BIRD DIVERSITY POST-FIRE IN BUTTE CREEK ECOLOGICAL PRESERVE

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DEDICATION

To my parents, Ruth and Tom Corridoni, for always believing in me and my goals. To my partner, Sam, for his unwavering support and encouragement. And to my dearest friend, Cesira, for always being there for me.

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ABSTRACT

BIRD DIVERSITY POST-FIRE IN BUTTE CREEK ECOLOGICAL PRESERVE

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Climate change and long-term fire suppression has led to a drastic increase in high-severity wildfires throughout the Western United States. In addition, there has been a substantial decline in avian biodiversity over the last fifty years, stemming from climate change and anthropogenic habitat loss and fragmentation. The 2018 Camp Fire in Northern California burned over 62,000 hectares of Sierra Nevada foothills, including a 37-hectare riparian corridor that runs along Butte Creek. Pre-fire, the Butte Creek Ecological Preserve served as key habitat for migratory and resident birds. The primary objective of this study was to examine the effect that wildfire had on bird species richness, diversity and relative abundance in the Preserve. The secondary objective was to investigate the presence and distribution of special status bird species throughout the Preserve. I analyzed five years of pre-fire and four years of post-fire point count survey data. A total of 80 avian point count surveys were conducted at eight points throughout the Butte Creek Ecological Preserve over nine years, beginning in 2006, and ending in 2022. Overall, bird community composition exhibited a slight post-fire shift, with an increase in ground-feeding species, and a reduction of aerial-foraging insectivores. There was a sizeable influx of non-native species within one year of the fire, particularly the European Starling

(*Sturnus vulgaris)*. There were also two non-native species detected solely post-fire, the Eurasian Collared-Dove (*Streptopelia decaocto)* and Rock Pigeon *(Columba livia)*. There was a moderate post-fire increase in the mean number of birds detected on the Butte Creek Ecological Preserve per survey. Woodpeckers appeared to benefit from the increase in snag habitat, as abundances doubled post-fire, and two new species were detected three years post-fire. Species richness increased post-fire, and pre- and post-fire diversity decreased minutely as well. There was an unusually high number of Willow Flycatcher *(Empidonax traillii)*, a California Threatened Species, detected post-fire in mid-August 2022. These data support that the Butte Creek Ecological Preserve remains to serve as crucial migratory stopover habitat for listed bird species as well as resident birds post-fire, and that overall bird diversity remained stable throughout a high-severity wildfire.

CHAPTER I

INTRODUCTION

Background

The repercussions of high-intensity wildfires on the landscape must be investigated if we intend to conserve biodiversity for the health of our ecosystems. Riparian ecosystems and the biota they support are vulnerable to the negative effects of wildfires, which increase in size and severity every year in the western United States. As climate change intensifies, high-severity wildfires will continue to be a major contributor to habitat loss, biodiversity decline, and species extinctions across the U.S. (Hoover and Hanson, 2022). There has been a cumulative decline of 2.5 billion birds across 419 species since the 1970's in North America (Rosenberg et al., 2019). This decline is attributed to habitat loss from both climate change and human development (Rosenberg et al., 2019). A loss of bird populations of this magnitude may result in species extinctions if no action is taken to remediate the habitat loss (Rosenberg et al., 2019).

Riparian ecosystems are integral to natural ecological processes, and the success and diversity of wildlife species may depend on the health and integrity of these areas (Riis et al., 2020). Riparian ecosystems play a vital role in robust avian populations by providing water, food, shelter, perches, breeding grounds, nesting sites and migratory stopover habitat (O'Connell et al., 1993). Conversely, the health of wild bird populations can be used as a factor in judging the health of the ecosystems in which they are found (Rosenberg et al., 2019).

California is a biodiversity hotspot, containing more ecosystems and wildlife species than any other state in the U.S. (Biodiversity, n.d.). As the third largest state, encompassing over 42 million hectares, it is not surprising that over 600 species of migratory and resident birds have been identified in California (Morgan and McNamee, 2023). Although California has been deemed ecologically diverse, as a result of habitat loss and fragmentation, biodiversity is declining at a rapid pace (Wiens and Gardali 2013; Biodiversity, n.d.). From 2018 to 2022, there was an average of 939,880 hectares burned annually in California (CAL Fire, 2022). In a severely burned forest, Knaggs et al. (2020) discovered a decreased bird species richness in comparison to low-intensity burned patches two years post-fire. Steel et al. (2022) found that ecosystems that have decreased edge and are affected by high-intensity fire are also predicted to decrease in bird species richness.

Despite the extensive research conducted in post-fire environments, research about how fire affects bird communities in riparian areas of California is lacking. More research is needed to better understand the long-term effects that fire can have on bird community composition. I will examine bird populations within the Butte Creek Ecological Preserve (BCEP), before and after high-severity wildfire. Eighty point count surveys were conducted over nine years, and I used this data to determine bird species richness, relative abundance, and diversity pre- and post-Camp Fire. In addition, the presence and distribution of special status bird species throughout the BCEP was investigated. These results will contribute to a growing body of knowledge of how birds respond to high-intensity wildfires and infer bird species resiliency to climate change.

CHAPTER II

LITERATURE REVIEW

Introduction

The following chapter is an overview of scientific literature pertaining to this research. The literature review will provide foundational background information about riparian ecosystems and their importance, as well as the habitat value they provide to birds. Then, the topics of naturally-occurring fire, wildfires driven by climate change, and the recovery of post-fire riparian ecosystems will be addressed. Additionally, the current research on the various bird responses to wildfire will be covered, as well as an overview of the special status species being studied, and the major threats to each of their populations.

Riparian Ecosystems

Riparian ecosystems are the areas of partially or mostly vegetated land immediately surrounding water bodies such as streams, rivers, and lakes, and the biological communities that inhabit them (Soman, 2007; Naiman and Decamps, 1997). The location of a riparian ecosystem is based upon the topography of the area, often found at the lowest point in a given region (Oakley et al., 1985; Dwire and Kauffman, 2003). According to the California Department of Fish and Wildlife's (CDFW) California Wildlife Habitat Relationships System (CWHR), Valley Foothill Riparian habitats can be identified by the presence of tree species such as: white alder *(Alnus rhombifolia)*, Fremont's cottonwood *(Populus fremontii)*, western sycamore (*Platanus racemosa*), box elder *(Acer negundo)*, valley oak *(Quercus lobata)* and Oregon ash (*Fraxinus latifolia)* (Mayer and Laudenslayer, 1988). Understory vegetation for Valley Foothill Riparian habitats is typically composed of native species such as: willow species *(Salix* spp.*)*, blue elderberry *(Sambucus cerulea)*, poison oak *(Toxicodendron pubescens),* California blackberry *(Rubus ursinus),* California grape (*Vitis californica)*, California rose *(Rosa californica)*, and buttonbrush (*Cephalanthus occidentalis*) (Mayer and Laudenslayer, 1988), as well as non-native species such as Himalayan blackberry (*Rubus armeniacus)*. Though riparian habitats make up a minority of habitat types in the United States, they are regarded as more biologically productive than any other ecosystem type (DeBano and Neary, 1996). Riparian ecosystems are often considered to be highly valuable to the biological communities surrounding them.

Riparian habitats provide essential ecosystem services that are vital to sustaining life (DeBano and Neary, 1996). Healthy riparian ecosystems support the productivity of diverse biotic communities (Gregory et al., 1991). The roots of riparian shrubs and trees can stabilize stream channels through soil retention (Soman, 2007). Riparian soil has complex root systems from flora growing near the water's edge which can filter out sediment, pollutants, and pesticides (Welch, 1991). This natural filtration system protects groundwater from contamination, and sedimentation resulting in improved water quality (Welch, 1991). Trees and shrubs can regulate water temperature by providing shade to the surface of streams, keeping water temperatures cool and stable, benefiting the health of both plants and animals (Gregory et al., 1991). Riparian habitats can be found next to low lying floodplains where the vegetation helps to slow flood waters, allowing recharge of groundwater aquifers (Welch, 1991). Shade provided by the tree canopies and evapotranspiration can cool surrounding air temperatures by 5°F-10°F (Meili et al., 2021).

Riparian ecosystems are especially valuable to wildlife species (O'Connell et al., 1993). Riparian ecosystems make up just 0.5% to 2.0% of the ecosystem types in the United States, yet they account for the majority of wildlife habitat (Dwire and Kauffman, 2003). Riparian areas are often highly trafficked by wildlife in search of a water source and represent the convergence of terrestrial and aquatic life (Oakley et al., 1985). Riparian habitats often have a dense tree canopy which provide wildlife with shade, cover, and protection from the elements (Norris, 2001). Research suggests that riparian ecosystems are significant in that they possess upwards of twice the amount of biodiversity as similar upland areas (Gregory et al., 1991). The rich biodiversity can be explained, in part, by the presence of water alone, which attracts all forms of life (Griggs, 2009).

Birds in Riparian Ecosystems

Riparian ecosystems support a diverse range of both resident and migratory birds. These areas are vital to maintaining rich biodiversity as they provide hunting grounds foraging habitat as well as food for many species (Gillies and Clair, 2008). The presence of shallow surface water on ponds and streams is used by many bird species foraging for small aquatic creatures and plants, such as waterfowl, rails, and heron species (*Ardea spp.)* (Oakley et al., 1985). In addition, the vegetated water's edge is where waterfowl are often found brooding and taking refuge (Oakley et al., 1985). The high concentration of dense, woody plants combined with downed woody debris provides shelter and hunting perches for many avian species (Naiman and Decamps, 1997). Due to the presence of lush vegetation in riparian areas, there can be an abundance of seeds and insects, which attracts both granivorous and insectivorous birds. With such an abundance of small ground-foraging birds using riparian habitats, predatory birds, such as hawks or owls, are often attracted to these areas. Osprey *(Pandion haliaetus)* are often attracted to broad snags to use as a nesting tree. Riparian ecosystems support bird foraging, hunting, breeding, rearing young, and provide critical migratory stopover habitat. Bird abundance and diversity depend on the health and intactness of these ecosystems (Oakley et al., 1985).

Riparian habitats offer an isolated environment, allowing for wildlife to migrate safely, absent of human interference. For example, in a spring study on migrating North American land birds, Skagen et al. (2005) found that migratory birds depend on access to riparian stopover habitat each year to complete their journey. The populations of land birds were the highest in riparian ecosystems with the greatest amount of tree canopy cover. In addition, birds appeared to prioritize high-quality riparian habitats in their migration routes. During fall migration, many birds rest, take refuge, and forage in riparian habitats. A decrease in riparian stopover habitat could lead to higher avian mortalities during migration, increased physiological stress on the birds, and lower rates of successful breeding the following spring. In order for birds to have access to adequate migration stopover habitat in the future, riparian ecosystems must be conserved (Skagen et al., 2005).

Fire

Fire as a Natural Disturbance

Fire is a natural process that has occurred in riparian ecosystems for thousands of years in the Western United States (Dwire and Kauffman, 2003; DeBano and Neary, 1996). Naturally occurring fires, often caused by lightning strikes, have occurred for hundreds of millennia. Indigenous tribes have been igniting fires on the North American continent for thousands of years (Ryan et al., 2013). Historically, naturally occurring low-intensity fires burned in numerous landscapes in North America, improving habitat for wildlife, bettering food sources for early people, and decreasing forest fuel loads (DeBano and Neary, 1996). There is a lengthy history of terrestrial environments evolving to need periodic fire to maintain a healthy structure (Dwire and

Kauffman, 2003). Studies report that fire in riparian ecosystems is required to maintain productive habitats, and that the biodiversity of these areas is conserved through natural disturbances such as fire (Bendix and Commons, 2017; Naiman et al., 1993). When an ecosystem becomes dependent on fire to sustain itself, balance can be difficult to maintain as long as fire is excluded (Agee, 1998).

Fire Suppression

Once Europeans settled in America, land use changed from periodic indigenous burning and sustainable tribal land stewardship, to logging, agriculture, and industry, severely altering previous fire regimes (Ryan et al., 2013). As urbanization expanded, fire was also increasingly suppressed, extending the fire return interval in many areas. Particularly in the Western United States, fire occurrence reached an all-time low by the 1970's (Ryan et al., 2013). Due to years of fire suppression, western forests accumulated greater amounts of leaf litter and dead woody material, resulting in dangerously high fuel loads. These high fuel loads can readily carry fire and contribute to higher intensity burns than an ecosystem may be adapted for. Restoring fire to its original role as a natural ecological disturbance is continually hindered by prolonged fire suppression (Saab and Powell, 2005).

Fire in Riparian Ecosystems

Riparian ecosystems possess unique characteristics that directly influence fire behavior (Dwire and Kauffman, 2003). Fire response in riparian ecosystems is dictated by fuel moisture, fuel distribution, stand density, vegetation type, and numerous other factors (Agee, 1993). Fuel loads are generally much higher in riparian ecosystems compared to upland areas in large part, due to the proximity to a water source (Pettit and Naiman, 2007). The proximity to water combined with a higher relative humidity, greater soil moisture, and enhanced shade from vegetation typically result in increased moisture content of both dead and live fuels (Dwire and Kauffman, 2003). These attributes can result in a lower fire intensity and a decreased fire return interval compared to that of higher elevations (Dwire and Kauffman, 2003). During wildfires, riparian ecosystems can play a unique role by acting as a fire break (Pettit and Naiman, 2007). A fire break allows for suppression to occur before the fire reaches landscape scale. In a study on wildfire in a coniferous forest in the Sierra Nevada mountains, just 6% of heavy fuels burned, while an estimated 90% of fine fuels burned (Bêche et al., 2005). As riparian ecosystems are burning hotter and more frequently in recent decades, the recovery process of post-fire riparian habitats must be understood.

Post-fire Riparian Ecosystems

The impacts of high-intensity wildfire in riparian ecosystems can be seen for decades (Williams and Bradstock, 2008). High-severity wildfires often consume vegetation, leaf litter, downed woody debris, organic matter, and oftentimes even tree canopies (Ice et al., 2004). Decreases in canopy shade and surface runoff can negatively impact water quality and elevate stream temperatures (Ice et al., 2004). Post-fire recovery outcomes are dependent upon the severity of the burn, local climate, elevation, proximity to a water source, and a multitude of other factors.

In low elevation low rainfall areas, the inundation of drought and fire-adapted species is a risk (Pettit and Naiman, 2007). In a study in a riparian forest in central New Mexico, it was suggested that wildfire is capable of increasing populations of the exotic species saltcedar (*Tamarix ramosissima)* while significantly decreasing populations of the native Rio Grande cottonwood *(Populus deltoides ssp. wislizenii)* (Smith et al., 2009). Although further research is required, this study has shown that both native and non-native species recover post-fire primarily via resprouting (Smith et al., 2009). Plant species that have adapted to resprout post-fire have an increased chance of recovery success over species that do not have this adaptation (Pettit and Naiman, 2007).

