004) and bats (McKean 1975), more research is needed to determine the magnitude of their effects in this and other systems (Towns et al. 2006).

Results also suggest that young restoration sites may be a source of agricultural pests, as vole populations were the highest in this habitat type. Impacts to neighboring farms, while potentially significant, may be relatively short-lived, however, because vole abundance drops off dramatically as the restoration sites mature, after 12–15 years (Figure 12). Nonetheless, we recommend that Barn Owl (*Tyto alba)* nest boxes be erected at young restoration sites to help control voles, the most common prey of Barn Owls on Sacramento River agricultural properties and restoration sites (Golet and Bogiatto unpublished data). Overall, a significant difference was found among site types (agricultural, young restoration, older restoration, and remnant) in the abundance of different species captured ($F_{3,\ 335} = 10.5$, $P < 0.001$). As restoration sites matured, abundances declined, such that older restoration sites and remnant habitats had abundance levels similar to agricultural lands—although species composition was markedly different. Significant differences in abundance were found among species ($F_{4,\ 335} = 10.3$, $P < 0.001$), with voles being the most captured species overall. Approximately three times as many captures were made in the fall ($F_{1,\ 351} = 9.1$, $P = 0.003$), than in the spring, but not for all species (significant species × season interaction, $F_{4,\ 335} = 8.6$, $P < 0.001$). To a large degree, this increase was due to summer breeding, as ~50% of the fall captures were immature animals.

### *Bats*

A short-term investigation of bat response to restoration was conducted in fall 2002 (Stillwater Sciences et al. 2003). The investigation, with the aid of the Anabat detection system, assessed bat activity at orchards, young and older restoration sites, and mature riparian remnant habitats. Anabat systems record ultrasonic echolocation calls by using a sophisticated ultrasonic microphone and cassette-tape interface (Waldren 2000). Identifying bat species based upon echolocation calls relies on a number of call or pulse parameters, including base frequency, call shape (slope as measured in octaves per second and overall pattern), pattern of calls within a sequence, interpulse interval, and call duration.

Because night-to-night variation in bat activity at individual sites can be high, valid comparative data are best obtained by many nights of repeated sampling at replicate locations (Hayes 1997; Ballantyne and Sherwin 1999). We deployed three Anabat II ultrasound detectors (Titley Electronics, Ballina, NSW, Australia) at each site over extended periods. Two replicate orchard and mature riparian forest sites were sampled over one long period (September 12–13 through October 21–22, 2002), and young and older restoration sites were sampled over two short periods (September 12–14 and September 26–27). Detectors were directed upward at 45° and mounted on transducers atop aluminum poles to decrease unwanted detections from ground-dwelling insects (e.g., crickets). To analyze the data, we used both generalized filters detecting all bat calls and specific ones for particular species or family groups.

Bat activity was higher in mature riparian forests than in orchards (Stillwater Sciences et al. 2003). Intermediate levels of activity were observed at restoration sites, with the older site (planted in 1991) tending to have higher levels of activity than the newly planted site ($F_{1,7} = 4.7$, $P = 0.067$, Figure 13). Interestingly, bat activity patterns declined at all restoration site sampling locations from the first sampling period to the second (2 weeks later). And although this difference was not statistically significant ($F_{1,7} = 2.3$, $P = 0.17$, Figure 13), it nonetheless suggests that it is important to collect data concurrently when drawing comparisons between sites. Higher recorded activity levels are strongly suggestive of higher bat abundances, although, theoretically, they may also result simply from higher calling rates.

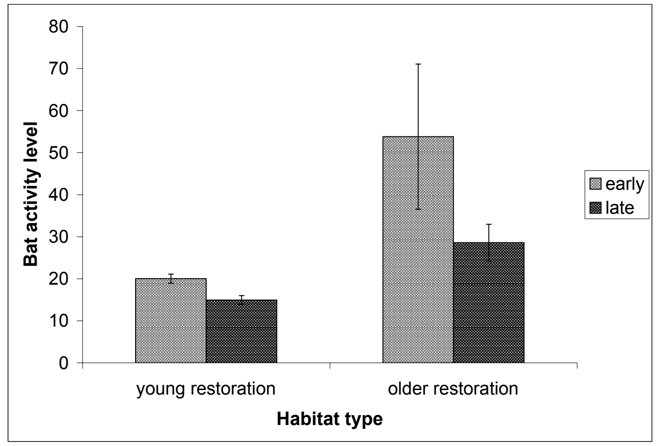


**Figure 13.** Bat activity levels (mean ± SE) at young (planted in 2002) and older (planted in 1991) restoration sites within the Sacramento River Project area, California. Bat activity is defined as the mean number of acoustic files per sampling period. "Early" refers to the September 12–14, 2002 sampling period, and "late" refers to the September 26–27, 2002 sampling period. At each site, detectors were deployed at three locations.

