Lower Putah Creek Watershed Plan Priority Project

Task 3: Performance Measurement and Adaptation

UCD students monitor nest box hatchlings

Final Report to State Water Resources Control Board
CALFED Watershed Protection Grant Agreement 10-325-550

Prepared for the Solano County Water Agency
By the UC Davis Museum of Wildlife & Fish Biology

August 11, 2015

Executive Summary

This report presents results from investigations conducted by the Museum of Wildlife & Fish Biology (MWFB), University of California, Davis under subcontract with Solano County Water Agency (SCWA) through a CALFED Watershed Protection Grant administered by the California State Water Quality Control Board to measure, analyze, and evaluate ecological responses to restoration in compliance with terms and conditions of Grant Agreement 10-325-550.

Previous assessments identified a need to reconfigure much of lower Putah Creek's floodplain habitat to create a smaller but more naturally-functioning ecosystem appropriate to current flows. Throughout this effort, land managers recognized the value of coupling these strategies with biological monitoring to improve Putah Creek's physical structure and function and identify site-specific strategies to improve habitat conditions and enhance biological resources. MWFB contracted with SCWA to address Contract Subtask 3: Performance Measurement and Adaptation.

Subtask 3 was divided into several components. Results for each of these components are presented below:

<u>3.1 Evaluate social cues</u>

3.1.1 Determine whether reliance on social cues limits range in riparian songbirds, thereby masking responses to habitat restoration.

- *Animals that prefer to settle near conspecifics may be unlikely to settle in empty or newly created habitat patches due to the lack of reliable cues of habitat quality.*
- *Studies suggest that territorial bird populations can increase dramatically following playbacks of vocalizations in appropriate habitat where either one or no pairs had been present during the previous year.*

3.1.2 Determine whether conspecific attraction to song can be used as a restoration tool and its effect on habitat restoration projects.

- *Our results suggested that broadcasting recordings of bird songs and calls can be effective in attracting conspecifics, especially in the spring*
- *Providing auditory cues to prospecting birds at critical junctures in the breeding cycle may thus provide a tool for attracting birds to restoration sites which lack conspecifics and their cues to habitat quality.*

<u>3.2 Conduct food web analysis</u>

3.2.1 Determine reliance on aquatic versus terrestrial insects in the birds utilizing next boxes.

- *From a landscape perspective, Putah Creek is a flying-insect-rich corridor, a pattern that becomes especially pronounced during summer drought.*
- *Food web analysis revealed that up to 76% of the prey base of birds nesting near the creek derived from aquatic origins and that aquatic-derived insect prey provided subsidies to avian consumers up to 0.5 km away from the creek.*
- *Isotopic analysis suggests that Tree Swallows become increasingly reliant on a creek-based diet of emergent aquatic prey over the course of the breeding season, coinciding with the decline of terrestrial insect prey.*
- *Insect subsidies delivered from riparian and aquatic systems are expected to be increasingly important during late season breeding, fall migration, and/or periods of drought.*

3.2.2 Determine dietary patterns with patterns of prey availability from insect surveys and habitat parameters from vegetation and stream surveys to quantify the relative importance of different restoration actions on food webs.

- *Of the sites studied, aquatic insect prey consumption was highest at Winters Putah Creek Park, where birds were observed foraging over the realigned creek channel as well as over a borrow-site pond created during floodplain excavation.*
- *This warm, fish-free, algae-rich body of water created ideal conditions for the rearing and emergence of certain aquatic insect taxa which the birds readily utilized.*
- *While warm-water conditions are being discouraged for the mainstem of the creek, isolated hydrological features such as this may provide valuable rearing habitat for aquatic insects that may, in turn, provide dietary subsidies for birds and other riparian organisms.*

3.3 Update the 2004 breeding bird atlas by river mile.

Sixty-nine species were confirmed as breeding in the lower Putah Creek watershed. Of those that were not confirmed breeding, five species met the criteria for probable breeders, nine met the criteria for possible breeders, and five species were observed but did not display any breeding behavior. Of the riparian focal species of conservation concern, Yellow Warbler and Western Wood Pewee met the criteria as probable breeders, and Willow Flycatchers were observed using habitat during the breeding season. No least Bell's

Vireos, Bank Swallows, or Yellow-billed Cuckoos were observed in the study area during the 2012-2013 atlasing period. These species have been observed from time to time on the creek, however.

ADDITIONAL STUDIES

MWFB was able to leverage contract funding to carry out some additional, non-stipulated studies to add value to the overall investigations. These additional value-added studies were:

A. Document mesocarnivore presence-absence on the creek

MWFB also leveraged student effort to develop a special wildlife practicum to assess mesocarnivore presence-absence along Putah Creek using camera traps. At the end of the project, the students analyzed and reported on the data they had collected (Nomann .

B. Assess the prevalence of heavy metal compounds in the food web

At one point in this project, MWFB partnered with USGS to analyze methyl-mercury loads in eggs from nest boxes placed along riparian longitudinal and transverse gradients. We found that eggs in nest boxes did indeed carry methyl-mercury loads (Joshua Ackerman USGS, pers. comm) and that nest boxes located closer to the creek contained higher levels of mercury than boxes further from the creek, suggesting that methyl-mercury was indeed being sourced from the creek. Mercury loads also increased with distance downstream, presumably because lower flow velocities and, hence, longer residence times facilitated conversion of inorganic mercury to methyl-mercury. These findings have direct relevance to restoration of aquatic habitats along Putah Creek since actions that increase flow velocities and decrease residence times should reduce the conversion of inorganic mercury to methyl-mercury.