Disturbed landscapes, such as those affected by extreme wildfire, are more vulnerable to infestation of invasive plant species (Zouhar et al., 2008). Research illustrates that post-fire invasive species increases are often linked to a sharp increase in resources such as sunlight (Zouhar et al., 2008). High-intensity wildfire in riparian ecosystems increased infestations of the aggressive invasive non-native species, giant reed *(Arundo donax*) in many parts of the U.S. (Coffman et al., 2010). The giant reed populations were nearly 20 times greater in the year following a 121-hectare wildfire near the Santa Clara River in California (Coffman et al., 2010).

Many of the long-term effects that high-severity wildfires have on riparian ecosystems are not yet known. Although many trees are burned in wildfires, this results in an increase in the number of snags, which are used by cavity-nesting birds as well as wood-boring species (Block et al., 2016). Additionally, despite the general consensus that large fires are catastrophic to the environment, long-term effects of large wildfires are not always detrimental to the ecosystem (William and Bradstock, 2008). A diversity of intensities in a fire mosaic is a crucial aspect that often results in benefits to the environment rather than only consequences (Burton et al., 2008). There is much to be learned about the long-term effects of large wildfires, particularly once climate change, and more severe fire intensities are factored in (William and Bradstock, 2008).

Bird Response to Wildfire

Research on avian response to wildfire is lacking, and more studies are needed to understand the long-term effect fire has on bird populations. In a study in Canadian boreal forests, areas where wildfire burned at a high intensity resulted in a lower bird species richness and functional diversity compared to that of unburned patches or low-intensity burned areas (Knaggs et al., 2020). Another study based in ponderosa pine (*Pinus ponderosa)* forests in Arizona looked at the effects of wildfire on birds, and found that one-year post-fire, wood-boring species, such as woodpeckers, and ground-feeding bird numbers increased dramatically (Lowe et al., 1978). These findings could be due to an increase in snags with wood-boring insects as well as an open canopy and more exposed ground in the heavily burned areas (Lowe et al., 1978). In this study, it was found that aerial foliage-gleaners, such as flycatchers, plummeted to zero three years post-fire, which could be partly due to decreased nesting sites as well as foraging habitat (Lowe et al., 1978). Abundances of warblers, vireos and other foliage-gleaners decreased in high-intensity burned patches (Bock and Block, 2005). In contrast, in moderate to severely burned patches of forest, there was an increased species richness three years post-fire compared to patches that did not burn (Bock and Block, 2005). In addition, thrushes, flycatchers, and woodpeckers responded positively to fire and numbers improved post-fire (Bock and Block, 2005). There can be a temporary spike in populations of wood-boring birds two to three years post-fire, which often correlates to an uptick in insects living in snags (Covert-Bratland et al., 2006).

There is a considerable amount of variability in different bird species' success rates in post-fire environments. Overall bird diversity and abundance in a burned area should increase if the fire results in more habitat complexity (Saab and Powell, 2005). White-breasted Nuthatch (*Sitta carolinensis*) and Western Bluebird (*Sialia mexicana*) populations increased in areas with open canopies and decreased habitat diversity (Tietje and Vreeland, 1997). However, overall species richness improved in areas with diverse habitat structure, meaning the presence of downed woody debris, leaf litter, and a vegetated understory. Although wildfire burning the leaf litter can positively affect seed-eating bird populations, such as Lark Sparrows (*Chondestes grammacus)* and Mourning Doves (*Zenaida macroura)*, the influx in ground-foraging bird species is said to be short-lived (Lowe et al., 1978; Renwald, 1977).

Study Species

Populations of three special status species have been consistently documented on the BCEP pre-Camp Fire. The Yellow Warbler and the Yellow-breasted Chat are known to be present on the BCEP during the breeding season and may use this site to breed and rear young. The Willow Flycatcher uses the BCEP as migratory stopover habitat, before and after it breeds at higher elevations. These three species utilize riparian areas, such as the BCEP, to forage and take refuge in the hot summer months.

Yellow Warbler

The Yellow Warbler (*Setophaga petechia*) is a migratory songbird that is classified as a Species of Special Concern in the breeding season in California (Shuford and Gardali, 2008). The Yellow Warbler is divided into three subspecies groups and 34 subspecies. This study focuses on *Setophaga petechia aestiva,* known as the American Yellow Warbler, which breeds in continental North America down to parts of Mexico and has six subspecies (Lowther et al., 1999). Present for only their breeding season, the *Setophaga petechia aestiva* subspecies is documented in California from the end of March until the beginning of October (Dunn and Garrett, 1997). The majority of those breed between April and the end of July (Dunn and Garrett, 1997) and are recorded breeding at elevations up to 2,133 meters west of the Sierras (Shuford and Gardali, 2008). After the breeding season, Yellow Warblers spend winters in the south, ranging from northern Mexico to central South America (Shuford and Gardali, 2008).

A breeding male Yellow Warbler has vibrant yellow plumage with reddish-brown breast streaking, while female and juvenile birds sport muted yellow plumage and barely noticeable breast streaks. Both sexes as well as immature birds have distinctive beady black eyes. Adults are considered to be sparrow-sized, generally between 11.9 and 18 centimeters long with a wingspan of 15.2 to 22 centimeters. A Yellow Warbler has an unmistakable, sweet, musical song, and a sharp yet soft chip note for an alarm call. The average lifespan of a Yellow Warbler is from eight to 10 years old.

Yellow Warblers are foliage-gleaners and can be found hovering in place to eat insects from the underside of leaves and twigs of riparian trees. The diet of Yellow Warblers consists mainly of insects, including caterpillars, spiders and bees, but they also consume a small number of berries, mostly in the winter months (Green, 2005). Preferring riparian habitat, Yellow Warblers are often found near streams and wet meadows, within close proximity to a water source (Lowther et al., 1999). Yellow Warblers build cup nests out of grasses, cottonwood fibers, and other plant matter, often positioning their nests in the fork of willow branches. Depending on the region of California, Yellow Warbler nests can be found in many riparian tree and shrub species, including cottonwoods, willows, alders, and numerous others (Grinnell and Miller, 1944). The Yellow Warbler has an average of one successful clutch per year with three to six eggs per clutch (Green, 2005). Known for an elevated level of site fidelity, Yellow Warblers have been documented returning to breeding territories year after year in California. The Yellow Warbler has had a notable presence at the study site pre-fire, and there is potential for this species to use the BCEP to breed.

Yellow-breasted Chat

The Yellow-breasted Chat (*Icteria virens*) is considered as a Species of Special Concern during the breeding season in California (Shuford and Gardali, 2008). The Yellow-breasted Chat is comprised of two subspecies, both of which breed in North America. The *Icteria virens auricollis* subspecies nests west of the Rocky Mountains (Shuford and Gardali, 2008) and is the subspecies being studied in this thesis. Yellow-breasted Chats are an elusive migratory songbird found in California from the end of March until the end of September (Garrett and Dunn, 1981; Unitt, 2004). Yellow-breasted Chats have been documented breeding from late April until early August in California (Eckerle and Thompson, 2001, Unitt, 2004), and have been found breeding from the Sacramento Valley floor up to 1,524 meters in elevation (Grinnell and Miller, 1944). Yellow-breasted Chats spend winters in Mexico and Central America.

As the largest warbler in North America, the Yellow-breasted Chat ranges from 17.8 to 19 centimeters in length with a 24.7 centimeter wingspan. Mature birds have olive-green upperparts, a lemon-yellow throat and breast, and white spectacles surrounding a bold, black eye. The bill of a Yellow-breasted Chat is thick and dark, with a tail longer than most other warblers, and it is often seen tail pumping mid-flight. Yellow-breasted Chats are known for their unusual vocalizations, as their song is a disorganized arrangement of squawks, whistles, and rattles (Godfrey, 1986). Yellow-breasted Chats often have an elusive demeanor and are almost always hidden in dense brush, making them very difficult to observe. Their loud vocalizations are oftentimes the solitary indication of their presence (Gebauer, 2004). The life expectancy of a Yellow-breasted Chat is between five to eight years old.

A breeding Yellow-breasted Chat favors established riparian habitats with an open canopy and a dense shrub component (Shuford and Gardali, 2008) and tends to avoid grass-dominated areas (Kroodsma, 1982). Typical nesting habitat for the Yellow-breasted Chat contains dense willow stands, Himalayan blackberry thickets, or California grape (Grinnell and Miller, 1944; Kroodsma, 1982), and closely borders streams and rivers. Nests are generally constructed one meter off the ground, hidden in impenetrable Himalayan blackberry thickets (Ehrlich et al., 1988). Yellow-breasted Chats have clutches ranging in size from one to four eggs (Campbell et al., 2001) and normally have two broods per year. A study in Indiana reported that the Yellow-breasted Chat has very low return rates to the same breeding site year after year (Thompson and Nolan, 1973). They feed on both insects and fruits depending on local availability, including wasps, grasshoppers, and beetles, as well as wild grapes, blackberries, and elderberries (Ehrlich et al., 1988). There is documented pre-fire Yellow-breasted Chat presence at the study site, and they potentially could be breeding there.

Willow Flycatcher

The Willow Flycatcher *(Empidonax traillii)* is a neotropical summer migrant, and a member of the flycatcher genus, *Empidonax*. North American flycatcher species are a particularly difficult group to identify by plumage alone, which is why their songs are readily used to definitively distinguish between species. There are four subspecies of Willow Flycatchers, all of which breed in North America. *Empidonax traillii brewsteri* breeds west of the Sierra Nevada Mountains up to the Cascade Range in Washington, and it the subspecies being discussed in this thesis. The Willow Flycatcher is a California Threatened Species and is often present in California beginning in mid-May. As early as June, it can be found at 2,000 to 2,438 meter elevations during the start of its breeding season (Zeiner et al., 1990). During late summer to early autumn, from mid-August to mid-September, Willow Flycatchers are often seen at lower elevations migrating south down the state, typically in riparian habitat (Zeiner et al., 1990).

Willow Flycatchers overwinter in southern Mexico, Central America, and northwestern South America.

The Willow Flycatcher is a slender flycatcher whose body is about 14.9 centimeters long, and has a wingspan of 19 to 23.8 centimeters, with olive-brown upperparts and a white throat (Bombay et al., 2003). The Willow Flycatcher has a pale-yellow belly, a muted olive-colored breast, and a faint eye ring, which are all characteristics of several *Empidonax* flycatcher species (Bombay et al., 2003). Both sexes of Willow Flycatcher have similar plumage making it difficult to tell them apart. A juvenile Willow Flycatcher is distinguishable by their brown upperparts and their brighter yellow bellies. A Willow Flycatcher has a distinctive “fitz-bew” song, which is the primary vocalization used to rule out all other *Empidonax* species (Bombay et al., 2003). Although both sexes of Willow Flycatcher have been reported to “fitz-bew,” males are found singing the majority of the time to attract mates and to defend territories (Bombay et al., 2003). The lifespan of a Willow Flycatcher is between three and four years old.

The Willow Flycatcher forages mainly by flycatching, which is the behavior when they perch at the top of a tree or shrubs and fly out briefly to catch insects mid-air, then land on a branch again and repeat the process. The diet of a Willow Flycatcher consists of primarily insects, and occasionally berries and seeds. Willow Flycatchers prefer to breed in dense willow or alder thickets near to a water source. In most of California this species is known to breed in wet meadows or montane riparian ecosystems with dense willow cover (Zeiner et al., 1990). Their nests are constructed of grasses and plant material weaved together and anchored to a shrubby species, and placed near the edge of a shrub, roughly one meter off the ground. The clutch size of a Willow Flycatcher is often between two and four eggs (Sanders and Flett, 1989), and they almost always rear only one brood per year. As with many other passerine species, they have a high-level of site fidelity to previously used breeding territory (Sedgwick, 2004). The Willow Flycatcher has been detected at the study site pre-fire during spring and fall migration.

Threats to Special Status Birds

The Yellow Warbler and Yellow-breasted Chat utilize riparian habitats to breed, and the Willow Flycatcher requires these areas to ensure a successful migratory journey. The fragmentation and destruction of high-quality riparian habitat in California due to development is a significant threat to each of their populations (Wiens and Gardali, 2013). Since Yellow-breasted Chats rely heavily on dense understory habitat for nesting, they are vulnerable to the removal of vegetation during flood-control activities in agricultural areas (Remsen, 1978; Shuford et and Gardali, 2008). In addition, Yellow-breasted Chats are adapted to utilize early to mid-succession habitats maintained by periodic fire, and without this natural disturbance regime, they may not return to a site in favor of a more productive habitat. Riparian habitat destruction in California stemming from human population increase and development is a serious threat to Yellow Warblers populations due to their reliance on riparian corridors for breeding. The native species, the Brown-headed Cowbird *(Molothrus ater)* often parasitize nests of each the Yellow Warblers, Yellow-breasted Chats and Willow Flycatchers (Ehrlich et al., 1988). Another possible threat to their population is pesticide spraying. This pertains to birds living in close range of agriculture, and affects them negatively either through decreased insect populations, or through direct consumption of insects that have been sprayed (Finch and Stoleson, 2000). As stated by Shuford and Gardali (2008), an impactful way to conserve sensitive bird species dependent on riparian habitats in the coming decades is by implementing landscape-scale habitat restoration projects.

Statement of the Problem

The focus of this thesis is to determine if the 2018 Camp Fire had an effect on the bird populations at the Butte Creek Ecological Preserve (BCEP). This research will contribute to a better understanding of how birds respond to severely burned riparian habitats. This study additionally investigates the post-fire population changes and the current abundances of three special status bird species on the BCEP: the Yellow Warbler, Yellow-breasted Chat and the Willow Flycatcher. In order to conserve the highest-value natural resources on the BCEP, this study aims to investigate the distribution of special status species, as areas with higher detections of sensitive species may be regarded as more high-value.

Purpose of the Study

The purpose of this study is to answer the following questions:

1. How did the 2018 Camp Fire affect the species richness, relative abundance and diversity of the bird populations at the BCEP?
2. How have the relative abundances of Yellow Warbler, Yellow-breasted Chat and Willow Flycatcher changed on the BCEP post-fire, and what are their current distributions?

In reference to the first research question, I predicted that:

- Overall bird species richness will decrease post-fire (Knaggs et al., 2020).
- Ground-feeding species relative abundances will increase one year post-fire (Stoddard, 1963).
    - Woodpecker species (*Picidae* spp.) relative abundance will increase (Lowe et al., 1978).
    - Raptor species relative abundance will increase immediately post-fire but decrease three years post-fire (Landers, 1987).