Visual observations confirmed that bats were roosting in the 11-year-old cottonwood trees at the older restoration site, and foraging at canopy level upon emergence. Some species (e.g., Pallid bat *[Antrozous pallidus]*) recorded at the older restoration site were not detected at the newer site. No red bat activity was recorded at the newly-planted 2002 forest immediately after sunset, but both the 1991 forest and the adjacent mature forest showed a peak in activity immediately following sunset, suggesting that red bats were roosting in the latter two habitat types. Also, researchers were able to identify California myotis *(Myotis californicus)* emerging from near the tree canopy. While the western red bat roosts in foliage, California myotis is thought to roost in crevices (e.g., under bark or in cracks formed by broken limbs), suggesting that restoration sites that are just over a decade old are already developing such features.

Differences in bat activity levels between the plots planted in 1991 and 2002 can be partially accounted for by the fact that the 1991 restoration plot offers roosting habitat while the 2002 plot does not; however, there also appeared to be more foraging activity at the 1991 plot. The implication is that the older restoration sites provide richer habitat overall for many species compared to the newly-planted sites.

Four special-status species (western mastiff bat, pallid bat, western red bat *[Lasiurus blossevillii]*, and yuma myotis) were detected through capture or by visual or acoustic record at riparian forest habitats in this study.

## DISCUSSION AND CONCLUSIONS

### Favorable Overall Response to Restoration

Collectively, these studies provide convincing evidence that riparian restoration along the Sacramento River has been successful in restoring a broad suite of faunal species. Not only were the restoration projects successful in providing habitat for special-status species (e.g., VELB, yellow-billed cuckoo, western red bat), but they were also highly effective in revitalizing the larger native riparian community. And the response has been rapid, with many species of diverse taxa colonizing the site in the first few years after implementation. Cavity-nesting birds (e.g., Nuttall's Woodpecker) and crevice-roosting bats (e.g., California myotis)—species often associated with mature forest features—began to occupy the restoration sites in fewer than 10 years. These observations are consistent with the very high rates of growth measured among floodplain trees at Sacramento River restoration sites (Griggs and Golet 2002).

Our results also suggest that local restoration projects may be producing positive spill-over effects. Increases in abundances of several bird species, for example, are taking place not only locally at the restoration sites, but also across the larger riparian landscape (Gardali et al. 2006). This macro-scale response is likely due to increases in riparian habitat patch sizes (and coincident reductions in habitat fragmentation) across the Project area, as strategically located agricultural lands are being replaced with habitat to both connect and expand existing remnants. However, a temporal trend caused by other factors (e.g., favorable climatic conditions) could also explain this pattern.

Although positive overall, some of these monitoring results provide cause for concern. The landbird study suggested that special attention be paid to the Lazuli Bunting because its population is declining in restoration sites, remnant habitats, and across the entire Central Valley. Hence, the amount of habitat may not be a population-limiting factor for Lazuli Bunting. Restoration and management for this species may require research on how invasive species (e.g., Brown-headed Cowbird *[Molothrus ater]*) shape the quality of the habitat. The rodent study warned that black rats, a potentially harmful predator, may increase as riparian forests expand along the river. More work is needed to determine whether rats are negatively impacting birds, bats, or other riparian species. As with problematic non-native plants (e.g., *Arundo donax, Lepidium latifolium*), certain animal populations may need to be curtailed via control measures.

### A Conservation Vision for the Sacramento River

Having restoration sites provide suitable habitats for native species in the near term is only one part of a larger conservation vision for the Sacramento River. Equally important is that natural riverine processes (e.g., flooding, erosion) be sufficiently operational. This is needed so that these sites, and their remnant counterparts, can be rejuvenated, lost, and created as is necessary to meet the diverse life-history needs of the native species that have evolved in the system (i.e., Attribute 9 of restored ecosystems, SER 2004). While continued low-level habitat management (e.g., control of invasive species) may be necessary, our conservation vision for the Sacramento River is that it be managed to provide functional habitats over the long term for native species without continued replanting. Indeed, if present-day restoration sites require extensive replanting in the future, then our long-term conservation goals will remain unmet. To prevent this, the river's habitat-forming processes must be actualized. The floodplain must remain hydraulically connected to the river, limited meander must be permitted, and, ultimately, the flow regime must be managed to meet ecological as well as human needs.

## Future Monitoring Needs

Localized monitoring confirms that Sacramento River restoration efforts are benefiting wildlife; however, additional monitoring is needed. Researchers need to better characterize the variability in response at restoration sites, and identify what makes some restoration sites more successful than others. Also, there is a need for a longer time series of data collection and more robust sample sizes for some studies and taxa. What will happen at these sites as they continue to mature, and as the planted individuals senesce and die? What plants will colonize, and what consequences will this have for wildlife? Although VELB are responding favorably to planted elderberry under current conditions, what will happen when forests mature around the planted bushes? Can conditions for natural recruitment of elderberry, and other important plants, be met in this highly regulated system? Long-term monitoring is also needed to characterize the response to restoration of species that exhibit high annual variation in measured parameters. These species include migratory birds and fish that are strongly influenced by factors outside of the project area, as well as species (e.g., rodents) that are strongly affected by natural riverine disturbances such as flooding.