C. Peer-reviewed publications

Contract funding enabled MWFB to hire a postdoctoral associate to assist museum staff in the development of peer-reviewed publications from data collected under this and previous grants. Using hierarchical multispecies occupancy models to estimate seasonal species richness and phylogenetic diversity in each watershed, we found that total species richness was equally as high in winter as in summer, and that phylogenetic diversity was higher in winter, with a considerable proportion of the winter avian diversity attributable to boreal-breeding Neotemperate migrants (Dybala et al. 2015). Our results provide evidence that maintaining and restoring high-quality riparian habitat for winter bird communities in California should be an important conservation priority. Broader recognition of the diversity of temperate winter bird communities and additional research into the factors affecting winter condition

and survival would facilitate effective conservation of high-quality winter habitat, benefiting Neotemperate migrants and year-round residents during a season that has important impacts on their population dynamics. Additional papers derived from this effort are currently in preparation.

DETAILED DISCUSSION - PROJECT ELEMENTS

Ecological Monitoring/Response to Restoration

MWFB measured, analyzed, and evaluated ecological responses to project actions using standardized, repeated surveys, habitat assessments, photodocumentation, detailed process-based inquiries, and multivariate analyses, drawing upon their extensive database specific to Putah Creek compiled over the past 14 years. MWFB employed a suite of species/taxa (*i.e.* plants, invertebrates, birds) that serve as ecological indicators of project-related changes in resource conditions. These groups are highly informative of ecosystem structure and function since they reflect variation across broad taxonomic divisions, multiple trophic levels, and differing life history strategies, and serve to integrate ecosystem function and environmental responses across a variety of spatiotemporal scales.

For each taxonomic group, we established spatiotemporal survey protocols that best characterized key periods in that taxon's life cycle. For example, in birds, four periods were surveyed: breeding, overwintering, and spring and fall migration. Invertebrate populations and plant cover and species composition were surveyed during the growing season.

PROJECT SUBTASKS

Subtask 3.1 Evaluate social cues

Conspecific attraction is the tendency for animals to settle near other members of their species. While it is widely believed that colonial species benefit from the presence of conspecifics through improved ability to locate food or ward off predators, until recently, few ecologists considered the possibility that conspecific attraction might also occur in territorial animals, including the vast majority of birds (Lack 1968), that actively defend space against conspecifics and appear to suffer lowered reproductive success as population density increases. Nevertheless, recent studies show that population density of territorial birds increased dramatically following playbacks of vocalizations in appropriate habitat where either one or no pairs had been present during the previous year. Reproductive success for these colonists also increased (Schlossberg and Ward 2004; see also Graber 1961; Sherry & Holmes 1985; Herremans 1993; Muller et al. 1997; Poysa et al. 1998). Conspecific attraction may occur because the presence of conspecifics in an area is a reliable cue of habitat quality. This phenomenon may have important implications for how birds use space and, therefore, for their conservation and restoration (Smith & Peacock 1990). Animals that prefer to settle near conspecifics may be unlikely to settle in empty or

newly created habitat patches. Conservationists could potentially use this preference for previously settled sites to lure animals into settling at unoccupied sites by artificially introducing the cues naturally produced by conspecifics (Reed & Dobson 1993). Thus, conspecific attraction could provide a powerful tool for managing and conserving birds in restoration landscapes.

To test whether conspecific attraction might also be operative in the fall, when migratory birds are actively prospecting for breeding sites for the following spring, we conducted playback experiments for three riparian focal species—Yellow Warbler, Western Wood-Pewee, and Warbling Vireo—that have suffered dramatic population declines in recent years in the Central Valley. We found that while densities of target species were too low to resolve any significant responses to playback, birds did appear to be attracted to the broadcasts. Overall, significantly greater numbers of individual birds were detected near speakers than away from speakers (Table 1). We suspect that, for certain species at least, playbacks are likely to be more effective during the spring since target species were generally silent in late summer and fall (with the exception of Western Wood-Pewee) and that there is a limited "audience" to hear songs and respond to them via settlement.

Many researchers are beginning to think that habitat management and restoration alone is not enough to attract birds back into habitats they once inhabited. The lack of social cues may be just as limiting for recolonization. There is compelling evidence that these social cues in some cases actually trump habitat, and in these cases vocal signals to birds that "this is a great place to nest" result in target birds settling for the breeding season (Ahlering and Faaborg 2006). We have tried conspecific attraction, playback of songs, on Putah Creek with limited success. Song playback appeared to have positive impact on the settling of yellow warblers in appropriate habitat at the Cosumnes River Preserve, however, where they bred successfully and subsequently returned for a second successful nesting season.

TABLE 1. Results of late summer/fall playback experiments

	# individuals observed*, multi-speaker trials	# individuals observed*, single-speaker trials	# individuals observed*, silent control trials
All bird species	391	258	197
Warbling Vireo	3	2	1
Western Wood-Pewee	2	0	2
Yellow Warbler	9	8	3

*Numbers are counts of individual birds coming within a 25-meter radius of the study site during a 10-minute observation window.

Subtask 3.2 Conduct food web analysis across the aquatic-terrestrial interface

Riparian food webs are characterized by complex linkages across the boundary between land and water (Fig. 1).

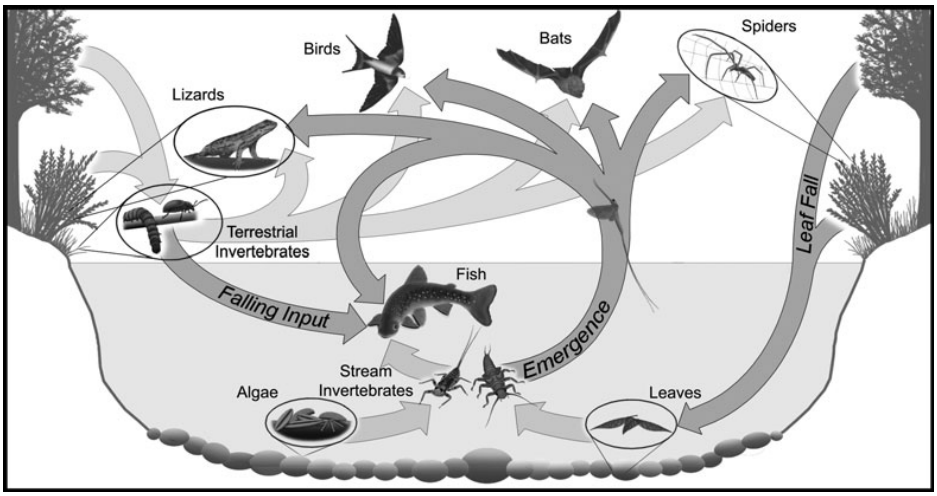


Fig. 1. Simplified riparian food web representing exchanges of nutrients and biomass between streams and their adjacent floodplains (Baxter et al. 2005).