    - Relative abundance of non-native (introduced) bird species will increase post-fire.
- Overall bird species diversity will decrease post-fire (Steel et al., 2022)

In reference to the second research question, I predicted that:

- The relative abundance of Yellow Warbler will decrease post-fire (Bock and Block, 2005) and will be detected the most at point one (Lacustrine and Valley Foothill Riparian habitat).
- The relative abundance of Yellow-breasted Chat will decrease post-fire and will be detected the most at point four (Valley Foothill Riparian and Blue Oak-Foothill Pine habitat).
- The relative abundance of Willow Flycatcher will decrease post-fire and will be detected the most at point five (Valley Foothill Riparian and Riverine habitat).

Definition of Terms

<u>California Threatened Species</u> – A native species or subspecies of bird, mammal, fish, amphibian, reptile, or plant that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by this chapter (CESA to the Federal Endangered Species Act, n.d.)

<u>Species of Special Concern</u> – The Department has designated certain vertebrate species as "Species of Special Concern" because declining population levels, limited ranges, and/or continuing threats have made them vulnerable to extinction. The goal of designating SSCs is to halt or reverse their decline by calling attention to their plight and addressing the issues of concern early enough to secure their long-term viability. Not all SSCs have declined equally; some species may be just starting to decline, while others may have already reached the point where they meet the criteria for listing as a threatened or endangered under state and/or federal endangered species acts (California Natural Diversity Database, 2023).

CHAPTER III

METHODOLOGY

Study Area

This study took place in Northern California (Figure 1), at the Butte Creek Ecological Preserve (BCEP) in Chico (Figure 2). Established in 1998, the BCEP was maintained with the principal objectives of preserving anadromous fish habitat, providing educational and research opportunities and restoring ecosystem processes (Hankins, 2007). The BCEP is a 37-hectare property encompassing a 1,219-meter stretch of lower Butte Creek and is located at the convergence of the Sacramento Valley and the foothills of the Sierra Nevada mountains. The BCEP is nestled in a valley surrounded by the rocky bluffs of Butte Creek Canyon and is primarily composed of Valley Oak Woodlands and Valley Foothill Riparian habitats (Figure 3). The land was purchased in 1998 and managed by Chico State Enterprises until September 2022, when there was a transfer of ownership and the Mechoopda Indian Tribe regained possession of their ancestral lands. The BCEP also serves as a wildlife migratory corridor for migrant birds, as well as a refuge for non-migratory species year round. Bordering the BCEP to the southwest is the California Department of Fish and Wildlife-owned 116-hectare Butte Creek Canyon Ecological Reserve, used for outdoor recreational activities.

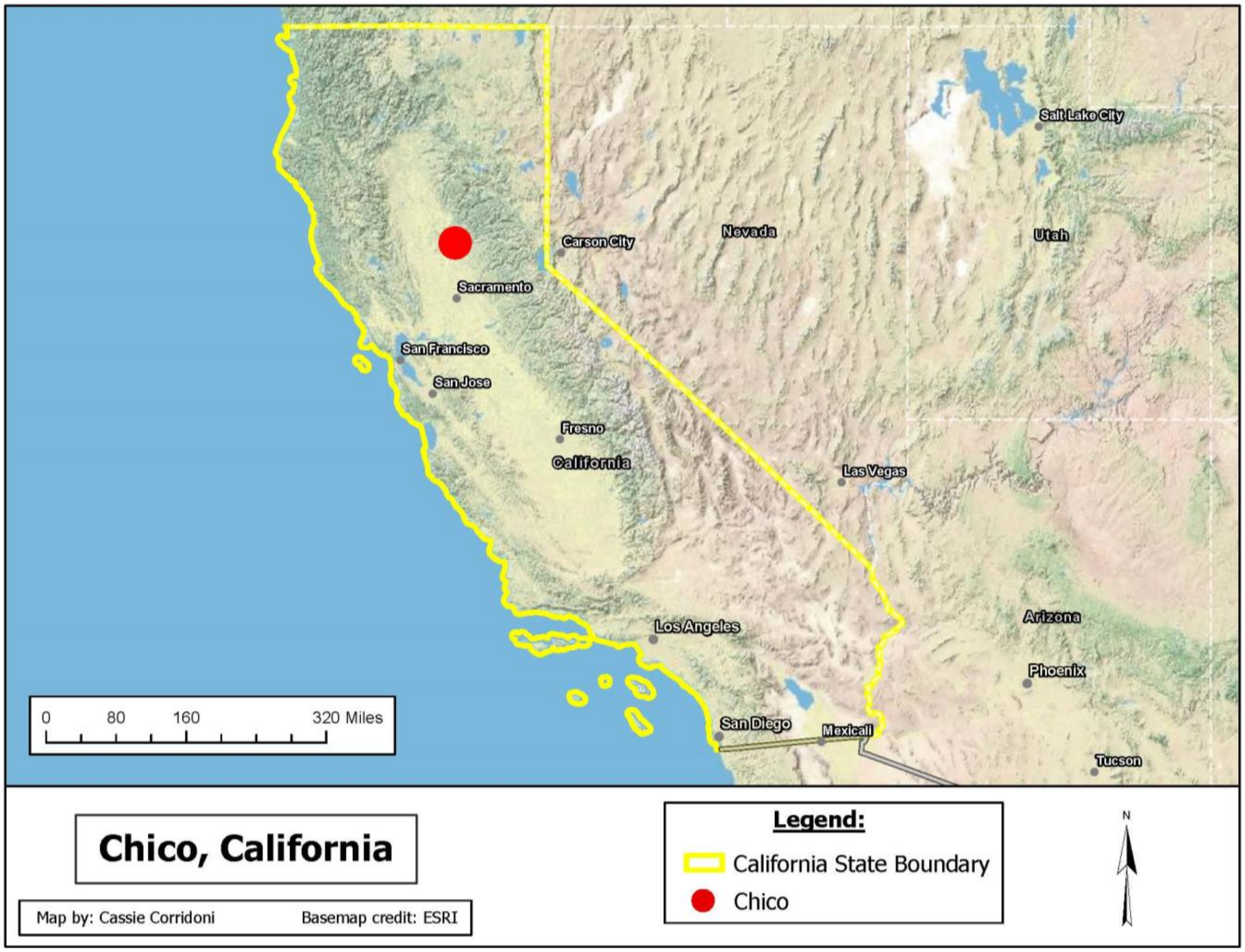

Figure 1. Chico, California**.** The Butte Creek Ecological Preserve study site is shown in red and is located in Northern California, at the start of the Sierra Nevada range foothills.

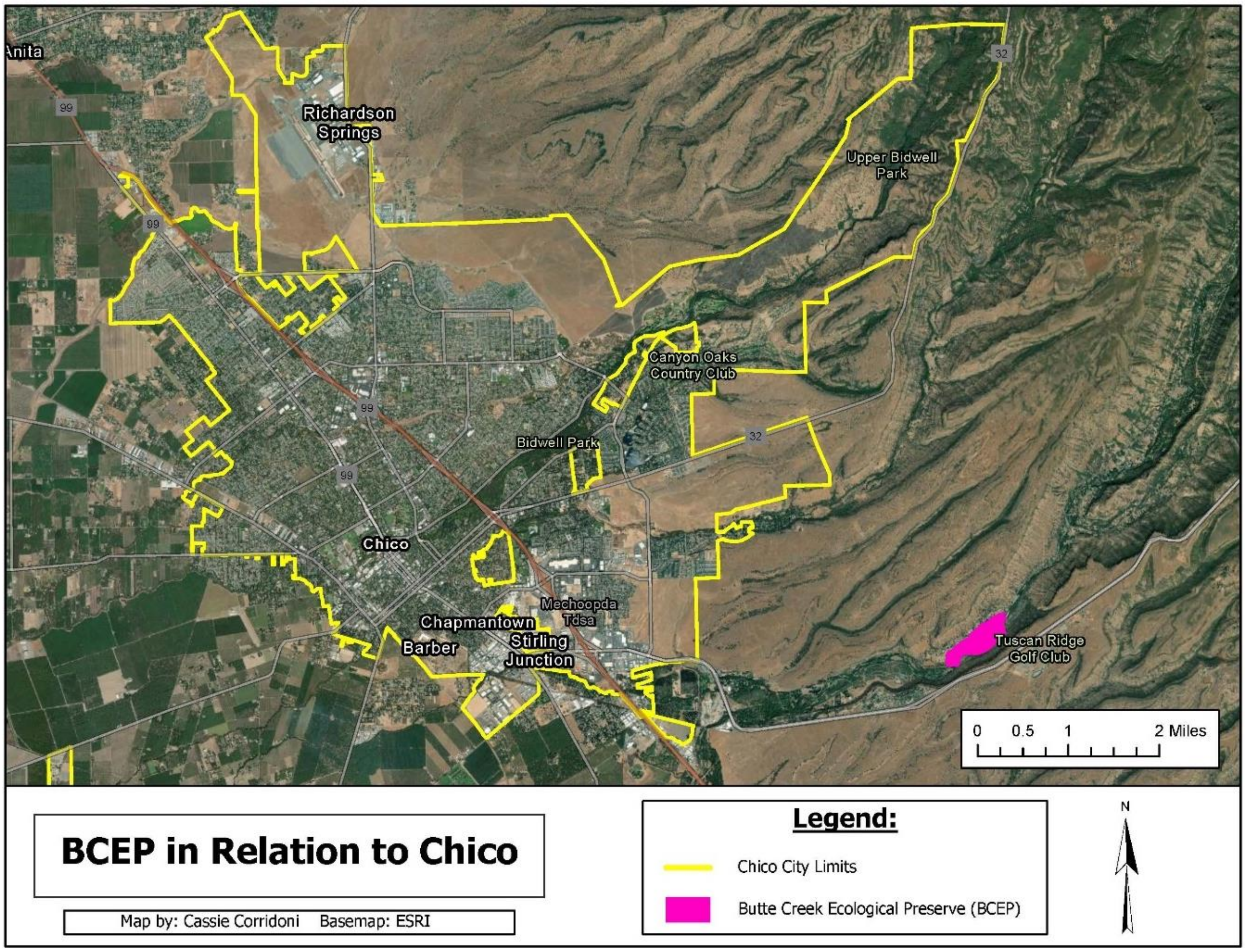

Figure 2**.** BCEP in Relation to Chico. The BCEP is located approximately 1.6 kilometers from Chico City Limits, in Butte County.

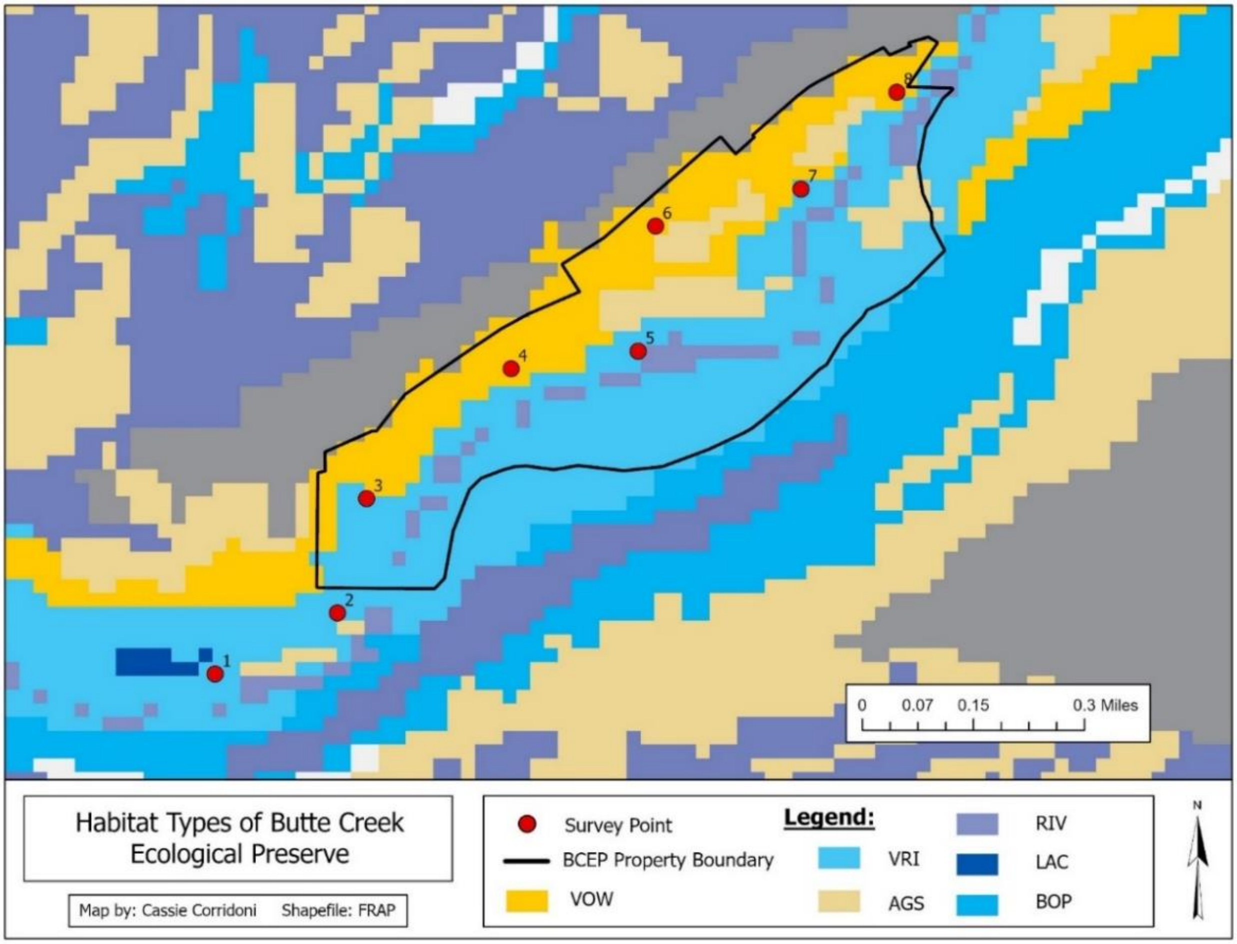

Figure 3. Habitats of the Butte Creek Ecological Preserve. The BCEP's diverse habitat types are displayed using a GIS shapefile from the California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (CAL FIRE FRAP). The habitat types are Valley Oak Woodland (VOW), Valley Foothill Riparian (VRI), Annual Grassland (AGS), Riverine (RIV), Lacustrine (LAC) and Blue Oak-Foothill Pine (BOP).

The climate of this region of California is considered Mediterranean with wet, cool, temperate winters, and hot, arid summers. The hottest month of the year is typically July, where the average temperature is 25.8°C, and the average maximum temperature for the past 100 years is 40°C (Chico Univ Farm, California). December and January are often the coolest months of the year, where the average temperature is 7° C, while the average annual precipitation in Chico is 68 centimeters (Chico Univ Farm, California).

The BCEP was severely burned in November 2018 when the Camp Fire ravaged Butte County (Appendix A and B). Appendix C and D displays images of the BCEP one month pre-Camp Fire. The Camp Fire burned over 61,000 hectares (Figure 4) (Rempel et al., 2021), and was the deadliest wildfire in California's history, as at least 18,000 structures were burned and 85 people died (Herring et al., 2020). The summer of 2017 had hotter than normal temperatures, as well as decreased rainfall, both of which contributed to the drying of excess fuels (Herring et al., 2020).

