Point Blue Report

Avian Monitoring of Northern Sierra Meadows

February 2015

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Conservation science for a healthy planet

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Cover photos*: The Yellow Warbler (*Setophaga petechia*) is now an abundant species along this restored reach of Red Clover Creek in the Upper Feather River watershed. Photos by Tom Grey and Stefan Lorenzato, respectively.*

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EXECUTIVE SUMMARY

Wet meadows that support a riparian deciduous vegetation community are arguably the single most important habitat type for birds in the Sierra Nevada. They support a diverse assemblage and high density of breeding birds, including several species of conservation concern. A substantial portion – likely more than half – of these meadows have been degraded or lost, reducing their value to birds, other wildlife, and people.

Restoration to reverse declines in meadow health has become a management priority in the Sierra Nevada. The Feather River watershed supports a relatively high density of hydrologically significant large riparian meadow systems. Point Blue has been monitoring meadow breeding bird populations in this watershed for nearly two decades.

We used a suite of previously identified meadow bird focal species to evaluate habitat quality for meadow birds at long-term monitoring sites and at sites recently restored. In comparing focal species metrics across the 22 meadow sites, we found little change in rankings between 2011 and 2014 for sites that have not been subject to restoration.

Our results provide evidence of the benefits to meadow birds from pond and plug restoration. We found a positive linear relationship with time since restoration and focal species abundance and richness for restoration sites up to 12 years old. Similarly, when we compared all sites that have been restored to reference sites, we found restored sites supported more species and higher abundance. Finally, using a before-after control-impact approach to evaluate the Red Clover Poco restoration, we found a clear decline 1 year following restoration followed by a substantial increase in focal species abundance from pre-treatment levels after only 4 years.

The meadows of the Feather River and adjacent watersheds are important for bird conservation in the Sierra Nevada. Our results suggest that while many of these meadows support very high density and diversity of meadow birds, many others support very low densities and diversity, indicating a need for restoration. Pond and plug restoration appears to be a useful tool in restoring meadow bird habitat in a relatively short period of time.

INTRODUCTION

Montane meadows are among the most unique habitat types in the Sierra Nevada. Access to perennial water and distinctive soil types leads to unique plant communities from the adjacent upland (Kondolf et al. 1996). Meadows are also disproportionately valuable compared to the area they cover in the Sierra Nevada for the ecological services they provide (Kattlemann & Embury 1996; Kondolf et al. 1996). Ecologically functional meadows are hotspots for biodiversity in the Sierra Nevada (Kattlemann & Embury 1996), and provide vital services such as flood attenuation, sediment filtration, water storage, and water quality improvement (DeLaney 1995; Woltemade 2000; Hammersmark et al. 2008), carbon sequestration (Povirk et al. 2001), and livestock forage (Torrell et al. 1996). Meadows that support riparian vegetation harbor high biological diversity. Less than 1% of the area of the Sierra Nevada is comprised of riparian habitat (Kattlemann & Embury 1996), but approximately 20% of the 400 species of terrestrial vertebrates that inhabit the Sierra Nevada are strongly dependent on riparian areas (Graber 1996). The Sierra Nevada's meadows support several rare and declining bird species, and almost every bird species that breeds in or migrates through the region uses riparian meadows at some point in their annual cycle (Siegel & DeSante 1999).

Unfortunately the majority of the meadows in the Sierra Nevada have been altered. Many are now in a state that is less productive, supporting fewer species and individuals of native animals and plants, and providing fewer ecological services (Ratliff 1985; Knapp & Matthews 1996; Castelli et al. 2000; Sarr 2002; Krueper et al. 2003). Grazing, timber harvest, roads, culverts, dams, diversions, mining, among other impacts, have contributed to meadow degradation (Ratliff 1985). Many of these systems cannot readily recover on their own (Allen-Diaz 1991; Micheli & Kirchner 2002; Chambers et al. 2004; Briske et al. 2008). Restoration to reverse the decline in meadow services has become a management priority in the Sierra Nevada region because of their high ecological value and limited landscape extent (NFWF 2010).

The Feather River watershed is a hotspot for meadow bird conservation in the Sierra Nevada. The proportion of the watershed that is comprised of meadow is among the highest in the Sierra Nevada, as it contains a number of very large meadow complexes such as those in Warner, Humbug , Red Clover, and Sierra Valley's. A few of the area's meadows still support among the highest densities of declining and threatened

meadow bird species in the Sierra Nevada. Species that have been extirpated in other parts of the Sierra, such as Swainson's Thrush and Willow Flycatcher, are still present, and Yellow Warbler is exceedingly abundant in remnant habitat in a number of locations. These high-density remnant populations are potential sources for colonizing restored areas. With its large meadow systems, existing populations of rare species, and a large number of highly degraded sites, meadow restoration in the Feather River Watershed should be a high priority for meadow bird conservation in the Sierra Nevada.

To evaluate the effectiveness of meadow restoration, we monitored a suite of meadow-associated bird species as indicators of meadow form and function. Birds are an effective tool for monitoring because: (1) many species are easily and inexpensively detected using standardized sampling protocols; (2) these species are sensitive to changes in habitat conditions, and (3) accounting for and maintaining many species with different ecological requirements can be used to implement landscape conservation strategies (Hutto 1998). For these reasons, using meadow-associated bird species as indicators of meadow form and function can be a powerful tool for informing adaptive management and restoration decisions in Sierra Nevada meadows. Birds can be used as indicators to identify conservation priorities, help guide meadow restoration design and management prescriptions, and establish and evaluate management and conservation targets. Further, birds are known to respond rapidly to riparian restoration efforts in the Western United States (Krueper et al. 2003; Gardali et al. 2006)

In this report we present information from long-term meadow bird monitoring in the upper Feather River and adjacent Deer Creek watersheds. We update comparisons of focal species metrics using 2014 data at our 22 meadow sites surveyed and provide an initial assessment of the response of meadow birds to pond and plug restoration.