The aim of this subtask was to investigate the importance of aquatic resources to terrestrial organisms (i.e. birds). It has been estimated that 10-30 mg/m^2 of aquatic insects emerge daily from California's riparian systems to become available as prey to terrestrial organisms (Sabo & Power 2002, Gratton & van Zanden 2009, Rundio & Lindley 2012). Thus, by extrapolation, over 2000 kg of aquatic insects are available each year to organisms along the 30 km stretch of lower Putah Creek. Projects that restore productive aquatic habitats are expected to translate directly to upland environments through aquatic-terrestrial cross-boundary subsidies. To test the strength of these linkages we sampled aquatic and terrestrial insects throughout the spring and summer, and analyzed the diet of an insectivorous bird, the Tree Swallow, from nest boxes located at varying distances from Putah Creek. Tree Swallows forage non-selectively on small insects so they are ideal indicators of the flying insect prey base along the creek.

Over 50% of the total insect biomass was collected in the sweeps closest to the creek. For aquatic insects, abundance declined rapidly and non-linearly with distance from water . The same held for terrestrial insects, whose densities were higher in the riparian corridor relative to upland grasslands (Fig. 2).

Using compound-specific isotope analysis of feather samples derived from over 300 nest boxes hosting Tree Swallows and other species, doctoral candidate Robert Walsh looked for evidence of aquatic/terrestrial prey consumption in adults and chicks. As expected, avian insectivores nesting in close proximity to Putah Creek foraged heavily on emergent aquatic insects; up to 76% of the prey base of birds nesting near the creek derived from aquatic origin. Here, it was estimated that ~110,000 insects (~1.2 lbs) could be delivered to just one brood over a typical 20-day nesting period. While aquatic prey consumption declined ~11% for every 100m distance away from the creek, upland-nesting Tree Swallows—up to 0.5 km away from the creek—consumed a considerable amount of aquatic-derived prey.

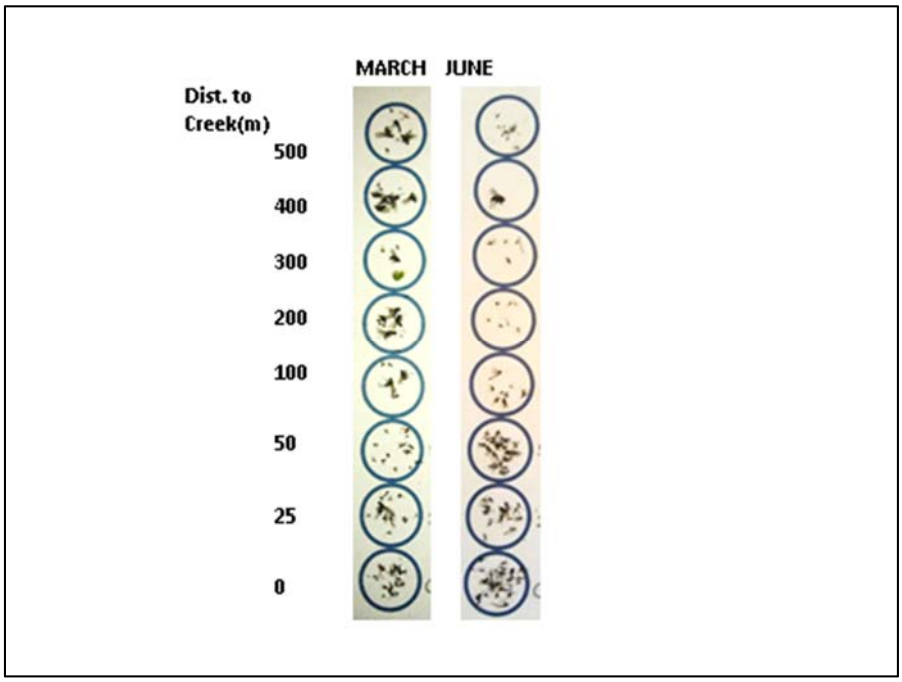


Fig. 2. Representative samples of emergent aquatic insects collected at increasing distances from the Putah Creek riparian corridor (Walsh unpublished data).

To put these findings in context, we compared nitrogen isotopic signatures from 44 swallow nestling feathers against a range of samples from specimens in the UC Davis Museum of Wildlife & Fish Biology's collections. These included species with almost exclusively aquatic diets (e.g., Belted Kingfisher) and species with almost exclusively terrestrial diets (e.g., Greater Roadrunner). We found isotopic signatures from Tree Swallows fell in between these ranges, in line with such wetland-dependent species as Northern Rough-winged Swallow and Marsh Wren (Fig. 3).