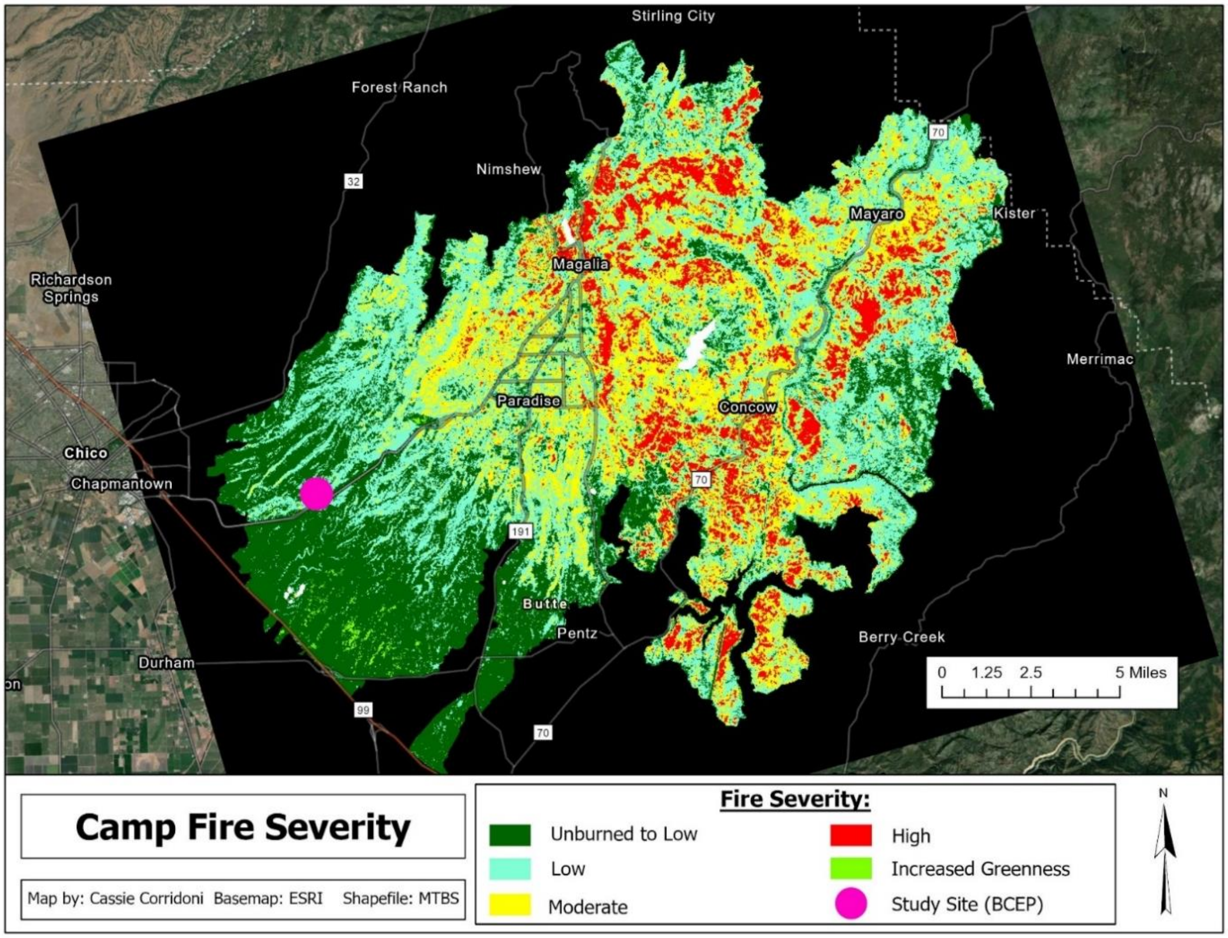

Figure 4. Butte County Camp Fire Severity. The full extent of the Camp Fire is shown, along with the MTBS fire severity mosaic. The Camp Fire burned more than 61,000 hectares.

Data Collection

Historical Data Collection (2006-2021)

Altacal Audubon Society, the local chapter of the National Audubon Society serving Butte, Glenn, and Tehama Counties, initiated point counts in 2006. At the inception of the point counts, surveys were conducted an average of six times per year from March 2006 to April 2010, with some years having up to eight surveys and some years only having two surveys. These surveys were typically conducted concurrent with bird banding at the BCEP, and timed to capture bird nesting season activity, which is considered to be February 1 through September by California Department of Fish and Wildlife (CDFW). There was a nine-year gap in data collection due to the lack of experienced birders available to conduct surveys, however, surveys restarted in April 2019, six months after the Camp Fire. From April 2019 to April 2021 surveys were conducted on average six times per year. There were 10 surveyors throughout all of the historical data, and surveys were typically conducted by one volunteer. Only experienced birders, competent with visual and aural birding skills, conducted the surveys. In 2006, eight survey points were established throughout the BCEP, selected to avoid duplicate detections as the points are spaced out approximately 250 meters apart (Ralph et al., 1993) (Figure 5).

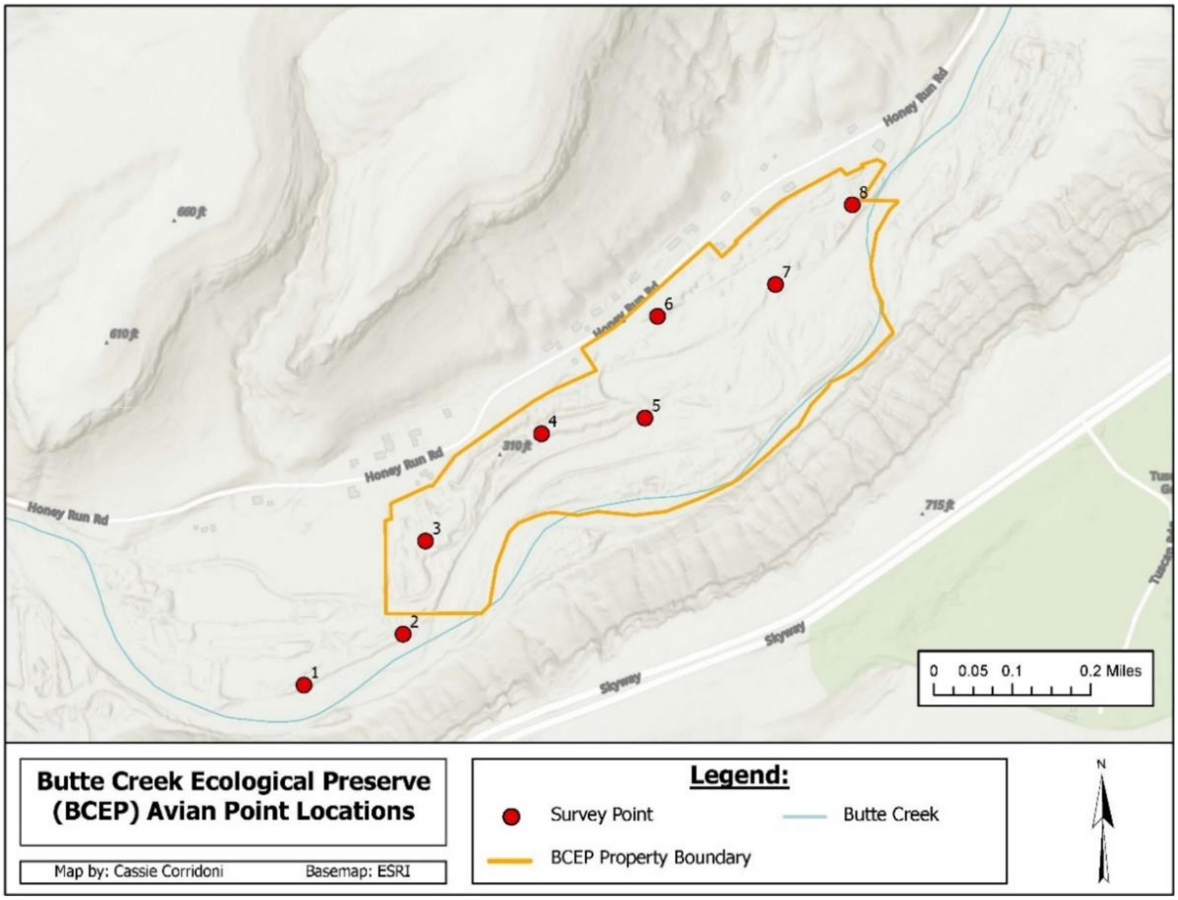

Figure 5. BCEP Avian Point Locations. The eight survey points used for point counts are displayed in red. The BCEP property boundary is shown in orange, along with the proximity to Butte Creek.

Recent Data Collection (2022)

I conducted 34 weekly point count surveys from February 2022 through October 2022. I served as the recorder, and an experienced Altacal Audubon Society member served as the primary surveyor. I utilized the protocols and datasheets that were used in the historical surveys. I began surveys on February 1, 2022 and continued weekly through October 31, 2022. This captured bird activity for the breeding season and well as a buffer period of time for fall migration.

Survey Protocol

Avian Point Count Survey Protocol

Surveys began within 15 minutes of local sunrise and continued for a maximum of three hours, per Ralph et al. (1993), as bird activity declines substantially by three hours post-sunrise. In historical surveys from 2006 to 2021, volunteers would mostly conduct surveys alone, as one person would be the primary surveyor as well as timekeeper and recorder. However, in 2022 surveys, each survey had at least two people, one experienced birder who was established as the main surveyor and who would count all of the birds detected audibly and visually and state the species and number of individuals. The second person was established as the recorder, and documented all of the field notes on the datasheets as well as kept time. Every bird seen or heard at each point was recorded, and no method of attracting birds was permitted. Coddington et al. (2009) The aim was to record every bird detected without counting any individuals twice, and to conduct surveys no closer than every seven days. Each survey required a five-minute visit to all eight point locations, making each survey last from two to three hours in total. If wind speeds reached 16 kilometers per hour or more, the survey was rescheduled due to the decreased bird activity as well as the danger of standing under snags in poor weather conditions.

Each five-minute survey was split into two time bins: three minutes followed by two minutes, as well as two distance bins: zero to 50 meters, and over 50 meters (Appendix E). The two time bin method was intended for potential future data comparisons with the national Breeding Bird Survey, which is only a three-minute survey. After the first three minutes, the recorder would promptly set a new timer for two minutes and the main surveyor would continue to count new birds that were detected within the final two minutes. The primary surveyor also specified if individuals were a "flyover," which is an individual(s) that fly overhead or through the area but does not land within 50 meters of the point. The expectation was to be as accurate as possible in estimating numbers of birds as well as declaring species. The recorder was required to have a knowledge of the four-letter bird banding codes, with which they documented the birds on the datasheets.

Habitat Surveys

On October 12, 2022, I determined the habitat type of each survey point location by referencing the California Wildlife Habitat Relationships Systems (CWHR) and by ground truthing the current landscape. In a 50-meter radius around the estimated center of each point, I determined the dominant vegetation strata of each point (tree, shrub, aquatic or herbaceous-dominated). I then recorded the dominant native and non-native plant species, and each point was categorized into a CWHR habitat type. The CWHR habitat abbreviations are: Annual Grassland (AGS), Blue Oak-Foothill Pine (BOP), Lacustrine (LAC), Riverine (RIV), Valley Foothill Riparian (VRI) and Valley Oak Woodland (VOW) (Figure 3). This process was made more difficult due to the Camp Fire drastically altering the landscape and burning the majority of the mature tree canopy as well as mature shrub layer. Fire severity at the BCEP was based upon Geographic Information Systems (GIS) layers from the Monitoring Trends in Burn Severity

(MTBS) interagency fire mapping program. MTBS used the Differenced Normalized Burn Ratio (dNBR) to estimate the severity of the Camp Fire impacts using Landsat imagery to compare ecosystem conditions pre- and post-fire (MTBS, n.d.). dNBR is created by subtracting post-fire NBR from the pre-fire NBR. For this burn severity map, the pre-fire imagery was captured on July 19, 2018, while the post-fire imagery was captured on July 22, 2019 (S. Bogle, personal communication April 17 2023). Figure 6 shows the burn as low-severity with patches of moderate-severity fire, however, since the post-fire imagery was captured almost nine months after the Camp Fire, this likely does not accurately portray the high-severity burn that occurred. In addition, Appendix A and B show the severity of the burn, in which many of the mature riparian trees were either burned to ash, or if they survived, had 2-meter burn scars left on the trunks (Eli Goodsell, personal communication).

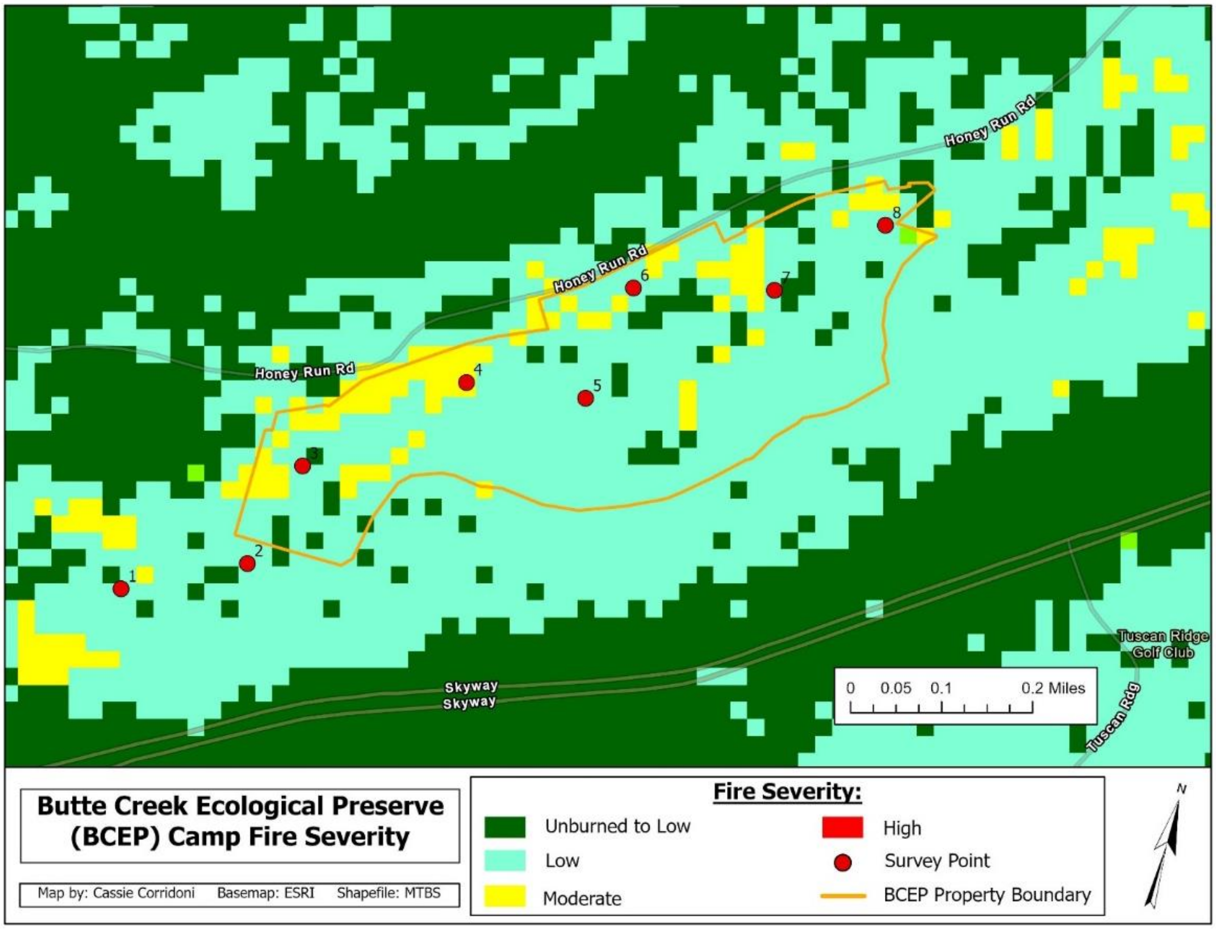

Figure 6. Butte Creek Ecological Preserve Camp Fire severity. The fire severity mosaic of the Camp Fire on the BCEP is shown with Monitoring Trends in Burn Severity (MTBS) data. Refer to Appendix D for a post-fire image along Butte Creek.