METHODS

Study Location

The study occurred within the upper Feather River and Deer Creek watersheds at the intersection of the Sierra and Cascade mountain ranges in northeastern California (Figure 1).

Site Selection

Several considerations went into selecting the meadow sites we sampled (Table 1; Figure 1). Following an inventory of 16 meadows in the greater Almanor Ranger District (ARD) area from 2000–2003, we selected eight meadows in the Upper North Fork Feather River and Deer Creek watersheds for long-term bird monitoring. We were interested in surveying wet meadows that supported (or should support) a riparian deciduous shrub community, and especially those sites that had recently undergone management changes (e.g. removal of grazing). With these two considerations in mind, we attempted to choose sites that represented the range of meadow settings and habitat conditions. Sites within the Last Chance, Red Clover, and Middle Fork Feather River watersheds (eastern Feather sites) were selected in 2009 and 2010 to monitor proposed or completed pond and plug meadow restoration projects. In 2010 we added Child's Meadow to our list of sites following its acquisition by The Nature Conservancy because it was adjacent to another long-term study site and provided a useful comparison of different long-term management strategies. In 2011 another new site in the Middle Fork Feather River watershed in Sierra County was added to monitor the response of meadow birds to cessation of grazing and willow planting. Finally, we used data for one analysis from an additional pond and plug project on a tributary to the Fall River in Shasta County.

Point Counts

Point count data measures secondary population parameters such as avian abundance, species richness, and diversity. Using these population parameters, we can make inferences about the avian community across time, locations, habitats, and land-use treatments. We conducted standardized five-minute variable circular plot point counts (Reynolds et al. 1980; Ralph et al. 1995). At each site we established multiple point count stations. Point count stations were placed a minimum of 50 m from meadow edges where feasible, and within 50 m of the primary stream channel where they existed. If the riparian corridor was less than 100 m wide, points were placed equidistant from each edge. Points along each transect were spaced at 200–250 m intervals. This resulted in a total sample of 265 points in the study area including: 77 points in the Upper North Fork Feather River sub-watershed; 39 points in the Deer Creek watershed; 54 points in the Last Chance Watershed; 67 points in the Red Clover Creek watershed; and 28 points in the Middle Fork Feather River watershed (Table 1).

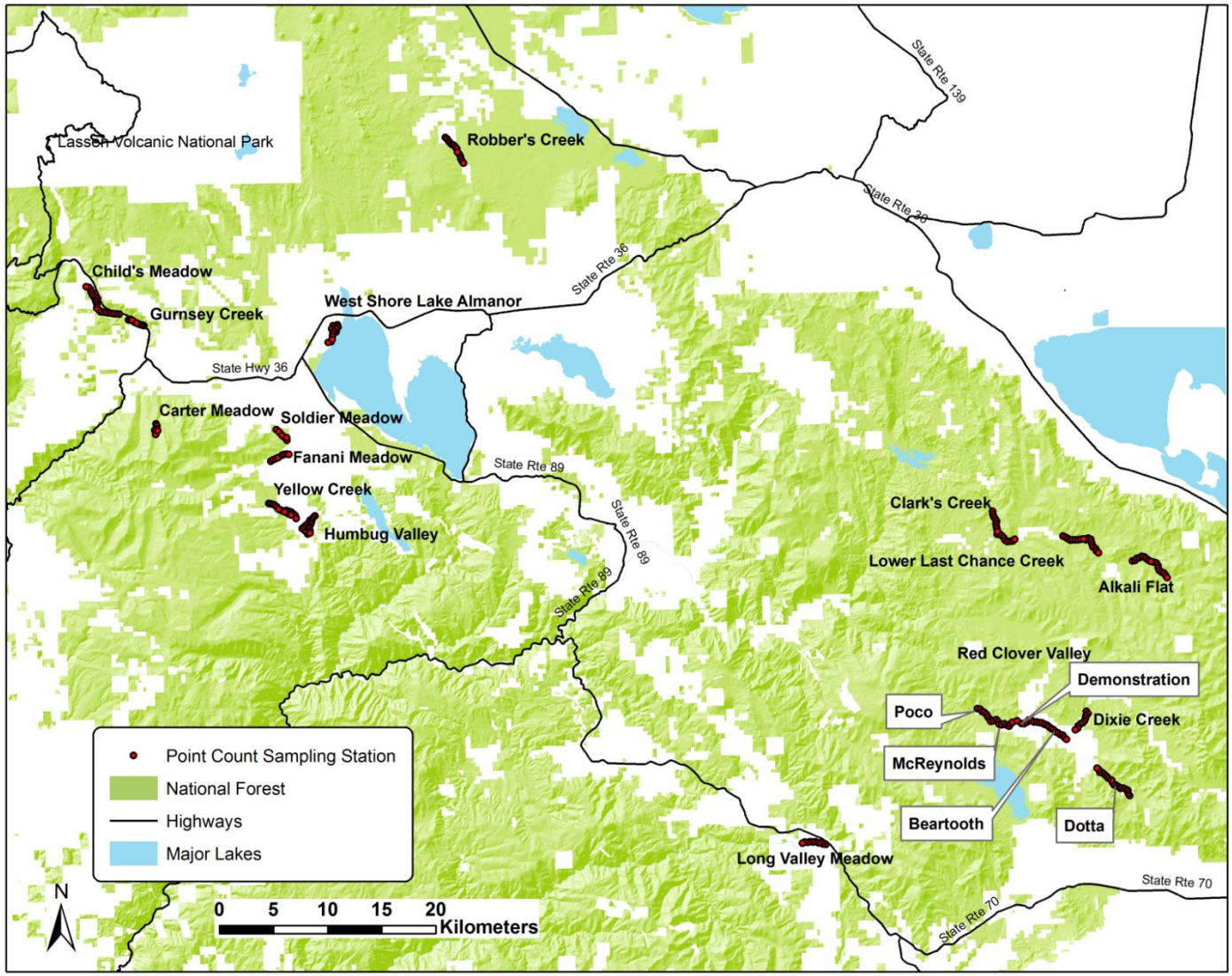

Figure 1. Location of meadow bird monitoring transects surveyed in 2014 in the Feather River and Deer Creek watersheds. Lemon Canyon Ranch is not on the map - located approximately 50km southeast of Red Clover Valley.