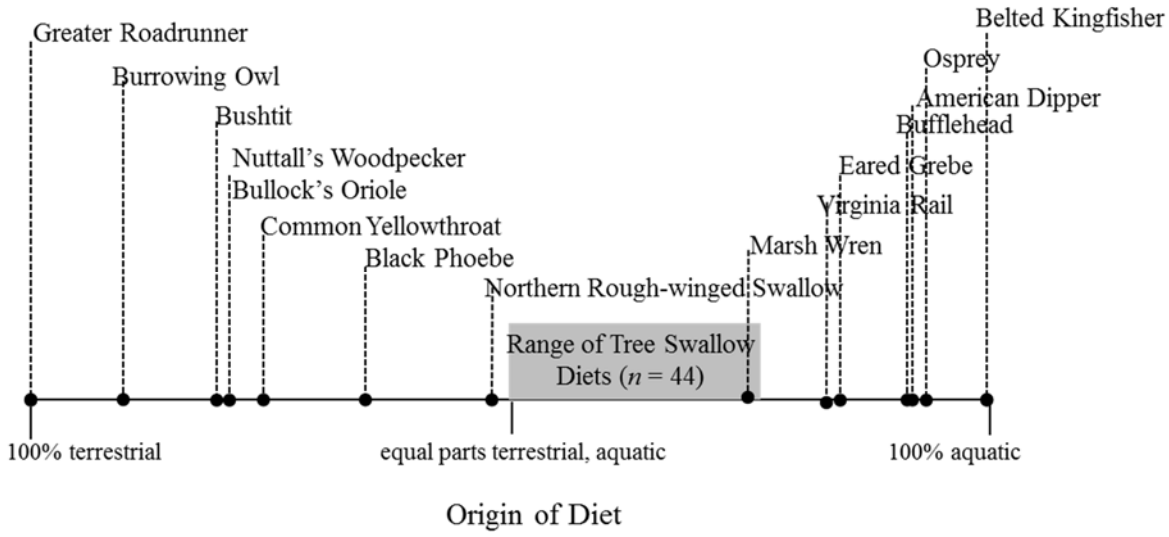


Fig. 3. Analysis of $d^{15}N$ values in feathers from Putah Creek Tree Swallow nestlings. Many other riparian songbirds also show signatures that suggest reliance on prey of aquatic origin.

From a landscape perspective, Putah Creek is a flying-insect-rich corridor, a pattern that becomes especially pronounced in summer (Fig. 4). Isotopic analysis suggested that Tree Swallows became increasingly reliant on a creek-based diet of emergent aquatic prey over the course of the breeding season, coinciding with a decline of terrestrial insect prey. If the generalist diet of Tree Swallows is reflective of the diets of other insectivorous birds, we suspect that these other species may also rely more heavily on emergent aquatic insect prey in dry periods, such as late season breeding or fall migration. Riparian habitat and subsidies are also likely to become more critical as climate change induced drought conditions become more prevalent in the future.

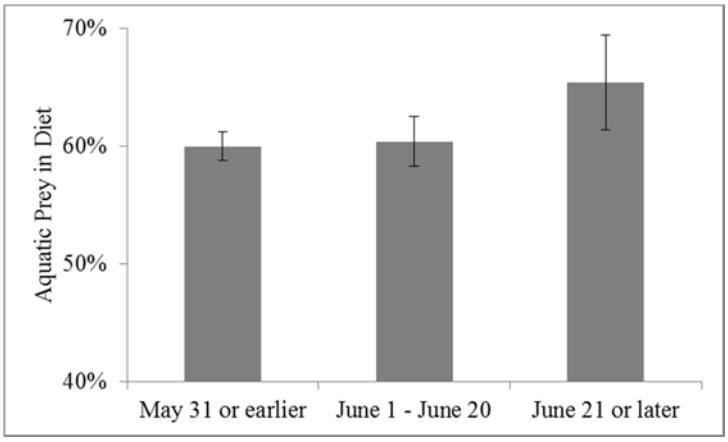


Fig 4. Average consumption of aquatic prey by Tree Swallows (with 95% confidence intervals). Late-season diets have a significantly greater amount of aquatic-derived prey.

Of all the sites we studied, aquatic insect prey consumption was highest at Winters Putah Creek Park, a site currently undergoing ecological restoration. Birds were observed foraging over the realigned creek channel as well as over a borrow-site pond created during floodplain excavation. This warm, fish-free, algae-rich body of water created ideal conditions for the emergence of some aquatic insect taxa, which the birds readily utilized. A related observation is the rapid vacation of Putah Creek by Tree Swallows once they have fledged young, with banded birds moving to nearby wetlands to forage (e.g., City of Davis Wetlands, Yolo Bypass). Thus, while warm-water conditions are discouraged for the mainstem of the creek, isolated hydrological features such as this may provide valuable rearing habitat for aquatic insects that in turn provide dietary subsidies for birds and other riparian organisms. However, the value of these warm, shallow, prey rich habitats is tempered by the fact that they may increase birds' exposure to methyl-mercury (see below).

SUBTASK 3.3 Update the 2004 Breeding Bird Atlas

The objectives of a Breeding Bird Atlas are to provide a complete, systematic inventory of the breeding birds in a region for both immediate goals and as a permanent record for the future. The main objectives of a Breeding Bird Atlas are to:

1. Provide the data necessary to produce accurate and up-to-date distribution maps.
2. Provide more accurate information on the breeding occurrences and habitats of rare species so that future management and resource use decisions can be made on a sound factual basis.
3. Identify fragile or unusual habitats supporting rare species that could become the focus of specialized conservation efforts.
4. Provide baseline data against which future changes in the status of breeding birds can be measured.
5. Provide a database for use in environmental project reviews.
6. Involve birders in a cooperative conservation effort and introduce them to an interesting and scientifically-valuable form of birding.

Twenty-seven river-mile blocks (EDAW 2005)—from the Interdam Reach to the Putah Creek Sinks—were surveyed repeatedly throughout the 2012 and 2013 breeding season by trained ornithologists using standardized procedures. Our objectives were to visit as many sites as possible, as many times as possible, to update the number confirmed, probable, and possible species breeding along Putah Creek. Some river-mile blocks were not accessible due to landowner restrictions. Determinations were predicated upon a series of commonly-accepted criteria based on a variety of cues (Table 2). Safe dates—dates beyond which birds are unlikely to be recorded while on migration—strengthened the validity of results. Observer effort was tracked and plotted against number of confirmed species, both overall

and by focal species (Fig. 5). Focal species consisted of riparian-dependent species, listed species, and other species of conservation interest to the region. From these results, we compiled the number of possible, probable, and confirmed breeders, overall and by focal species, for each river mile block (Fig. 6).