Data Analysis

Data Input

I entered the point count data into the California Avian Data Center (CADC) which is compatible with the Point Blue Conservation Science datasheets used in the data collection. I input 46 historical surveys that took place between 2006 to 2021, and 34 recent surveys that took place in 2022, making 80 total surveys input into the CADC. Twenty-seven surveys were conducted pre-fire (prior to 2018) and 53 were conducted post-fire (after 2019) (Appendix F). A benefit to having nine years of data and 80 surveys worth of detections is that data collected vigorously, and over large temporal spans oftentimes results in increased accuracy for diversity measurements (Longino et al., 2022). While I was inputting datasheets, there were several instances where a bird species was noted as detected but no number of individuals was recorded, and in these cases, I assumed that one individual of that species was detected in each of these instances. I exported the data onto a Microsoft Excel spreadsheet, where I organized and analyzed the data.

Detections

The total number of detections for each survey was calculated by summing each individual bird observed and/or heard, without differentiating between juvenile, subspecies, or sex. Detections were calculated for each survey year, each point pre- (2006-2010) and post-fire (2019-2022). Mean, minimum and maximum annual detections were also calculated.

Species Richness

Species richness is defined as the number of different species found in a particular community and is calculated by summing the number of different species present. Even though rare species are more difficult to detect, they provide a crucial addition to community species richness (Colwell and Coddington, 1994). Species richness was calculated for each survey year, and for pre- and post-fire detections. I created a species accumulation curve by analyzing newly detected species throughout the study, as well as annually.

Relative Abundance

Relative abundance is the measure of how common or rare a species is in relation to other species within a community. This measure encapsulated the bird species composition at the BCEP and accounted for both the rarities and the common birds to create a representative percentage of the total community. Relative abundance was calculated for each species for all nine years of data, as well as one pre- (2006-2010) and one post-fire (2019-2022) cumulative percentage. Both the annual as well as the pre- and post-fire percentages were used in further analyses. Three analyses grouped birds by their taxonomic families, which can be referenced on Appendix G. Another analysis categorized all detected bird species into four foraging guilds: aerial-foragers, ground-feeders, vegetation-associated foragers, and water-associated foragers (Appendix H). The aerial-foraging guild was comprised of 16 species, the ground-feeding guild had 44 species, the vegetation-associated guild had 47 species, and the water-associated guild was made up of 28 species.

Diversity

Diversity is the number of different species combined with the abundance of each species in a particular location. The greater the variety of different species combined with high abundances will result in greater species diversity.

The Shannon Diversity Index (SDI) is a mathematical measure used to calculate the diversity of species in a given area. The SDI uses the species richness and relative abundance of a given population in order to calculate diversity as a numeric value. The SDI formula is H = -

$\sum[p_i) \times \ln(p_i)]$, where *H* is the diversity index, $-\sum$ is the negative sum, p_i is the *p*, proportion of the community comprised of species, *i*, and *ln* is the Natural log. The higher the *H*-value, the higher the diversity of species in a community. For example, an *H*-value of 0 means that there is only one species in that community, and the highest possible *H*-value for a community with 100 species would be 4.605. The *H*-values in the SDI typically range from 1.5 to 3.5, although there is no maximum value. The *H*-values for each survey year were calculated, as well as one *H*-value for pre- and post-fire.

There was an outlier in the dataset of 2,000 Cliff Swallows (*Petrochelidon pyrrhonota*) recorded on May 17th, 2006, which skewed detections, relative abundance and diversity *H*-values. Throughout the entirety of the study, there were no additional detections larger than 610 individuals of any bird species. There were no other observations of any swallow species of this size, therefore I removed it from my analyses.

CHAPTER IV

RESULTS

Habitat Types

The BCEP was a diverse location and the survey points established pre-fire in 2006 aimed to capture a representative sampling of the unique landscape. The Camp Fire greatly altered the habitat of the BCEP. These habitat descriptions are from 2022, over three years post-fire, and do not detail pre-fire habitat (Table 1). Point one was on adjacent CDFW property, and overlooked a large pond and had a sweeping view of the southern wall of Butte Creek Canyon. There was a dense thicket of willow and alder between Butte Creek and the pond, and the trail dead ended where it met Butte Creek. Point two was nestled between a few mature riparian trees that survived the fire, and an open grassland leading down to the creek. Point two was located on CDFW property close to the southeastern boundary of the BCEP. Point one and two were both within the closest proximity to Butte Creek of the eight points, and the creek could typically be heard flowing year round from these two points. Points three through eight were all found within the BCEP boundary, and were progressively farther from Butte Creek, until point eight met the creek again. Point three was near the southeastern boundary, near Honey Run Road and had more mature trees than many other points as well as burnt and stump-sprouted riparian shrubs. Point four was located on the nature trail, had mature unburned riparian trees on the south side of the trail, as well as severely burned oaks on the north side of the trail. Point five was found off the nature trail tucked behind a dense patch of willow and Himalayan blackberry, and Butte Creek could be heard from this point. Point six was the closest point to the parking lot, which was a point of interest for unusual birds on the BCEP. In addition, it encompassed a small open grassland area as well as having a couple of mature unburned trees but was sparsely vegetated compared to other points closer to the creek. Point seven was located off of the nature trail and was on the south side of a minor slope, with chaparral species on the north side and dense riparian shrubs such as willow on the north side. Point eight was the northwestern most point, found at the end of the nature trail, and was located on an expanse of cobble. The middle of the point had little to no vegetation, and the outer areas were dense with stump-sprouted shrubs and burned trees.

Table 1. Habitat types of survey points

Point	Habitat type	Vegetative dominance	Dominant plant species
1	LAC, VRI	Aquatic, Tree	Sandbar willow, white alder, Fremont cottonwood, Himalayan blackberry, toyon, broadleaf cattail, blue elderberry, California sycamore
2	VRI, AGS	Tree, Herbaceous	California sycamore, interior live oak, blue elderberry, sandbar willow, Fremont cottonwood, Himalayan blackberry, valley oak, woolly mullein
3	VRI, AGS	Tree, Herbaceous	Fremont's cottonwood, California sycamore, foothill pine, blue elderberry, interior live oak, valley oak, black mustard, yellow-star thistle
4	VRI, BOP	Tree	Poison oak, foothill pine, arroyo willow, interior live oak, Sierra coffeeberry, valley oak, California sycamore
5	VRI, RIV	Tree, Aquatic	Sandbar willow, white alder, interior live oak, California sycamore, Himalayan blackberry, poison oak, blue elderberry, California greenbriar, black mustard, yellow-star thistle
6	BOP, VOW	Tree	Interior live oak, poison oak, Sierra coffeeberry, foothill pine, valley oak, toyon, sandbar willow, yerba santa, California grape
7	VRI, RIV	Tree, Aquatic	Sandbar willow, interior live oak, foothill pine, mule fat, buckbrush, greenleaf manzanita, valley oak
8	VRI, BOP	Tree	Foothill pine, white alder, sandbar willow, interior live oak, naked buckwheat, valley oak, poison oak, blue elderberry

The habitats of each of the eight survey points were classified using the California Wildlife Habitat Relationships System (CWHR). The habitat types are: Annual Grassland (AGS), Blue Oak-Foothill Pine (BOP), Lacustrine (LAC), Riverine (RIV), Valley Foothill Riparian (VRI) and Valley Oak Woodland (VOW). Many of the points were combinations of two CWHR wildlife habitat types.

Detections

Detections varied substantially from year to year: the first survey year (2006) resulted in 1,456 detections over eight surveys, and the most recent survey year (2022) resulted in 10,265 detections over 34 surveys (Table 2). However, once the yearly detections were averaged by the number of surveys conducted that year, the detection variability decreased considerably. The three highest detection averages all occurred post-fire: 2020, 2021 and 2022. There were 27 pre-fire surveys from 2006 to 2010, which resulted in 6,001 detections, and there were 53 post-fire surveys from 2019-2022, which resulted in 15,431 detections.

Table 2. Detections.

Year	Annual detections	Surveys per year	Mean detections per survey	Range of min/max detections
2006	1456	8	182	128-294
2007	2201	8	275	124-804
2008	1393	7	199	144-283
2009	460	2	230	166-264
2010	491	2	246	242-249
2019	1992	9	221	119-567
2020	2505	8	313	188-600
2021	669	2	335	121-548
2022	10265	34	302	147-904

The total annual bird detections are shown in the table below for all survey years. The number of surveys conducted each year is listed, with the annual mean detections and a range of annual detections per survey. Detections per survey increased post-fire.

Individuals from all nine survey years are totaled in Table 3, with detections listed in ascending order for each point. Point one, which was Valley Foothill Riparian (VRI) and Lacustrine (LAC) habitat types, resulted in the highest detections at 3,754 individuals, while point six resulted in the second highest total at 3,166 detections, and is Valley Oak Woodland (VOW) and Blue Oak-Foothill Pine (BOP) habitat. The two points that had a Riverine (RIV) component, point seven and five, had the two lowest detections.

Table 3**.** Detections at each point for all years.

Point	Detections	Habitat type
7	2038	VRI, RIV
5	2242	VRI, RIV
4	2346	VRI, BOP
2	2388	VRI, AGS
3	2516	VRI, AGS
8	2982	VRI, BOP
6	3166	VOW, BOP
1	3754	VRI, LAC

Point one had the highest detection total at 3,754 and was Valley Foothill Riparian (VRI) and Lacustrine (LAC) habitat types. The CWHR habitat types are: Annual Grassland (AGS), Blue Oak-Foothill Pine (BOP), Lacustrine (LAC), Riverine (RIV), Valley Foothill Riparian (VRI) and Valley Oak Woodland (VOW).

Species Richness

As shown in Figure 7, the mean species richness detected per year throughout the study was 76, and the cumulative species richness for all 80 surveys was 135. Annual species richness in 2006 was 75, while species richness peaked in 2022 at 115 species, although it had the outlier of 34 surveys. In 2019, the year after the Camp Fire, nine surveys were conducted which resulted in a species richness of 79, which was equal to the pre-fire 2008 species richness which had seven surveys.

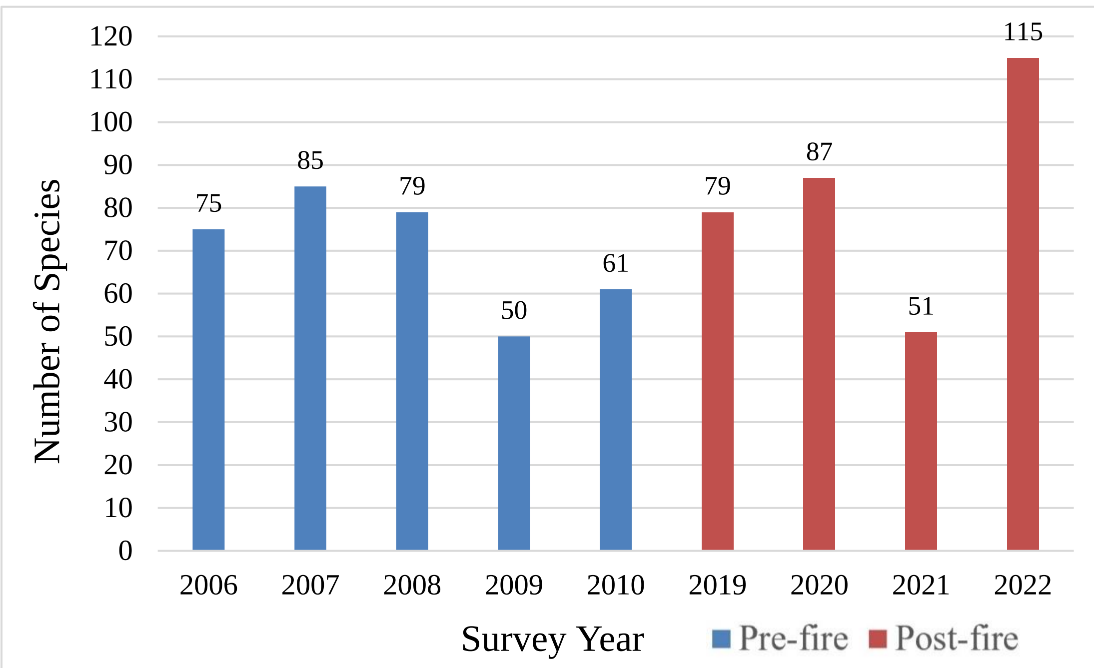

Figure 7. Species richness. The number of species detected each survey year was shown for both pre-fire (2006-2010) and post-fire surveys (2019-2022). Mean species richness for all years was 76, and total species richness for all years was 135.

Figure 8 shows the species accumulation curve over nine years and 80 total surveys. Annual species accumulation curves can be referenced in Appendix I. The curve was steep until the fifth survey, where there were roughly 70 species detected at that point. After the fifth survey, the curve leveled out and the number of new species detected per survey decreased substantially, although cumulative detections continued to increase steadily. By 55 surveys, the curve nearly becomes flat, with fewer new species detected as each survey is conducted.