Table 1. Meadow point count transects surveyed in the upper Feather River and Deer Creek watersheds with transect codes, year established, and dates surveyed in 2014.

Transect	Code	# of points	Year established	1st Visit	2nd Visit
Lake Almanor Watershed					
Robber's Creek	ROCR	14	2004	10-June	30-June
West Shore Lake Almanor	WSLA	13	2004	30-May	25-June
Butt Valley Watershed					
Fanani Meadow	FAME	8	2003	9-June	27-June
Soldier Meadow	SOME	7	2001	9-June	27-June
Yellow Creek Watershed					
Humbug Valley	HUVA	17	2003	4-June	24-June
Yellow Creek Riparian	YCRI	18	2001	28-May	18-June
Deer Creek Watershed					
Carter Meadow	CAME	7	2004	13-June	28-May
Gurnsey Creek	GUCR	10	1997	13-June	28-June
Child's Meadow	CHME	22	2010	11-June	27-June
Last Chance Watershed					
Alkali Flat	ALFL	18	2009	2-June	26-June
Clark's Creek	CKCR	18	2009	2-June	24-June
Lower Last Chance Creek	LLCH	18	2009	2-June	26-June
Red Clover Watershed					
Dixie Creek	DXCR	10	2010	12-June	23-June
Red Clover Beartooth	RCBT	11	2010	3-June	19-June
Red Clover Demonstration	RCDE	5	2010	3-June	19-June
Red Clover Dotta	RCDO	18	2010	3-June	19-June
Red Clover McReynolds	RCMC	13	2010	3-June	19-June
Red Clover Poco	RCPO	10	2010	3-June	19-June
Middle Fork Feather Watershed					
Long Valley Meadow	LVME	10	2010	4-June	16-June
Lemon Canyon Ranch	LCRA	18	2011	27-May	10-June
Total		265		27 -May	30 -June

We recorded all birds detected at each station during the five-minute survey. We placed detections in one of six distance categories (< 10 m, 10–20 m, 20–30 m, 30–50 m, 50–100 m, and >100 m) based on the initial detection distance from the observer, and recorded the method of initial detection (song, visual, or call). We recorded separately those birds flying over the study area and not observed using the habitat. Counts began around local sunrise and were completed within four hours. We visited each transect twice each year between 27 May and 10 July (Table 1 for 2014 dates). Surveys were completed by highly experienced observers with extensive knowledge of the songs and calls of northern Sierra birds and well-versed in point count methodology. Observers used an electronic range finder to assist with distance estimation at each point count station.

Focal Species

Our analysis was limited to focal species, representing only a subset of the species encountered. A focal species group is likely to provide a better measure of the health of meadow habitat than using all species combined (Chase & Geupel 2005). We used the 14 meadow focal species identified by Campos et al. (2014). The primary considerations for inclusion were a strong association with meadow or riparian habitat and appropriately surveyed with passive point count methods. As a sum they represented a range of meadow habitat attributes and included: Wilson's Snipe (*Gallinago delicata*), Red-breasted Sapsucker (*Sphyrapicus ruber*), Calliope Hummingbird (*Selasphorus calliope*), Willow Flycatcher (*Empidonax traillii*), Swainson's Thrush (*Catharus ustulatus*), Warbling Vireo (*Vireo gilvus*), Wilson's Warbler (*Cardellina pusilla*), Yellow Warbler (*Setophaga petechia*), MacGillivray's Warbler (*Geothlypis tolmiei*), Song Sparrow (*Melospiza melodia*), Lincoln's Sparrow (*Melospiza lincolnii*), Mountain West White-crowned Sparrow (*Zonotrichia leucophrys oriantha*), and Black-headed Grosbeak (*Pheucticus melanocephalus*).

Pong and Plug Restoration

A number of the meadows evaluated in this report have been restored using the pond and plug technique. For those unfamiliar with this approach, a brief summary of the approach may prove useful in interpreting our results. Pond and plug restoration is a technique in which (a) alluvial materials are excavated from the existing incised channel and floodplain using heavy equipment, (b) excavated alluvial materials are used to plug sections of the incised channels (c) stream flow is then re-routed into a remnant channel

or a newly constructed channel with smaller dimensions (especially depth) than the degraded incised channel. The excavated areas then fill as the ground water elevation rises to near the meadow surface forming a series of ponds. The primary goal of this technique is to restore connectivity between the stream and its floodplain. In all of these projects grazing was rested for at least 3 years following restoration, but thereafter grazing intensity varied by site and year at generally low to moderate intensity.

Table 2. Point Blue meadow bird focal species and their conservation status. NTMB = Neotrpical Migratory Bird.

Common Name	Species Name	Conservation Status
Sandhill Crane	*Grus Canadensis*	State Threatened
Wilson's Snipe	*Gallinago delicata*	NTMB
Red-breasted Sapsucker	*Sphyrapicus ruber*	Declining in the Sierra[1]; NTMB
Calliope Hummingbird	*Selasphorus calliope*	USFWS Species of Concern
Willow Flycatcher	*Empidonax traillii*	State Endangered, USFS Sensitive, NTMB
Warbling Vireo	*Vireo gilvus*	NTMB
Swainson's Thrush	*Catharus ustulatus*	Declining in Sierra[1], NTMB
Black-headed Grosbeak	*Pheucticus melanocephalus*	NTMB
Yellow Warbler	*Setophaga petechia*	State Species of Special Concern, NTMB
MacGillivray's Warbler	*Geothylpis tolmiei*	NTMB
Wilson's Warbler	*Cardellina pusilla*	Declining in Sierra[1], NTMB
Song Sparrow	*Melospiza melodia*	None
Lincoln's Sparrow	*Melospizia lincolnii*	NTMB

[1]Based on Sauer et al. 2013, NTMB = Neotropical Migratory Bird.