TABLE 2. Breeding Determination Criteria	
CONFIRMED (CO)	
ON	occupied nest
NY	nest with young seen or heard (If young cowbird chick present with another young, NY for cowbird and nest owner)
NE	nest with eggs, bird sitting on nest or egg, eggshells found beneath nest or dead nestlings (if cowbird egg, NE for cowbird and nest owner)
FS	adult carrying fecal sac
CF	adult carrying food for young
FY	adult feeding recently fledged young
FL	recently fledged altricial young or downy precocial young incapable of sustained travel
CN	adult carrying nest material (use this code with care)
NB	nest building (except by wrens and woodpeckers)
DD	distraction display or injury feigning (see also Probable-A for agitated)
PE	physiological evidence obtained from bird in the hand (brood patch, egg in oviduct, etc)
UN	used nest or eggshells found (careful documentation required)
PROBABLE (PR) - must be after safe dates (if any), otherwise record as Possible	
A	agitated behavior, scolding of observer as if nest or young nearby
T	territorial defense; individual or pair holding territory (chasing birds of the same species, territorial singing)
S	territory presumed thru song or breeding calls at same location on at least 2 occasions 7 or more days apart
B	nest building by wrens, or hole excavation by woodpeckers
N	visiting probable nest site
C	courtship behavior or copulation observed
P	pair in suitable habitat during breeding season
POSSIBLE (PO) - must be after safe dates (if any), otherwise record as Observed	
√	individual (male or female) seen in suitable nesting habitat during breeding season
X	singing male in suitable habitat during breeding season
OBSERVED (OB)	
X	observed using habitat

Sixty-nine species were confirmed as breeding in the lower Putah Creek watershed. Of those that were not confirmed breeding, five species met the criteria for probable breeders, nine met the criteria for possible breeders, and five species were observed, but did not display any breeding behavior (Fig. 5 & 6). Of the riparian focal species of conservation

concern, Yellow Warbler and Western Wood Pewee met the criteria as probable breeders, and Willow Flycatchers were observed using habitat during the breeding season. No Bell's Vireos, Bank Swallows, or Yellow-billed Cuckoos were observed in the study area during the 2012-2013 atlasing period. These species have been observed from time to time on the creek, however.

Seven of the reported new breeding taxa on Putah Creek, Hairy Woodpecker, Pileated Woodpecker, Pacific-slope Flycatcher, Chestnut-backed Chickadee, Brown Creeper, Dark-eyed Junco and Western Tanager, are species of wooded uplands that have filtered down the creek corridor to a lowland setting of suitable habitat structure. These species breed at higher elevations in the upper Putah Creek watershed, and we suspect that they will ebb and flow in response to population dynamics, resource availability, and a changing climate.

With our new nesting records, we can confirm that the riparian obligate species of special concern in the Sacramento Valley still pioneer and can attempt to nest if conditions are ripe. Modern restoration of habitat along Putah Creek is still constrained by flood conveyance concerns and a deeply incised channel. The creek will never regain its hydrologic function. However habitat restoration has recently focused on reestablishing floodplain function, albeit in a constrained aspect, from the Solano Diversion Dam east 10km to past Winters. Sedimentation removal, non-native plant removal and braided channel construction are primary methods used along the stretch. Additional instream modifications have increased flow rates allowing for scouring and better water quality conditions. This latter restoration is targeting spawning habitat for salmonids; but benefit emergent insect productivity and therefore insectivorous birds. Other limiting factors to successful nesting of native songbirds include nest predation by roof rat (*Rattus rattus*), competition for suitable cavities with non-native birds such as European Starling (*Sturnus vulgaris*) and House Sparrow (*Passer* domesticus) and brood parasitism by Brown-headed Cowbirds.