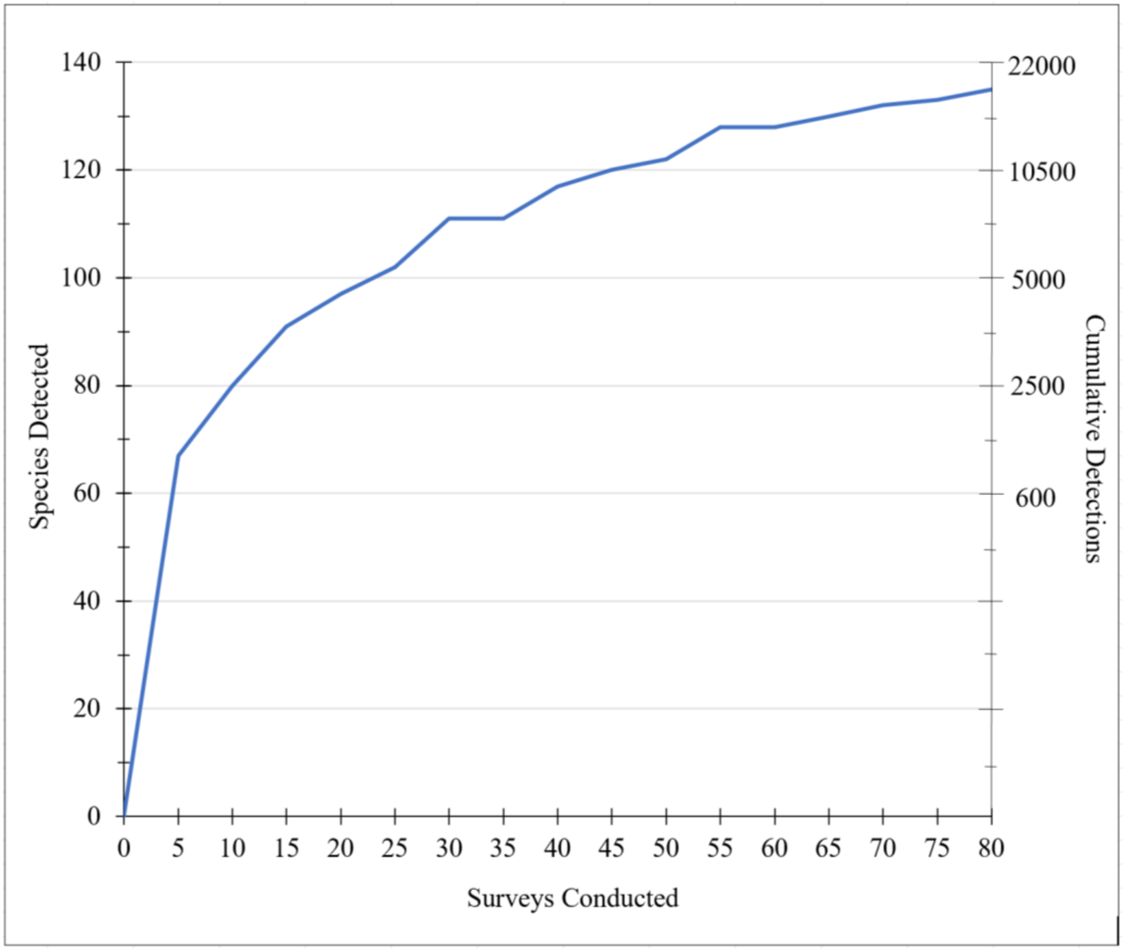

Figure 8. Species accumulation curve for all surveys. The number of species detected increases with each additional survey, however, the curve leveled out around 55 surveys. As the additional species detected decreased, the cumulative detections increased.

Relative Abundance

The five bird families that had the greatest changes in pre- and post-fire relative abundance are shown in Figure 9. *Fringillidae* (finches) and *Hirundinidae* (swallows) relative abundances declined 9.92% and 7.95%, respectively. There was a 2.39% drop in relative abundance of *Parulidae* (warblers). *Passerellidae* (sparrows) increased 2.86% and *Picidae* (woodpeckers) had an uptick of 4.53% in relative abundance.

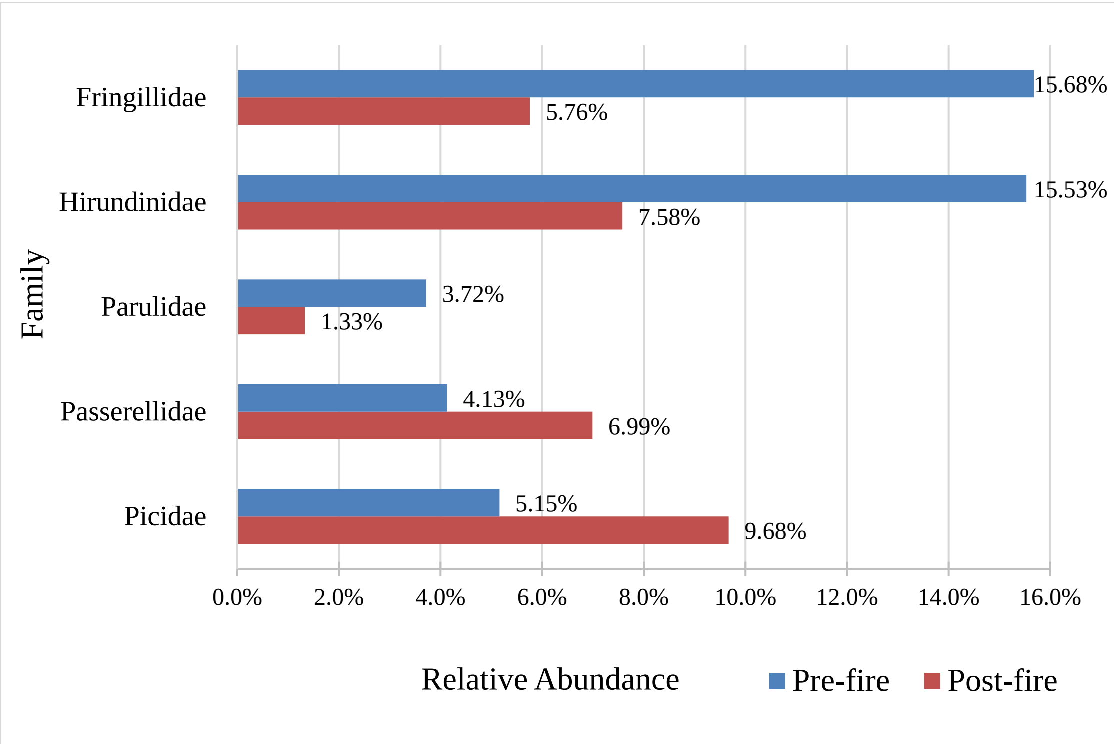

Figure 9. Relative abundance of five bird families pre- and post-fire. *Fringillidae* (finches) and *Hirundinidae* (swallows) resulted in significant declines in post-fire relative abundance, while *Passerellidae* (sparrows) and *Picidae* (woodpeckers) exhibited moderate increases, and *Parulidae* (warblers) showed a minor increase post-fire.

The relative abundance of four bird foraging guilds before and after the Camp Fire are depicted in Figure 10. Aerial-foraging species relative abundance dropped 8.34% post-fire, while ground-foraging species relative abundance increased 5.94%. Vegetation-associated foragers decreased a minimal 1.34%, and water-associated species exhibited an increase in relative abundance of 3.78%.

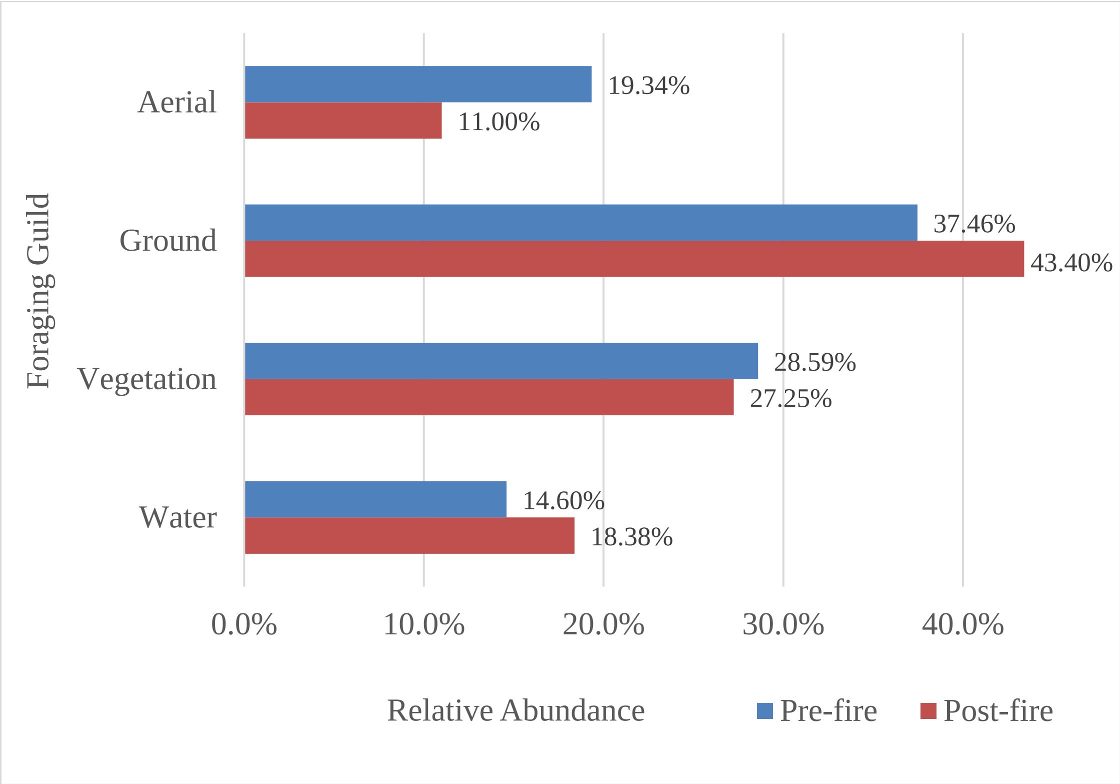

Figure 10. Relative abundance of foraging guilds pre- and post-fire. Ground-associated species had the greatest increase in relative abundance post-fire (2006-2010), while aerial-foragers exhibited the sharpest post-fire (2019-2022) decline.

Ground-feeding species relative abundance showed minimal variance pre- and post-fire, as well as when compared annually (Figure 11). The mean relative abundance across all nine survey years is 39.65%. The inaugural survey year (2006) resulted in 37.77% relative abundance of ground-foragers, while the most recent survey year (2022) had a relative abundance of 44.56%. As a whole, ground-feeding bird relative abundance increased 6% from pre- to post-fire.

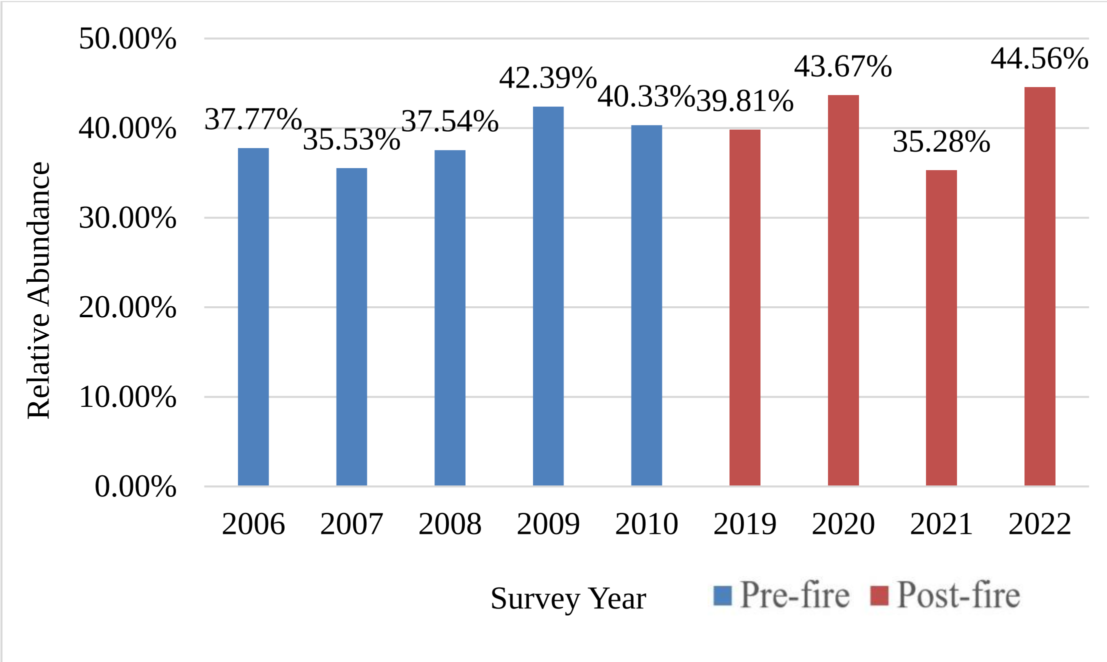

Figure 11. Ground-feeding species annual relative abundance. The ground-feeding species relative abundance remained above 35% throughout the entirety of this study. The cumulative pre-fire ground-feeding relative abundance is 37.46% and post-fire is 43.40%, making a roughly 6% increase.

The relative abundances of woodpeckers varied minimally pre- and post-fire among seven species in the family *Picidae*. As a family, woodpeckers increased from 5.16% pre-fire to 9.67% post-fire (Table 4). Lewis's Woodpecker (*Melanerpes lewis)* and Red-breasted Sapsucker (*Sphyrapicus ruber)* were never detected until after the Camp Fire, yet Hairy Woodpecker *(Leuconotopicus villosus)* and Downy Woodpecker *(Picoides pubescens)* relative abundances decreased slightly post-fire. Acorn Woodpecker *(Melanerpes formicivorus)* relative abundance almost tripled post-fire and were the most abundant woodpecker species pre-fire as well.

Table 4. Relative abundance of woodpeckers pre- and post-fire.

Woodpecker Species	Pre-fire	Post-fire
Acorn Woodpecker	2.17%	5.96%
Downy Woodpecker	0.62%	0.49%
Hairy Woodpecker	0.33%	0.13%
Lewis's Woodpecker	0.00%	0.12%
Northern Flicker	0.67%	1.52%
Nuttall's Woodpecker	1.37%	1.43%
Red-breasted Sapsucker	0.00%	0.02%
Total Relative Abundance	5.16%	9.67%

Acorn Woodpeckers had the most notable increase in relative abundance post-fire, while woodpeckers as a whole almost doubled after the Camp Fire.

The post-fire relative abundance of raptor species increased to almost three times the pre-fire numbers (Figure 12). The taxonomic bird families that are included in the raptor classification are: *Accipitridae, Cathartidae, Falconidae,* and *Pandionidae,* and include 13 raptors. Pre-fire annual relative abundances ranged from 1.52% to 4.07%, while post-fire annual relative abundances ranged from 2.99% to 6.14%.