Statistical Analysis

For all analyses we used naïve point count detections uncorrected for detection probability, thus abundance metrics herein represent indices rather than true densities (Johnson 2008). We had no reason to suspect that detectability of species varied among transects because the vast majority of detections were auditory and listening conditions

within 50 m were excellent at all transects. The indices of bird abundance and species richness herein are defined as the mean number of individuals and species detected per point per visit in one year. Abundance and richness estimates from all points within each site within a year were averaged to produce the point-level estimates of abundance and richness for each site. Calculating means of the indices of abundance and species richness for transects allows for comparisons between sites or habitats consisting of different numbers of point count stations, but does not provide a measure of the total number of individuals or species across an entire transect or individual meadow.

First, we calculated the mean per-point focal species richness and abundance (sum of all detections of all focal species) within 50 m of the observer at each of 22 meadow sites in 2014. We used the average from the two visits to each site. We present this information along with the average from all sites combined with the 95% confidence interval surrounding that estimate. We used the same calculations to compare differences between 2011 and 2014– the wettest and driest year in our 10 year dataset, respectively – at the nine west side meadows in our dataset. We excluded the eastern Feather River sites because the majority of those sites have been restored in the last 10 years.

We then used generalized linear mixed effects models to test for differences in focal species abundance, focal species richness, Song Sparrow abundance, and Yellow Warbler abundance, between the pre-restoration 2010 breeding season and post-restoration years from 2011–2014 at Red Clover Poco. We chose these species because they represent the vast majority of our focal species detections at these sites. We employed a before-after control-impact framework for this analysis. Our impact sample included 10 points in the Red Clover Poco restoration area. Our control sample included the 63 point count locations that have not been restored as of the 2014 breeding season in the Red Clover and adjacent Last Chance Creek watersheds. The sample unit was a single visit to a 50-m radius point count station. We used the count for each species for each survey visit for all individuals within 50 m of the observer. Year and restoration status (unrestored/restored) were included as factors and were the only fixed effects in the model. We included point and transect as random effects, with a separate intercept modeled for each point and transect to account for the repeated measures on points and transects within and among years. Residual plots of the models indicated that the Poisson distribution fit the data well. A significant ($P < 0.1$) treatment-by-year interaction term indicated an effect of treatment in a given year post-

restoration. We relaxed the threshold for significance to account for the very small sample size and thus power to detect an effect.

To investigate the response of birds up to 12 years since restoration at pond and plug meadow restoration sites, we used generalized linear mixed effects models to test for trends in focal species abundance, focal species richness, Song Sparrow abundance and Yellow Warbler abundance at six restoration sites in the North and Middle Fork Feather River watersheds, and one along Bear Creek – a tributary to the Fall River in Shasta County. As of 2014 these seven sites were between 1 and 12 years post-restoration. As such, this is a space-for-time-substitution analysis, which is widely used in ecological modeling. The sample unit was the count of each species within a 50-m radius point count station. We used the maximum count for each species over the two (or in the case of Bear Creek one) surveys for each year for all individuals within 50 m of the observer. The fixed effect in this model was the year since restoration, treated as an integer. Point, transect, and the year of the survey were treated as factors and included as random effects, with a separate intercept modeled for each factor level in each random effect to account for the repeated measures at each of these scales. Residual plots of the models indicated that the Poisson distribution fit the data well. We used a likelihood ratio test to evaluate whether the inclusion of a quadratic term on year since restoration provided a better fit to the data compared to the non-quadratic fit.

Lastly, we compared metrics of avian abundance and richness at restored and unrestored point count stations in the North and Middle Fork Feather River watersheds (eastern Feather sites only). We used t-tests to evaluate differences in pooled focal species abundance and focal species richness.

All statistical analyses were performed in program R version 3.0.2 (R Core Team 2013). Generalized linear mixed models were built with a Poisson probability distribution and log link function using the package lme4 (Bates et al. 2011). The threshold level of significance for all statistical tests, unless otherwise noted, was $P = 0.05$.

Data Management & Access: Sierra Nevada Avian Monitoring Information Network

All avian data from this project is stored in the California Avian Data Center and all public land data can be accessed through the Sierra Nevada Avian Monitoring Information Network web portal (http://data.prbo.org/apps/snamin). At this site, species lists, interactive maps of study locations, as well as calculations of richness,

density, and occupancy can be generated as selected by the user. Study site locations can also be downloaded in various formats for use in GPS, GIS, or online mapping applications as well. Non-avian data (e.g., site narratives, vegetation) are stored on Point Blue's server and backed up off-site.

RESULTS

Meadow Comparison

In 2014, we monitored 22 meadow transects/project areas in the Feather River and Deer Creek watersheds. Focal species richness ranged from a high of 1.7 species/acre at Yellow Creek Riparian to a low of 0.1 at Red Clover Dotta Restoration, with a mean of 0.9 (*95% CI*: 0.5 – 1.2) across all transects (Figure 2). Combined focal species abundance ranged from 2.6 individuals/acre at Red Clover McReynolds to 0.1 at Red Clover Dotta Restoration. Song Sparrow was the most abundant species across all point count locations, averaging 0.57 individuals/acre, followed by Yellow Warbler (0.38), Red-winged Blackbird (0.34), Brewer's Blackbird (0.27), and Savannah Sparrow (0.13).

Dry vs. Wet Year

We compared focal species metrics in 2011 and 2014 at the nine west side meadows that have not been actively restored in our dataset. 2011 was the wettest year in our 11 year dataset and 2014 was the driest. Both focal species richness and abundance were higher ($P < 0.05$) in 2014 at five of the nine meadows; there was no difference between years at the remaining four (Figure 3). The two highest elevation sites, Carter Meadow and Robber's Creek, showed the greatest difference between years.