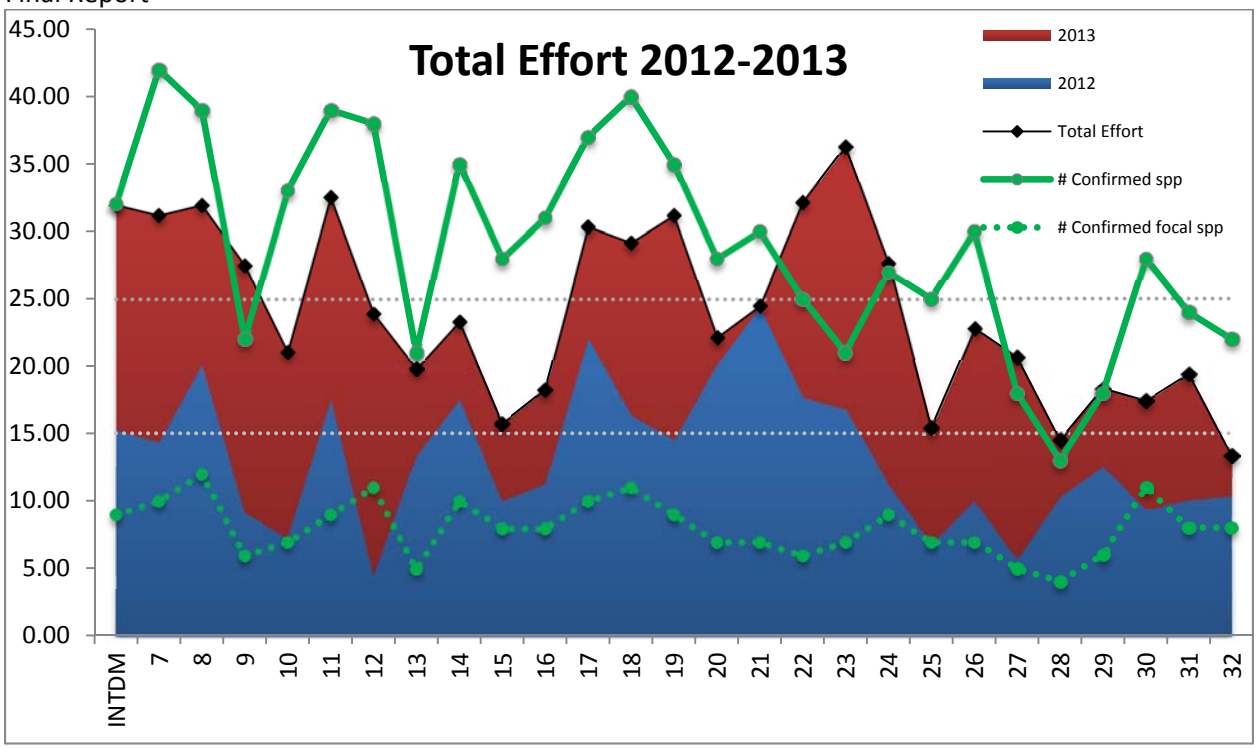


Fig. 5. Observer effort and number of confirmed species by river mile (EDAW grids) plotted by site and year

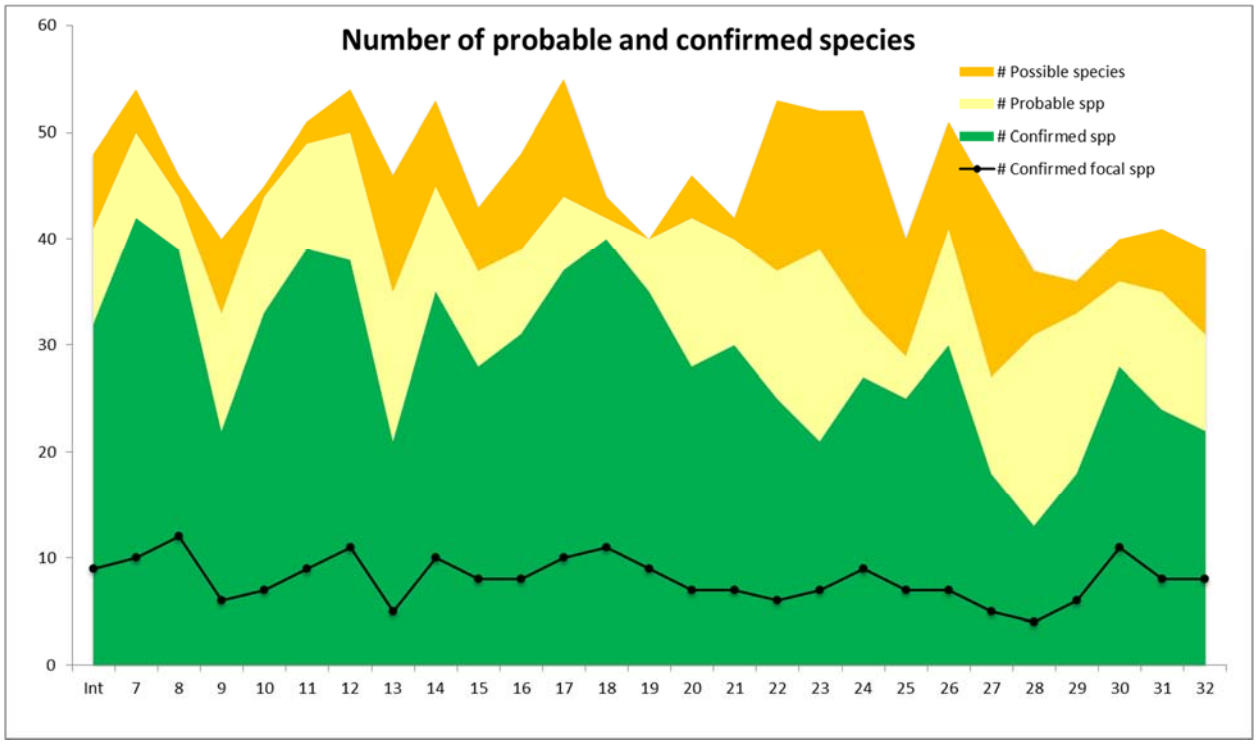


Fig. 6. Number of possible, probable, and confirmed breeders by river mile (EDAW grids).