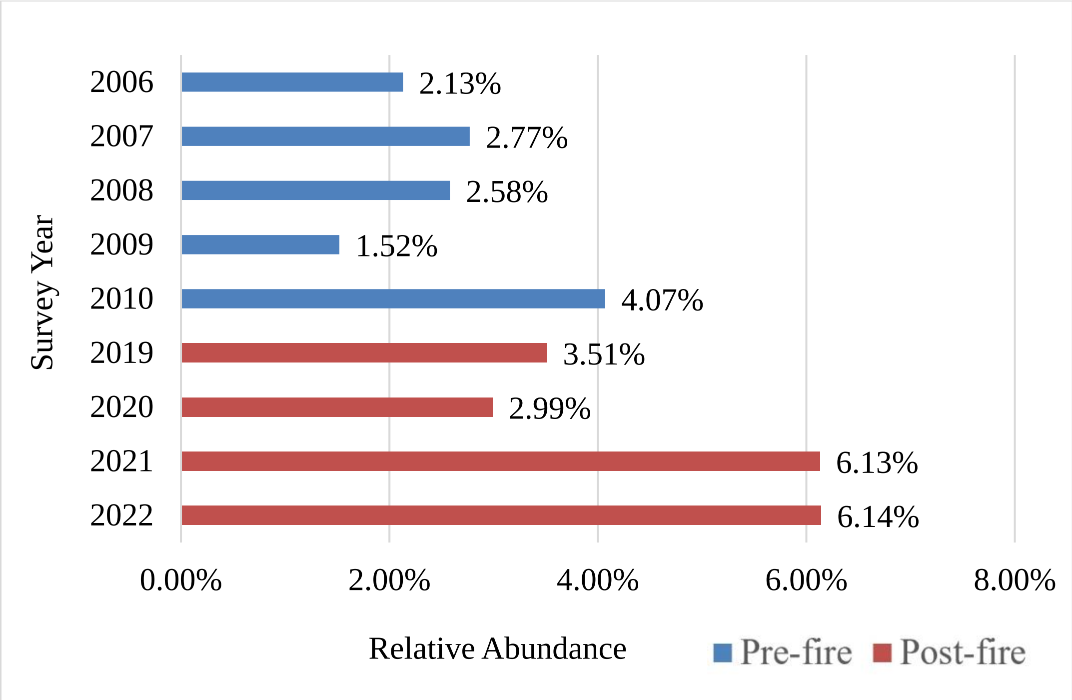

Figure 12. Relative abundances of raptors. Thirteen raptor species from four families displayed a nearly three-fold increase in relative abundance post-fire.

The relative abundance of four non-native (introduced) species at the BCEP greatly increased post-fire (Table 5). The European Starling (*Sturnus vulgaris)* relative abundance increased from 0.92% pre-fire to 5.95% post-fire. Eurasian-collared Dove (*Streptopelia decaocto*) and Rock Pigeon *(Columba livia)* were never detected until after the Camp Fire, and House Sparrow (*Passer domesticus)*, although their post-fire relative abundance is just 0.64%, had tripled from pre-fire numbers.

Table 5. Relative abundance of non-native species pre- and post-fire.

Non-native Species	Pre-fire	Post-fire
Eurasian-collared Dove	0.00%	1.96%
European Starling	0.92%	5.95%
House Sparrow	0.27%	0.64%
Rock Pigeon	0.00%	0.01%
Total Relative Abundance	1.19%	8.56%

The total non-native species relative abundance increased to 8.56% from 1.19% pre-fire. European Starlings increased the most out of the other three non-natives, at over six times their pre-fire relative abundance.

Diversity

The BCEP is a diverse location, with pre- and post-fire diversity ranging from 2.93 to 3.86 on the Shannon Diversity Index (SDI). Annual diversity fluctuated over the course of the study, although 2006-2010 *H*-values remained constant, with three of five years having *H*-values between 3.56-3.59 (Table 6). The 2010 SDI *H*-value was 3.56 and the 2019 *H*-value was 3.57, although the number of surveys was nearly five times greater in 2019.

Table 6. Annual diversity.

Year	Surveys per year	SDI *H*-value
2006	8	3.59
2007	8	3.58
2008	7	3.83
2009	2	3.18
2010	2	3.56
2019	9	3.57
2020	8	3.49
2021	2	2.93
2022	35	3.86

The SDI *H*-values were calculated for each of the nine years surveys were conducted. Diversity values did not exhibit a major change from pre- to post-fire as they remained similar to pre-fire values, even three years post-fire.

Bird diversity remained constant in a pre- and post-fire comparison of *H*-values, although there was a slight decrease post-fire (Table 7). The overall pre-fire *H*-value was 3.90, while the overall post-fire *H*-value was 3.85.

Table 7. Diversity, detections and species richness pre- and post-fire.

	Detections	Surveys conducted	Mean detections per survey	Cumulative species Richness	Mean species richness	SDI *H*-value
Pre-fire (2006-2010)	6001	27	222	107	70	3.90
Post-fire (2019-2022)	15431	53	291	121	83	3.85

Although pre-fire detections and species richness were both significantly less than post-fire numbers, the pre-fire diversity is marginally greater than post-fire.

Special Status Species

There was a total of 38 Yellow Warblers detected pre-fire from 2006-2010, and 11 (28.9%) were detected at point five, which was Valley Foothill Riparian and Riverine habitat (Table 8). Ninety Yellow-breasted Chats were detected pre-fire, with 18 (20%) also found at point five. There were only four Willow Flycatchers detected pre-fire, and two (50%) were detected at point eight, which was Valley Foothill Riparian and Blue Oak-Foothill Pine.

Table 8. Pre-fire detections of special status species.

Point	Yellow Warbler	Yellow-breasted Chat	Willow Flycatcher
1	8	10	0
2	4	15	0
3	0	14	0
4	1	16	0
5	11	18	1
6	0	5	1
7	8	7	0
8	6	5	2
Total	38	90	4

Detections of special status species found at each survey point are summed from 27 pre-fire surveys conducted between 2006 and 2010. Point five had the greatest detections of Yellow Warbler and Yellow-breasted Chat while point eight had the greatest detections of Willow Flycatcher.

There were 73 Yellow Warblers detected post-fire from 2019-2022, and 20 (27.3%) were found at point seven, which was Valley Foothill Riparian and Riverine habitat (Table 9). Twenty-seven (18.1%) of the 149 Yellow-breasted Chats detected post-fire were found at point one, which was Lacustrine and Valley Foothill Riparian habitat. Forty-three total Willow Flycatchers were detected post-fire and point five, which was Valley Foothill Riparian and Riverine habitat, had the greatest number detections at 11 (25.5%).

Table 9. Post-fire detections of special status species.

Point	Yellow Warbler	Yellow-breasted Chat	Willow Flycatcher
1	14	27	10
2	7	25	6
3	3	16	5
4	6	22	3
5	11	26	11
6	4	14	1
7	20	10	6
8	8	9	1
Total	73	149	43

Detections of three special status species found at each survey point are summed from 53 post-fire surveys from 2019 through 2022. Point seven had the greatest detections of Yellow Warblers, point one had the most Yellow-breasted Chats, and point five had the greatest detections of Willow Flycatchers.

Special status species were detected on the BCEP April through September pre-fire (2006-2010) (Table 10). Prior to the Camp Fire, Yellow Warblers and Yellow-breasted Chats were detected in the greatest numbers in the BCEP in May, with 18 (47.3%) and 44 (48.8%) detections each, respectively. The Willow Flycatcher was only detected in three months and had the highest number of detections in September, which was just two (50%).

Table 10. Pre-fire detection months of special status species.

	Yellow Warbler	Yellow-breasted Chat	Willow Flycatcher
April	3	17	0
May	18	44	1
June	5	10	1
July	5	19	0
August	0	0	0
September	7	0	2
Total	38	90	4

Special status species detections months based off of 27 pre-fire surveys from 2006-2010. Yellow Warbler and Yellow-breasted Chat had the greatest detections in May, while the Willow Flycatcher had the greatest detections in September.

After the Camp Fire, Yellow Warblers had the highest BCEP presence in May, with 25 (34.2%) detections, and the next greatest presence in September with 23 (31.5%) individuals (Table 11). The Yellow-breasted Chat was detected the greatest amount in May and had 57 (38.2%) detections. The Willow Flycatcher was detected, by far, the most in August with 32 (74.4%) individuals.

Table 11. Post-fire detection months of special status species.

	Yellow Warbler	Yellow-breasted Chat	Willow Flycatcher
April	2	9	0
May	25	57	1
June	9	38	7
July	1	39	0
August	13	3	32
September	23	3	3
Total	73	149	43

Post-fire surveys conducted between 2019-2022 captured that Yellow Warbler and Yellow-breasted Chat had the greatest detections in May, while the Willow Flycatcher had the greatest detections in August.

Relative Abundance

Special status species' relative abundance decreased less than 0.5% as a whole post-fire and occupied just 2.2% of the BCEP bird community pre-fire (Table 12). Yellow-breasted Chat and Yellow Warbler relative abundance decreased to roughly one-third of their pre-fire abundances. Willow Flycatcher relative abundance increased from 0.07% to 0.28%, which is four times their pre-fire abundances.

Table 12. Relative abundance of special status species pre- and post-fire.

Special Status Species	Pre-fire	Post-fire
Yellow-breasted Chat	1.50%	0.97%
Yellow Warbler	0.63%	0.47%
Willow Flycatcher	0.07%	0.28%
Total Relative Abundance	2.20%	1.72%

The Yellow-breasted Chat and Yellow Warbler relative abundances saw moderate decreases post-fire, however, the Willow Flycatcher relative abundance increased to four times its pre-fire abundances.

CHAPTER V

DISCUSSION

The objective of this study was to investigate the effect that the Camp Fire had on the bird community composition at the Butte Creek Ecological Preserve (BCEP). The primary outcomes were to determine the pre- and post-fire bird species richness, relative abundance and diversity, as well as the current presence and distribution of special status species. Throughout the nine year study, bird diversity displayed minor fluctuations in the four years of post-fire data when compared with the five years of pre-fire data, rather than a drastic decrease as predicted. The data also revealed that the BCEP supports well over 100 species of birds post-fire, although species composition has shifted likely due to ecosystem structural changes.

Species Richness

Species richness is often considered to be the most basic measure of diversity in an ecosystem. Previous research has suggested mixed results regarding how bird species richness is affected in areas of high-severity wildfires. Knaggs et al. (2020) found that species richness was lower two years post-fire in areas of high-severity wildfire in uplands compared to nearby unburned and low-intensity burned areas. My results suggested that species richness did not decrease post-fire. Pre-fire survey years 2006-2008 as well as post-fire survey years 2019 and 2020 all have between seven and nine annual surveys each, making them the simplest to directly compare. These three pre-fire years have species richness values between 75 and 85, while the two post-fire survey years have species richness values between 79 and 87. Based off of this, any changes in pre- and post-fire species richness are negligible, especially with the high degree of disturbance that occurred on the BCEP post-fire, which would still be evident in 2019. Another study by Bock and Block (2005) found that species richness increased three years post-high-severity burn compared to unburned patches. Some results from my study suggested that species richness increased post-fire, such as the 2022 survey year, which had 115 species, the highest of any other year. There were 14 species detected solely pre-fire, and 27 species detected solely post-fire. In addition, pre-fire mean species richness was 107 while post-fire mean species richness was 121, providing additional evidence of a potential overall increase. Tietje and Vreeland (1997) reported that species richness improved in burned areas that resulted in increased habitat complexity, containing mature trees, a lush understory, and leaf litter present. Although the BCEP species richness did have a modest increase post-fire, it cannot be attributed to increased habitat complexity.

Relative Abundance

Ground-feeding species

One of the aims of this study was to find the relative abundance of each species present on the BCEP and to detect any patterns that emerged pre- and post-fire. Birds were divided into four foraging groups to reflect how the current habitat affected their ability to find food post-fire. There was some evidence that the bird community composition has been altered slightly post-fire. The results indicated that the ground-feeding guild increased 6% from pre- to post-fire, most likely attributed to the loss of the tree canopy and increased exposed ground. Smucker et al. (2005) found that two ground-feeding species, the Dark-eyed Junco (*Junco hyemalis*) and Lazuli Bunting, both increased in relative abundance post-fire, and my results suggested the same increases. Bock and Block (2005) claimed that the post-fire influx of ground-feeding species, such as Lark Sparrow and Mourning Dove, were merely temporary. My results revealed that Lark Sparrow increased in relative abundance one year post-fire followed by an even greater increase three years post-fire. My results for Mourning Dove, however, supported the initial hypothesis and exhibited an increase one year post-fire, followed by a decline in years two and three post-fire.

Foliage-gleaning species

My results for vegetation-associated foliage gleaners were mixed. In a severely burned patch of forest, Bock and Block (2005) found that abundances of warblers, vireos and other foliage-gleaning birds decreased. The BCEP results supported the theory that relative abundances of warblers and vireos would decrease post-fire. This decrease in foliage-gleaners is most likely attributed to not only the loss of mature riparian trees, but also the mid-story tree and shrub layer post-fire. A study by Smucker et al. (2005) stated that Cassin's Vireo (*Vireo cassinii*), Golden-crowned Kinglet (*Regulus satrapa*), Ruby-crowned Kinglet (*Regulus calendula*), and Yellow-rumped Warbler (*Dendroica coronata*) all decreased in relative abundance post-fire. My results showed that Cassin's Vireo and Yellow-rumped Warbler decreased post-fire, however, both Golden-crowned Kinglet and Ruby-crowned Kinglet increased in relative abundance post-fire. These mixed results could potentially be attributed to the foraging habitat of both Cassin's Vireo and Yellow-rumped Warbler being eliminated in the Camp Fire, as these two species selectively forage in mid-story tree canopies. The Ruby-crowned Kinglet is known to forage at all levels, from low brush to treetop, making them a highly adaptable species, which could help explain their increase post-fire.

Aerial-foraging species

A study by Lowe et al. (1978) found that flycatchers decreased to zero three years post-fire, which was potentially attributed to decreased insect populations, as well as vegetative nesting sites. My study has contradicted those findings, as the BCEP flycatcher population has not had a notable decrease. In fact, the Willow Flycatcher, a sensitive species in California, exhibited an increase in relative abundance three years post-fire. Murphy et al. (2021) found that insectivore populations responded negatively to wildfire as a foraging guild. My study showed mixed results, as aerial-foraging species, made up of primarily insectivorous birds, decreased substantially as a guild as well. However, swallows comprised the majority of this decline, while flycatcher relative abundances remained the same.