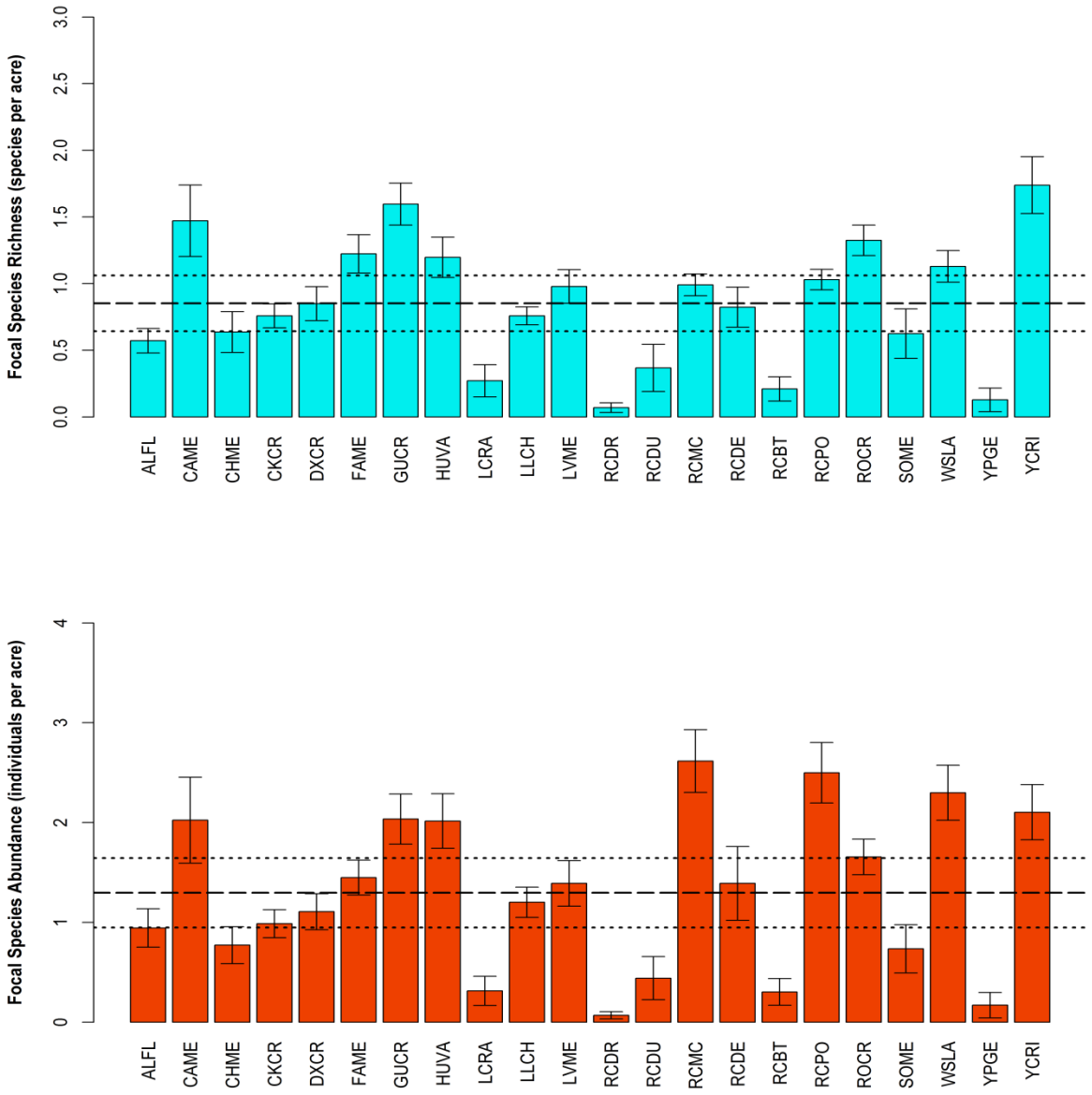

Figure 2. Focal species richness and abundance at 22 sites in the Feather River & Deer Creek watersheds in 2014. Dashed and dotted lines are the mean and 95% confidence interval for all sites combined, respectively. Error bars are standard error and transect codes are defined in Table 1.