ADDITIONAL STUDIES

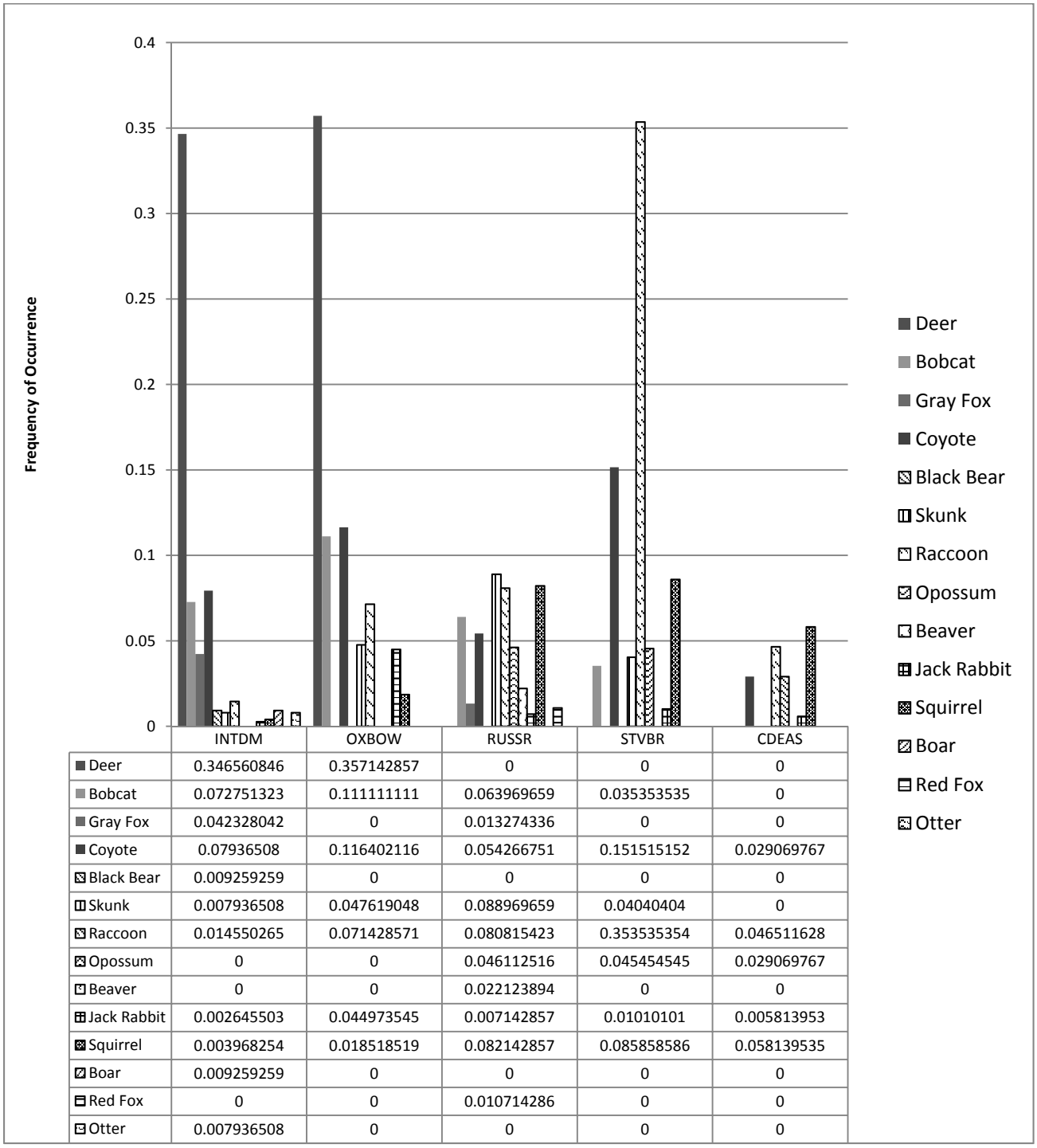
A. Document mesocarnivore presence-absence on the creek

We deployed camera traps at five different study sites arrayed along longitudinal (*i.e.* upstream-downstream) and transverse (i.e. creek-upland) gradients. Remotely-operated motion-sensing cameras (camera traps) have become inexpensive, useful tools for conducting wildlife investigations, providing photographic evidence of species presence, population estimates, information on activity patterns, predation, body condition, and feeding ecology (Hughson et al. 2010). For each site, we set up two Bushnell HD Trophy Cams, rotated on a monthly (lunar cycle) basis along established wildlife trails or crossroads. We deployed cameras in pairs, with one camera near the creek and another in the upland, generally along the levee or upper river terrace.

Overall, we captured images of 14 different wild mammalian species across all sites (Fig. 7). We also detected feral and domestic cats and dogs and a number of large birds. Coyote, raccoon, black-tailed jackrabbit, and Western gray squirrel were detected at all sites. Interestingly, we did not detect opossum at either of the two most upstream sites. Striped skunk, and most surprisingly, bobcat (Fig. 8), were widespread and found at all but the most-downstream sites.

Figure 8. Bobcat caught in a camera trap near Davis, CA.

Results from this study help us understand mammal distribution and habitat use along Putah Creek. Bobcat sightings were much more frequent and widespread than we expected. Because the surrounding areas of Putah Creek are heavily populated and managed intensively for agriculture, we did not expect to encounter this seemingly shy and retiring species. Bobcats are entirely carnivorous, but they are generalist predators. Their propensity to feed on a variety of rodents and other small mammals may help explain their wide distribution along the creek. We are encouraged that these useful carnivores are now protected under The Bobcat Protection Act, prohibiting their trapping in California, and the sale and export of their skins.



	INTDM	OXBOW	RUSSR	STVBR	CDEAS
Deer	0.346560846	0.357142857	0	0	0
Bobcat	0.072751323	0.111111111	0.063969659	0.035353535	0
Gray Fox	0.042328042	0	0.013274336	0	0
Coyote	0.07936508	0.116402116	0.054266751	0.151515152	0.029069767
Black Bear	0.009259259	0	0	0	0
Skunk	0.007936508	0.047619048	0.088969659	0.04040404	0
Raccoon	0.014550265	0.071428571	0.080815423	0.353535354	0.046511628
Opossum	0	0	0.046112516	0.045454545	0.029069767
Beaver	0	0	0.022123894	0	0
Jack Rabbit	0.002645503	0.044973545	0.007142857	0.01010101	0.005813953
Squirrel	0.003968254	0.018518519	0.082142857	0.085858586	0.058139535
Boar	0.009259259	0	0	0	0
Red Fox	0	0	0.010714286	0	0
Otter	0.007936508	0	0	0	0

Fig. 7: Frequency by site and species for Putah Creek, CA. Sites arrayed along a longitudinal gradient. INTDM is located at river mile 3, OXBOW at 9, RUSSR at 17, STVBR at 18-19, and CDEAS at 28-29.