For some taxa, it would be highly beneficial to expand upon the initial surveys profiled in this paper simply to gain more information about how they interface with habitats along the river. In particular, more studies should be conducted on bats. Although we know that several special-status bats use the riparian zone extensively, we do not have a good sense for the life-history requirements of individual species, nor do we know enough about how habitat use patterns vary seasonally. Studies of landbirds provide a good example of the richness of information that can come from conducting research during the breeding, migration, and wintering periods.

For comparison purposes, future studies should also be conducted in young riparian forests that have naturally recruited. All of the studies profiled in this paper drew comparisons between restoration sites and mature riparian forests, yet younger natural sites likely have different wildlife use patterns than mature stands. Young natural sites typically have lower elevations relative to the river than either restoration sites or older natural stands, and this likely influences a variety of physical, chemical, and biological processes which have important consequences for wildlife.

Because the remnant habitats of the Sacramento River are degraded by a variety of factors (e.g., altered/arrested flooding and erosion patterns due to dams and riprap), they cannot be viewed as true experimental controls, or representative of reference conditions. More research should be conducted to help identify factors that limit the viability of species that inhabit these sites, and to determine the extent to which present conditions could be improved, both at the remnant sites and at the restoration sites to which they are compared.

In addition to increased site-based monitoring, we also need to determine how successful horticultural restoration projects have been at achieving recovery goals (e.g., CALFED [2000b] goals for habitat and native at-risk species) at the landscape scale. Researchers should use remote sensing and field-based monitoring data to better characterize existing habitats, and to identify factors that influence species abundance, distributions, fecundity, and survival at a variety of habitat types (e.g., restoration, agricultural, and remnant) over the larger riparian landscape. Only by examining the system as a whole can we define the relative contribution that horticultural restoration projects are making to ecosystem recovery. A holistic approach to monitoring will provide the added benefit of allowing us to characterize the overall health of the river and track changes through time.

Future monitoring of wildlife response to restoration should include studies of special-status aquatic and semi-aquatic organisms, such as Chinook salmon *(Oncorhynchus tshawytscha)* and northwestern pond turtle *(Clemmys marmorata marmorata)*. Studies should be initiated to determine to what degree replacing floodplain agricultural land with natural riparian habitats confers benefits to these species. It is expected that restoration projects improve water quality and provide the river with beneficial inputs of terrestrially-derived prey and woody debris (NRC

2002), yet these assumptions have not been adequately tested on the Sacramento River.

Although much of the research conducted to date has focused on evaluating the effects of horticultural restoration, future monitoring should also be directed at understanding how the ecosystem responds to projects (e.g., levee setbacks, riprap removal) that restore natural river processes of bank erosion, flooding, and meander migration. Revitalization of natural processes is difficult to accomplish on highly managed river systems such as the Sacramento; however, it may be achieved when large blocks of land are assembled through conservation purchases (e.g., the Hamilton City J-levee project, USACE 2004; Golet et al. 2006). As such projects move forward, it is imperative that they have sufficient monitoring associated with them so that opportunities for learning can be realized, and restoration can become more successful and cost-effective.

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Review of the draft revised recovery plan for VELB

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**Questions posed by USFWS:**

1) Have we assembled and considered the best available scientific and commercial information relevant to this species?

Yes, the plan appears to have considered the best available information relevant to the VELB, including the most recent peer-reviewed research by Holyoak, Talley, Huxel and Collinge and colleagues, as well as reports and reviews submitted to the Federal Register and USFWS directly.

2) Is our analysis of this information correct?

Yes, I find that the analyses and conclusions are consistent with the data. For example, the plan concludes that there are still many uncertainties regarding the extent of the geographic range of the VELB and the dynamics of the species' abundance and distribution. The plan concludes that the main threat to the VELB is loss of habitat, and supports appropriate mitigation measures (planting of elderberries in suitable habitat). The plan uses information from the literature to guide suggested measures for VELB mitigation sites, including size and density of plantings, as well as the importance of transplanting elderberry bushes from impact sites. The plan describes additional threats, such as predation by Argentine ants, climate change, and pesticide drift, which are undoubtedly less likely to be easily ameliorated by mitigation actions, but that should be avoided as much as possible at protected sites.

3) Are our scientific conclusions reasonable in light of this information?

Yes, the scientific conclusions are reasonable and consistent with the available data. It is clear that more long-term studies, especially repeated surveys of VELB sites, are needed to more fully understand population dynamics and to develop more specific, quantitative, defensible recovery goals. But given the current state of knowledge, the recovery goals and targets seem appropriate.

In Table 2, which describes recovery actions and estimated costs, I would like to see some metric related to feasibility, e.g., how likely is it that land in each sub-basin can and will be acquired and managed to support persistent VELB populations? The time estimate for completion is 2050. I think it would be useful to provide a detailed "roadmap" of planned acquisitions and management actions that provide some assurance that this is highly feasible, given current and future resource availability. This would usefully be accompanied by a literal geographic description of when and where habitat protections will occur.