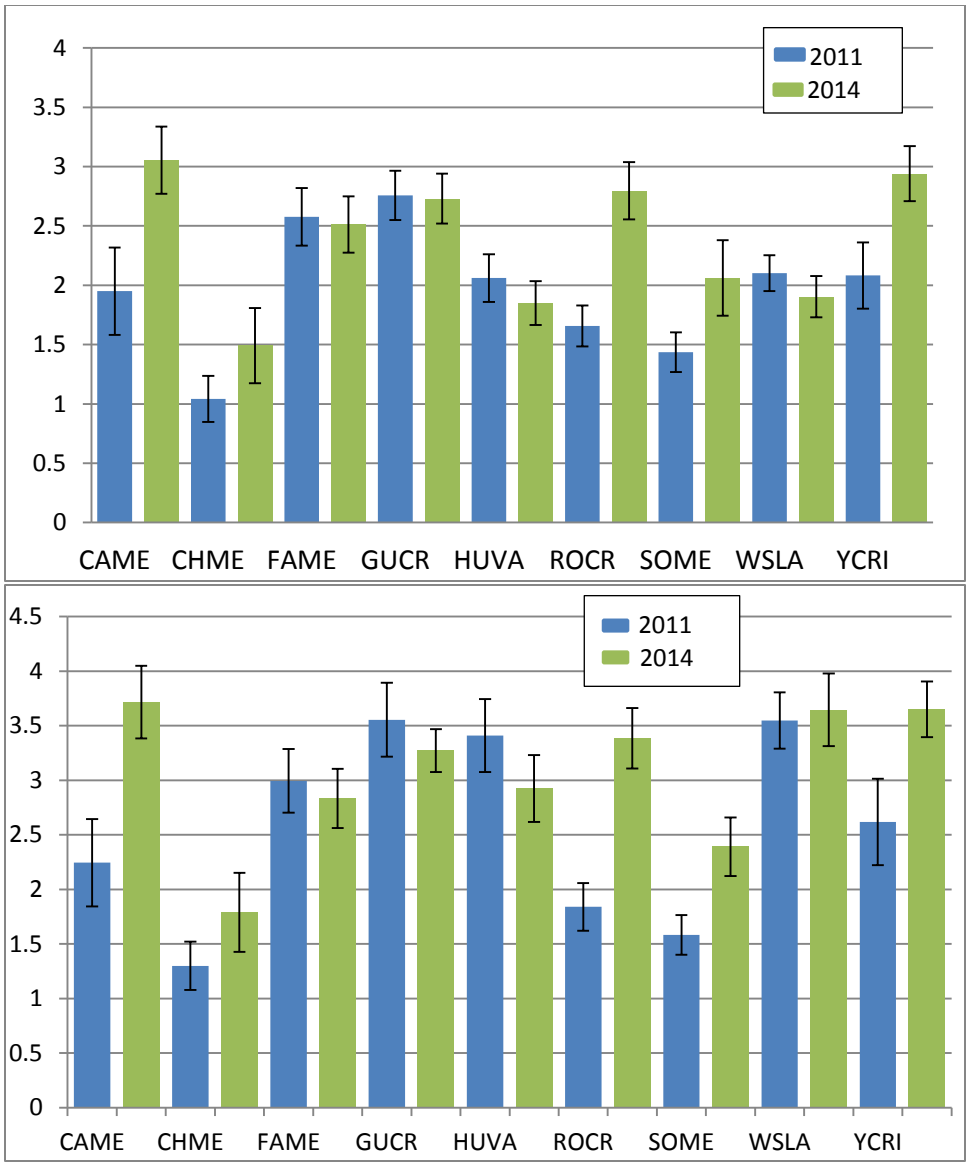

Figure 3. Focal species richness (top) and abundance (bottom) at 9 meadows in the Upper Feather River and Deer Creek watersheds in 2011 and 2014 with standard error. Transect codes are defined in Table 1.

Restoration effects at Red Clover Poco

Comparing metrics of avian abundance from the Red Clover Poco restoration and reference sites suggests some short-term negative impacts of the restoration on birds followed by a generally increasing trend (Figure 4). From 2010 (pre-restoration) to 2011 (first breeding season after restoration), both Yellow Warbler abundance ($P = 0.024$) and focal species abundance ($P = 0.018$) declined in the Poco project area compared to unrestored control locations. By 2012, both Yellow Warbler abundance and focal species

abundance returned to pre-restoration levels and have remained there or above through 2014. Song Sparrow abundance appears to have been increasing at Poco since 2011 compared to unrestored locations, however, due to our small sample size, only in 2014 was the difference large enough to be statistically significant ($P = 0.05$). In 2014, Song Sparrow abundance had increased 174% from 2010 levels, while at unrestored locations abundance increased 58%. We did not detect an effect of restoration on focal species richness for any year since restoration ($P > 0.1$). The Poco project area had significantly higher densities and richness of focal species prior to restoration than other sections of Red Clover Creek we have been monitoring (Figure 4).

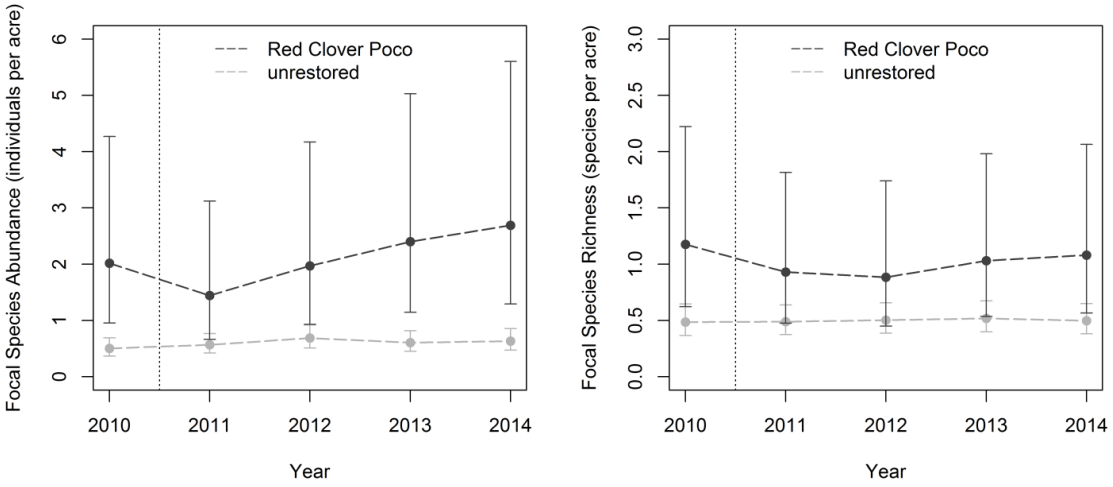

Figure 4. Focal species abundance and richness at Red Clover Poco before (2010) and after (2011 – 2014) restoration compared to unrestored areas with 95% confidence intervals.

Restored vs. Unrestored

At our eastern Feather River watershed sites, focal species abundance was 83% higher in 2014 at restored compared to unrestored sites ($\bar{x}_{\text{restored}} = 1.43$, $\bar{x}_{\text{unrestored}} = 0.78$, $t_{109} = 3.97$, $P = <0.001$) and focal species richness was 37% higher ($\bar{x}_{\text{restored}} = 0.74$, $\bar{x}_{\text{unrestored}} = 0.54$, $t_{143} = 2.68$, $P = 0.008$; Figure 5).

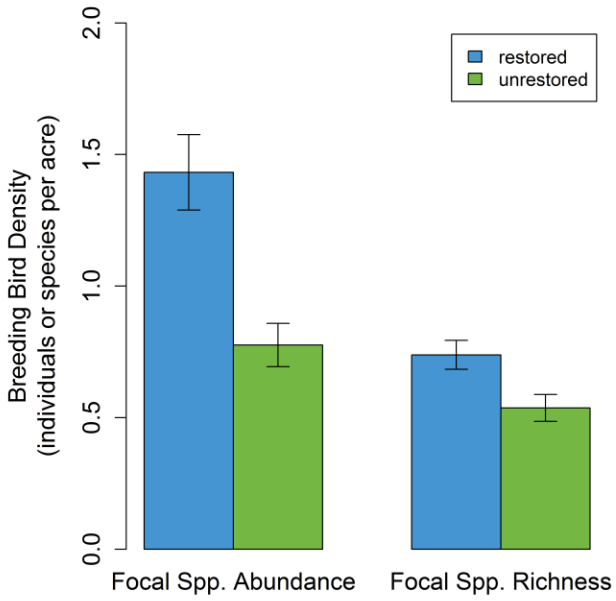

Figure 5. The abundance and richness of meadow focal species at restored and unrestored meadows sites in the the Feather River watershed in 2014 with standard error.