B. Bioaccumulation of methyl-mercury

Natural weathering, mining waste, venting from natural geothermal springs, and discharges and runoff have all contributed to the introduction of mercury to the area's water bodies. Putah Creek has been listed on the Clean Water Act Section 303(d) list of impaired water bodies for excessive mercury. In 2009, we collaborated with scientists at USGS to investigate methyl-mercury loads in cavity-nesting birds breeding along Putah Creek. As expected, USGS found that methyl-mercury loads in eggs from boxes nearer the creek contained higher levels of mercury than boxes further away (Fig. 9). This is presumably due to the greater percentage of mercury-laden aquatic prey consumed by the parent birds compared with birds nesting in uplands. Mercury loads also increased with distance downstream, presumably because lower flow velocities and longer residence times facilitated conversion of inorganic mercury to methyl-mercury.

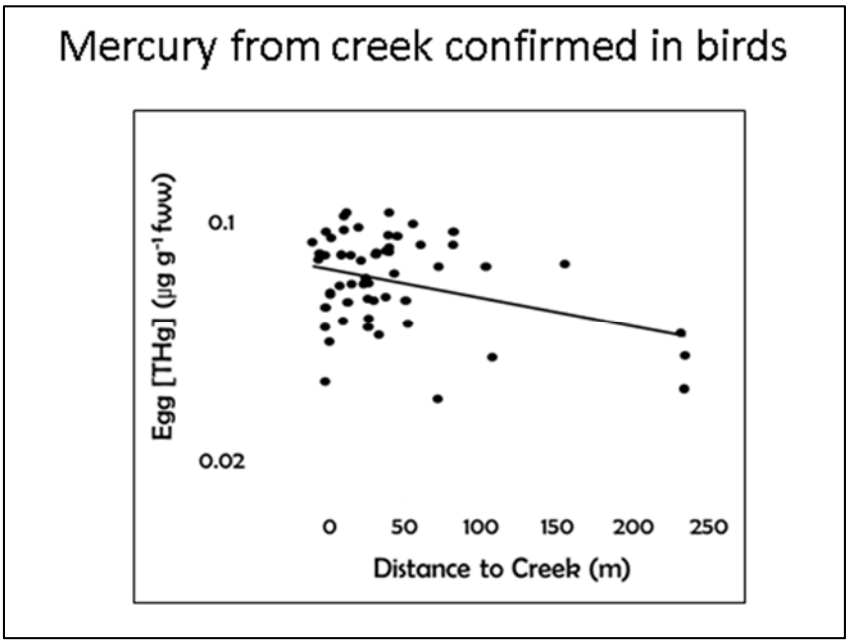


Fig. 9. Methyl-mercury loads in sampled Tree Swallow eggs from nest boxes located at increasing distances from Putah Creek. (USGS 2009)

The levels observed are not expected to be lethal, but research has shown that even low-levels of mercury (analogous to those observed in the wild) can lead to deleterious effects. This includes changing vigilance towards risk (Kobiela et al. 2015) and nest attendance (Jackson et al. 2011), which clearly impact a bird's fitness. Consequently, attention to

mercury dynamics during restoration remains important. These findings have direct relevance to restoration of aquatic habitats along Putah Creek. Restoration actions that increase flow velocities and decrease residence times of water should discourage the conversion of inorganic mercury to methyl-mercury.

C. Peer-reviewed papers

1) Long-term changes in the breeding bird community reveal improvement in the condition of a novel riparian ecosystem

In this study, we quantified long-term changes in the density, diversity, structure, and stability of the breeding bird community and its functional groups with a focus on riparian-dependent species[1]. Biodiversity conservation increasingly depends on our ability to enhance the structure and function of human-modified, novel ecosystems which now dominate Earth's terrestrial surface. However, modifications to these ecosystems may be largely irreversible, making ecological restoration an unachievable goal and comparisons to undisturbed systems unrealistic. Instead, we adopted an alternative, reconciliation framework to evaluate long-term changes in the lower Putah Creek watershed, a novel riparian ecosystem in California's Central Valley, in response to management designed both to benefit biodiversity and meet human needs. We detected increases in the density and stability of the riparian-dependent species group, along with directional change in the structure of the overall breeding bird community toward increasing presence of riparian-dependent species. These responses echo previously-documented shifts in the fish community toward native species, providing evidence for improvements in the overall condition of this novel riparian ecosystem (Kiernan et al. 2012). However, we also identified functional groups that have not yet responded to management, indicating room for further improvement and identifying ecosystem attributes that may require additional attention. Our approach provides information valuable for assessing ecosystem condition, evaluating the effectiveness of management actions, and guiding conservation planning, particularly in a novel ecosystem.

2) Seasonal use of Putah Creek habitats by Neotemperate migrant birds

We used the results of our analysis of seasonal bird use at specific sites along Putah Creek to address the role of winter vs summer habitat quality in avian population regulation, and conservation (Dybala et al. 2015). There has been little discussion and/or analysis of the importance of conserving temperate wintering habitat for landbirds in North America,

[1] Dybala, K.D., A. Engilis Jr., J.A. Trochet, I.E. Engilis, and M.L. Truan. In review.

despite the presence of billions of Neotemperate migratory landbirds that winter in the United States every year. Thus, we believe that restoration actions could better target the wintering needs of these species.

To estimate the degree to which winter bird communities might be a conservation priority, we examined the temporal distribution of avian diversity using riparian habitat in the Putah Creek watershed, pairing these results with similar results obtained for the Cosumnes River Preserve (Sacramento Co) in California's Central Valley. Using hierarchical multispecies occupancy models to estimate seasonal species richness and phylogenetic diversity in each watershed, we found that total species richness was equally as high in winter as in summer, and that phylogenetic diversity was higher in winter, with a considerable proportion of the winter avian diversity attributable to boreal-breeding Neotemperate migrants. Our results provide evidence that maintaining and restoring high-quality riparian habitat for winter bird communities in California should be an important conservation priority. Broader recognition of the diversity of temperate winter bird communities and additional research into the factors affecting winter condition and survival would facilitate effective conservation of high-quality winter habitat, benefiting Neotemperate migrants and year-round residents during a season that has important impacts on their population dynamics.

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