Time Since Restoration

We found a positive relationship with time since restoration for Song Sparrow and Yellow Warbler abundance, as well as focal species abundance, and a near-significant positive relationship with focal species richness (Figure 6). For every year after restoration our model predicted 6.8% more Song Sparrows ($P = 0.02$) and 9.4% more Yellow Warblers ($P = 0.02$) per acre compared to the previous year. Overall focal species abundance and richness were predicted to increase 85% and 68% from years 1 to 12 post restoration. A quadratic term for time since restoration was not supported for any of the response variables ($P > 0.1$) suggesting the density of meadow species is still increasing for at least the first 12 years following pond and plug restoration.

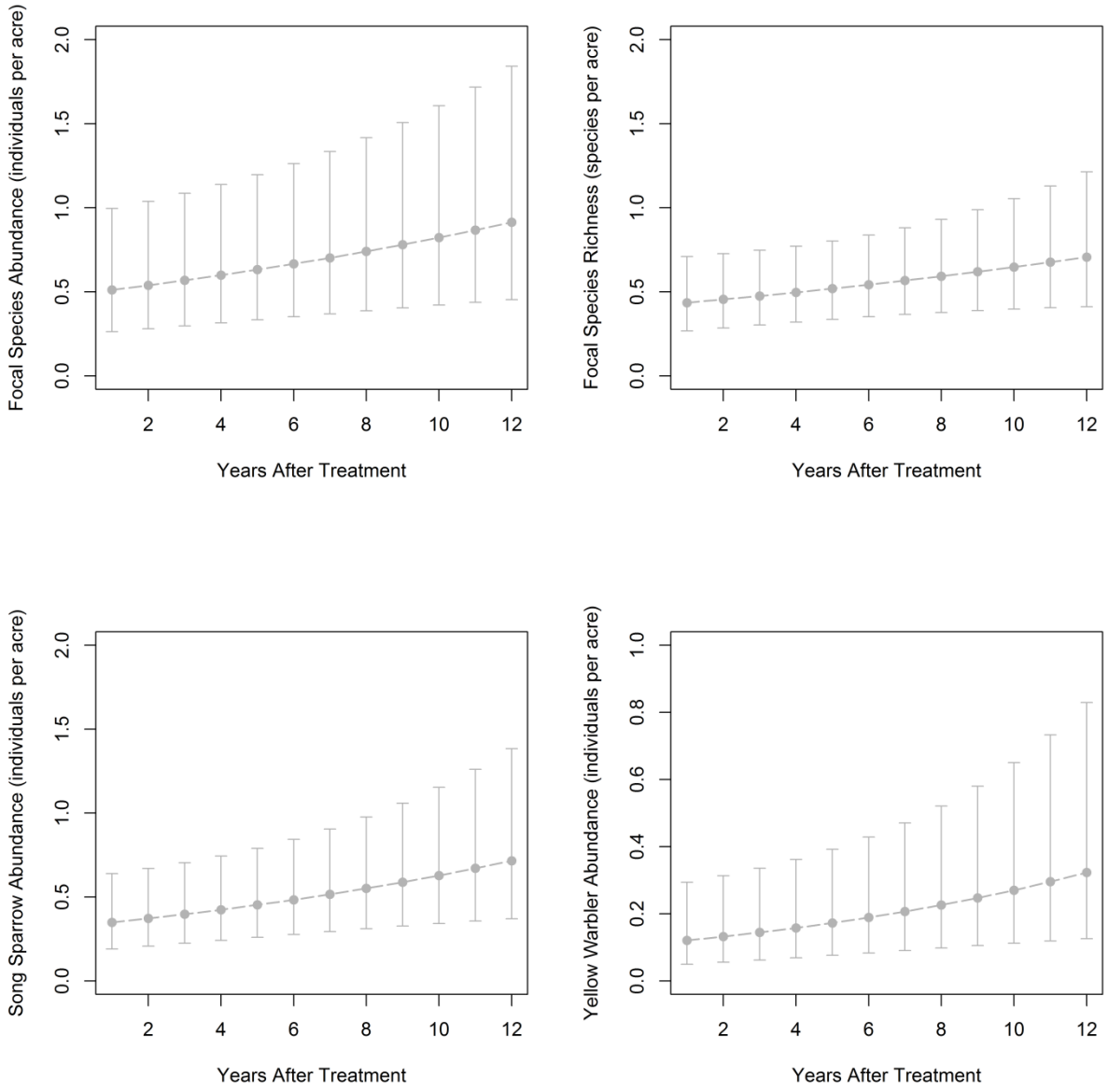

Figure 6. The effect of time since restoration on four meadow bird metrics at eight pond and plug restoration projects in the Northern Sierra and Southern Cascades with 95 % confidence intervals.

DISCUSSION

Meadow Comparison

Our findings in 2014 continue to illustrate the substantial variation in the density and abundance of birds across meadows in the Feather River and adjacent watersheds. A number of sites continue to support very rich and abundant meadow bird populations. Carter Meadow, Gurnsey Creek, and Yellow Creek support exceedingly rich meadow

bird communities, and Red Clover McReynolds and Poco along with Carter Meadow and West Shore Lake Almanor support very high densities of meadow birds. These sites are supporting 4 to 10 times more meadow bird species or individuals than degraded sites. While these eastern sites may not have the potential to support the same richness of meadow birds as west side meadows (Campos et al. 2014), data from restored reaches on these same streams shows these sites have the potential to support higher diversity and much higher abundance of meadow birds. The lack of riparian deciduous shrubs and trees and channel incision that impairs floodplain function is common to these sites that have depauperate meadow bird communities. Restoring floodplain function, actively planting riparian vegetation, and employing compatible grazing, can dramatically increase habitat suitability for meadow birds, as we discuss in the following sections.

Pond and Plug Restoration

The Red Clover Poco restoration project is one of the few pond and plug projects where we have both pre-restoration data and at least 3 years of post-restoration data. Our results suggest there may be a very short-term negative impact of restoration implementation on meadow birds. Though plug failures, that were not fixed until after the first growing season, may have delayed the vegetative response at this site and may explain some of the decline in bird abundance and richness we observed in 2011. Despite a small sample size that translates into low power to detect change, we were still able to detect a significant increase in the abundance of meadow focal species in the fourth year after restoration. The increase in focal species abundance was driven primarily by increasing density of Song Sparrows in the project area. Comparing pre-restoration data at Red Clover Poco to adjacent sites in the Red Clover Valley, we found Poco supported higher density and richness of meadow focal species than other sites in the valley (Burnett & Fogg 2011). If the density of birds is similar following restoration at Red Clover Beartooth and the recently completed Dotta project, these sites should realize even greater gains from baseline levels than Poco.

The first year of post-project data from the Yellow Creek PGE and Red Clover Dotta projects provides further indication that positive meadow bird response to restoration is not immediate. Both of these sites had among the lowest meadow bird indices prior to restoration and that did not change in 2014, the first growing season post-restoration. While restoring floodplain function and meadow wetness is surely important for

meadow-dependent birds, habitat structure – in the form of dense patches of riparian shrubs, trees, and sedges – are at least equally important (Campos et al. 2014). The time lag from restoration of function to structure development likely explains the trajectory in meadow bird densities we observed following restoration. Bird densities continue increasing over a decade post-restoration. High density willow planting and minimizing grazing pressure on riparian shrubs may accelerate the vegetation response to restoration, thereby accelerating the positive avian response.

The Clark's Creek and Alkali Flat pond and plug projects in the Last Chance Creek watershed have not realized the same increases in meadow focal bird species as those elsewhere in the Upper Feather River watershed. The riparian deciduous vegetation recruitment at these sites has been far below that observed in Red Clover Valley or Long Valley. The amount of post-project willow planting, grazing management, watershed area and position, or soil characteristics may all be influencing the response of vegetation at these sites. Continued monitoring of pond and plug restorations should be a high priority to more fully evaluate its effects on meadow birds across the Sierra Nevada.

The majority of pond and plug restoration sites are from areas with eastern Sierra habitat conditions and corresponding avian communities (e.g. eastern Feather River, Little Truckee River). The potential meadow bird richness at these eastern sites is lower than sites on the west side of the upper Feather River and Deer Creek watersheds (Campos et al. 2014). Thus, even under ideal conditions, the potential meadow focal richness of these sites is likely lower than those further west. Restoration of west side meadow habitats should be prioritized in order to promote meadow bird diversity in the Sierra Nevada. For example, the Yellow Creek Riparian transect, just upstream from Yellow Creek PG&E, has one of the highest meadow bird richness indices in our sample, demonstrating that the potential bird density for the recently restored PG&E project area greatly exceeds those on the east side of the watershed.

In 2014 there were no Willow Flycatcher detected breeding in any of the pond and plug projects we monitored. The two territorial birds detected in previous years at Long Valley have not been detected for two consecutive years. Based on our extensive experience evaluating Willow Flycatcher habitat in the Northern Sierra, many of these projects appear to be creating suitable habitat conditions for the species, including standing water, dense patches of willow, and a tall, sedge-dominated herbaceous layer.

We suspect this lack of a response is due to the distance of these sites from potential source populations. These pond and plug projects are all 30 km or more from known Willow Flycatcher breeding meadows; more than 20 km beyond the average dispersal distance observed for the species in the Sierra Nevada (Loffland et al. 2014). In Humbug Valley there are breeding Willow Flycatcher less than 2 km from the Yellow Creek PG&E restoration. This site should provide a better evaluation of the potential for pond and plug restoration to create habitat for this endangered species. Restoring meadows within close proximity to existing Willow Flycatcher occupied sites, especially those believed to have high productivity (e.g. Warner Valley), should be a priority to recovering this species.

Measures of Restoration Success

Using Campos et al.'s (2014) avian metrics of restoration success, 8 of the 22 meadow sites in this report met the criteria of high-quality habitat for focal species richness and 5 of 22 met the criteria for high-quality habitat for Yellow Warblers. We would expect a number of the sites in our dataset that have been restored in the last 3 years will begin to show increases in focal species in the next couple of years. Continued monitoring to ensure substantial investments in restoration are resulting in long-term success would be prudent.

CONCLUSIONS

Meadows are a small but disproportionately important component of the Sierra Nevada ecosystem. They provide a rich array of ecological services, not the least among them is the biodiversity they sustain. No single habitat is more important to the conservation of Sierra Nevada birds than wet meadows. Only three Sierra Nevada breeding bird species are listed as endangered in California: Sandhill Crane, Great Gray Owl, and Willow Flycatcher – dependence on healthy meadows is their common thread. While this report is limited to evaluating breeding birds, following the breeding season healthy wet meadows can be inundated with high densities of a diverse bird assemblage that use these areas for molting and fueling migration (Burnett & Geupel 2001). For these reasons, restoration of wet meadows should be among the highest priorities for avian conservation in the Sierra Nevada. There is clearly much work to be done to restore the many thousands of meadow acres that are not currently supporting the densities or diversity of meadow birds they almost certainly once did. Our results suggest the pond

and plug technique is a viable tool to significantly increase meadow bird density and richness in a relatively short time frame (~5 years). As momentum builds to restore the wet meadows of the Sierra Nevada, continued evaluation of meadow restoration projects will be needed to inform the adaptive management process.

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