Woodpeckers

There were varied results in the relative abundance of woodpeckers pre- and post-fire. In general, woodpecker numbers improved, particularly Acorn Woodpecker and Northern Flicker. A study by Lowe et al. (1978) found that one-year post-fire, wood-boring birds, such as woodpeckers, increased dramatically. The findings were attributed to an increase in snags as well as an open canopy in the heavily burned areas (Lowe et al. 1978). A similar increase in relative abundances of five of the seven woodpecker species detected in this study was seen one year post-fire. Another example of varied results was the presence of Lewis's Woodpecker and Red-breasted Sapsucker, which were only detected post-fire. Lewis's Woodpecker is known for being a weak primary cavity nester. This species prefers decayed trees that do not require total manual excavation and could potentially be attracted to the sharp increase in burned snag habitat on the BCEP. In addition, Smucker et al. (2005) also found that one species was detected only pre-fire in an eight-year study: the Black-backed Woodpecker (*Picoides arcticus*). In general, woodpecker populations improved post-fire in a study by Bock and Block (2005). My results support this finding, as woodpecker relative abundance nearly doubled post-fire. Covert-Bratland et al. (2006) found that the spike in abundances of wood-boring birds, such as woodpeckers, two to three years post-fire can be a temporary increase. My results were mixed, in that woodpecker relative abundance increased from almost 5% in 2010, to nearly 9% in 2019, which was an anticipated post-fire influx. However, the numbers decreased to roughly 4-5% from 2020 to 2021, and three years' post-fire, relative abundance of woodpeckers has increased again, to over 11%.

Non-native Species

There is a lack of research on the effect that wildfire has on non-native and invasive bird populations. The European Starling is a non-native, invasive species that exists in nearly any type of disturbed habitat (Kaufman, n.d.). European Starlings can wreak havoc on ecosystems not only due to their tendency to overpopulate areas, but also from the numerous diseases they carry, which can affect both mammals and birds. European Starling populations increased 5% post-fire, which was the greatest increase of all four non-natives detected in this study. Eurasian Collared-Doves are an aggressive non-native, invasive species rampant with diseases and often found in disturbed landscapes. Fujisaki et al. (2010) found that Eurasian Collared-Dove populations are greater in areas that are altered by humans. Eurasian Collared-Doves were never detected on the BCEP pre-fire, but their relative abundance jumped to nearly 2% post-fire. Brown-headed Cowbirds are a species native to North America but are commonly considered to be an invasive species as their survival strategy relies on parasitizing other species' nests (Kaufman, n.d.). The Brown-headed Cowbird is known to parasitize Yellow Warbler, Yellow-breasted Chat and Willow Flycatcher nests. The relative abundance of Brown-headed Cowbird in the BCEP decreased by nearly half post-fire, which decreases the likelihood that the post-fire declines of special status species can be attributed to this species.

Diversity

Bird diversity was expected to decline post-fire primarily due to habitat structural changes including tree canopy elimination, mid-story reduction and an increase in exposed ground. Bird diversity did not significantly drop post-fire, as revealed by the Shannon Diversity Index values, in fact, diversity did not even exhibit a notable post-fire change. Saab and Powell (2005) found that overall bird diversity should increase as long as the fire results in increased habitat complexity, however the Camp Fire did not create a more complex habitat structure at the BCEP and yet diversity stayed relatively the same. Knaggs et al. (2020) found that bird functional diversity was lower in severely burned patches compared to low-intensity burned patches of forest, however, my study shows that diversity did not decrease substantially. Steel et al. (2022) also found that areas burned in high-intensity fires are predicted to decrease in bird species richness, as long as they also result in decreased edge habitat. As the BCEP has decreased edge habitat post-fire, my results contradict this study, as diversity has not decreased. Greenberg et al. (2023) found that bird diversity was doubled in high-severity burned areas when compared to unburnt patches, and my results suggest that BCEP bird diversity was not adversely affected post-high-severity wildfire.

Special Status Species

The responses of Yellow Warbler, Yellow-breasted Chat and Willow Flycatcher to high-severity wildfire are understudied. Yellow Warbler relative abundance decreased slightly post-fire, which could be a result of decreased insect populations, as they are insectivorous foliage-gleaners, as well as the loss of the tree canopy, which is their primary foraging habitat. Yellow-breasted Chat relative abundance also decreased slightly post-fire, however, their diet consists of around half insects and half fruits, and they forage in dense, shrubby, low areas. Instead, their decrease could potentially be a result of less desirable habitat due to the fire eliminating the middle and dense lower forest story and exposing the ground in many areas that were previously shrubby and overgrown, which they prefer. Willow Flycatcher relative abundance increased post-fire, which could suggest that the fire improved habitat along Butte Creek for this species. This could also potentially suggest that there is a lack of migratory stopover microhabitats due to the adjacent areas burning as well, so large populations flock to the BCEP for the dense willow and alders. On August 13th, 2022, there were 24 Willow Flycatchers detected in one survey, which is an unusually high count for the small area and time period. This survey, along with relatively higher than normal detections in both June and August of 2022 suggests that even post-fire, the BCEP provides crucial migratory stopover habitat for the Willow Flycatcher.

Notable 2022 Detections

One Neotropic Cormorant *(Nannopterum brasilianum)* flew over the BCEP on March 23, 2022 with a gulp of 21 Double-crested Cormorants (*Nannopterum auritum).* Neotropic Cormorants are not migratory species and typically live year round in Mexico and the Southwestern U.S. such as parts of New Mexico, Arizona, and Texas, although they have been expanding their range northward in recent years. This occurrence is one of the northernmost records in California (L. Huber, personal communication, 26 February 2023).

A solitary Brewer's Sparrow (*Spizella breweri)* was detected on June 21, 2022. Brewer's Sparrows summer breeding grounds start in the Eastern Sierra Nevada's and stretch as far north as British Columbia and as south as Colorado (L. Huber, personal communication, 26 February 2023).

An adult Golden-crowned Sparrow ***(****Zonotrichia atricapilla)* was detected on June 30, 2022, feeding on seeds in the BCEP parking lot. Golden-crowned Sparrows typically migrate to

Northern British Columbia and Alaska to breed during the summer and have left California's Central Valley by the end of April (L. Huber, personal communication, 26 February 2023).

A juvenile Rose-breasted Grosbeak *(Pheucticus ludovicianus)* was seen on June 30, 2022, during a survey. This is an eastern U.S. bird species, typically only detected east of the Rocky Mountains. This individual was in a gross of Black-headed Grosbeaks (*Pheucticus melanocephalus)* (L. Huber, personal communication, 26 February 2023).

There was a lone Cedar Waxwing (*Bombycilla cedrorum)* that flew over the BCEP on July 30th, 2022. Cedar Waxwings are migratory songbirds that breed in the summer months (June-August) in Canada and Northern Maine, and this was the first occurrence on eBird of the species being present in Butte County in the month of July. The closest breeding Cedar Waxwings are in Northwestern California (Humboldt & Del Norte counties) (L. Huber, personal communication, 26 February 2023).

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The primary goal of this research was to determine the effect the Camp Fire had on the bird community at the Butte Creek Ecological Preserve (BCEP). In addition, this study aimed to investigate the presence and distribution of special status birds on the BCEP. The results confirmed that there are current populations of Yellow Warbler, Yellow-breasted Chat and Willow Flycatcher found during the breeding season, which is defined by California Department of Fish and Wildlife (CDFW) as February through September. In accordance with CDFW guidelines for nesting birds, I recommend that no substantial work is carried out on the BCEP between these months at points 1, 2, 5 and 7 as well as areas with similar habitat in order to minimize disturbance for nesting birds. If any work must occur between the months of February and September, it should be minimized, and the following mitigations measures set forth by CDFW should be followed. Mitigations include the presence of a Designated Biologist, which is a CDFW designation for a person who is knowledgeable and experienced in the biology of the listed species. The Designated Biologist shall complete a preliminary nesting bird survey prior to work starting, as well as being present during work to monitor bird activity. If nesting bird activity is noted, the Designated Biologist will flag a 45-meter buffer around the area in order to not disturb the rearing of young, or possibly halt work depending on the circumstances. Once the Designated Biologist has declared that the birds have fledged the nest, the work can continue. Additional information about special status species as well as nesting bird avoidance is available on the CDFW website (wildlife.ca.gov).

Specific mitigations for each special status species based upon this research are summarized in Table 13, including a map on Appendix J. The three points with the greatest number of post-fire detections for each species will be considered priority areas to avoid substantial work such as: cutting willows, brush removal, and burning, particularly between the months of February and September. Priority areas for the Yellow Warbler are point seven, one and five, and preferred nesting substrates are willow and alder. Priority areas for the Yellow-breasted Chat are point one, five and two. GPS coordinates can be referenced on Appendix K. Preferred nesting substrates are Himalayan blackberry, California blackberry and willow. Priority areas for the Willow Flycatcher are point five, one, seven and two (point seven and two had equal the number of detections). Preferred foraging habitat for Willow Flycatcher are mainly willow and white alder, but also riparian trees such as valley oak, Western sycamore, and Fremont cottonwood. In addition to points one, two, five and seven, any areas on the BCEP bordering Butte Creek with similar vegetation should be considered priority areas as well.

Table 13. Mitigations for Special Status Species.

	Yellow Warbler	Yellow-breasted Chat	Willow Flycatcher
Priority vegetation:	Willow, white alder	Himalayan blackberry, California blackberry, willow	Willow, white alder
Priority areas:	Points 7, 1, 5	Points 1, 5, 2	Points 5, 1, 7, 2

The points with the highest detections of special status species are listed along with priority plant species that are used for nesting and foraging.

Recommendations

Future research would benefit from the continuation of point count surveys using the same methodology for at least one additional year, resulting in five years of pre- and five years of post-fire data. The data should continue to be input into the California Avian Data Center (CADC) as well. All of the historical and future surveys should be input into the online web-based birding database, eBird, as individual checklists, so that others can have access to data collected on the BCEP (eBird.org). In addition to continuing point count surveys, nest searches for special status species nesting on the BCEP, such as Yellow Warbler and Yellow-breasted Chat could provide additional insight to which specific areas and substrates are being utilized and could pinpoint where habitat restoration efforts should be focused.

Limitations of the Study

As with any research, there are limitations which can influence the results. The BCEP is located on the south side of Honey Run Road, which is a residential road with sporadic traffic. Homes surround the BCEP in all directions except for the south side, and dogs were often heard barking during the surveys, which could potentially affect bird detections. In addition, Skyway Road is located directly south of Butte Creek and traffic noises were heard during surveys, potentially impacting detections as well. Human error is one limitation to consider, as the detection of birds depends upon the surveyor hearing or seeing the individual, as well as accurately identifying it. As surveyors rely on visual or auditory cues to detect a bird's presence, in some cases, there is the possibility that detections do not reflect true populations. In addition, there is a measure of skill needed when it comes to determining the approximate direction and location of a bird that is heard but not seen. The surveyors did their best to approximate if a bird that was only heard and not seen was under or over fifty meters from the point.

There is a large data gap due to no volunteer availability from May 2010 to March 2019, and nine years with no surveys is not ideal for a pre- and post-fire study. Additionally, the pre- and post-fire data comparison utilized different sample sizes, which can often occur in studies that take place over long temporal spans. One of the overall goals was to conduct surveys at least seven days apart, however, there were times when this was not possible, and several 2022 surveys were only spaced apart as little as five days, or as much as two weeks apart. Since the BCEP was burned so severely, there was an abnormal abundance of snags which can create hazardous surveying conditions on exceptionally windy days. Thus, there were several instances where surveys had to be postponed a few days due to the risk of falling limbs and/or trees. The small scale of this study is a limitation in itself, as additional locations that were affected by the Camp Fire could increase the accuracy of the results. Lastly, Figure 5 utilized an outdated GIS layer that does not show Butte Creek where it currently flows.

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APPENDIX A

Appendix A.

The BCEP Two Weeks Post-fire. This photo was taken between points six and seven on November 20, 2018, 12 days after the Camp Fire. Photo credit: Dr. Don Hankins

APPENDIX B

Appendix B**.**

The BCEP Two Weeks Post-fire on Butte Creek. This photo was taken along Butte Creek on November 20, 2018, 12 days after the Camp Fire. Photo credit: Dr. Don Hankins

APPENDIX C

Appendix C.

The BCEP One Month Pre-fire. This is the BCEP on October 10, 2018, roughly one month before the Camp Fire, near point six.

APPENDIX D

Appendix D.

The BCEP One Month Pre-fire. This was taken on the nature trail on October 10, 2018, approximately one month pre-fire. Photo credit: Gary Day.

APPENDIX E

Appendix E. Blank Datasheet. This is a sample datasheet that was used in the point count surveys.

			TYPICAL DETECTION				FLYOVERS				JUV	FLUSH	FIELD NOTES
			0 to 50m		> 50m		ASSOC.		IND.		CNT	CNT	
STN #	START TIME	SPP. CODE	0-3 MIN	3-5 MIN	0-3 MIN	3-5 MIN	0-3 MIN	3-5 MIN	0-3 MIN	3-5 MIN			

APPENDIX F

Appendix F. Dates of Surveys

Survey Number	Year	Month	Day	Surveyor
1	2006	March	27	Garcia
2	2006	April	20	Skram
3	2006	April	28	Garcia
4	2006	May	3	Garcia
5	2006	May	11	Garcia
6	2006	May	17	Garcia
7	2006	June	5	Garcia
8	2006	July	16	Garcia
9	2007	January	19	Skram
10	2007	March	5	Garcia
11	2007	April	1	Garcia
12	2007	April	15	Skram
13	2007	April	24	Skram
14	2007	May	10	Skram
15	2007	June	3	Garcia
16	2007	September	7	Skram
17	2008	April	8	S. Huber
18	2008	May	11	S. Huber
19	2008	May	29	Skram
20	2008	July	1	Skram
21	2008	September	9	Skram
22	2008	September	12	S. Huber
23	2008	December	7	S. Huber
24	2009	March	10	Garcia
25	2009	December	29	Skram
26	2010	April	8	S. Huber
27	2010	April	28	Garcia
28	2019	April	4	Newman
29	2019	April	6	Sobon
30	2019	April	28	Doster
31	2019	May	11	Sobon
32	2019	May	27	L. Huber
33	2019	June	16	Sobon
34	2019	July	14	Newman
35	2019	November	15	Newman
36	2019	December	21	Garcia
37	2020	January	29	Garcia

38	2020	February	16	Garcia
39	2020	March	17	Garcia
40	2020	April	12	Garcia
41	2020	May	9	Garcia
42	2020	May	26	Hersey
43	2020	September	19	Garcia
44	2020	December	30	Sobon
45	2021	March	2	Swartout
46	2021	April	5	Swartout
47	2022	February	9	L. Huber
48	2022	February	16	S. Huber
49	2022	February	23	L. Huber
50	2022	March	2	L. Huber
51	2022	March	9	L. Huber
52	2022	March	16	L. Huber
53	2022	March	23	L. Huber
54	2022	April	2	L. Huber
55	2022	April	7	L. Huber
56	2022	April	20	Corridoni
57	2022	May	1	Corridoni
58	2022	May	6	Corridoni
59	2022	May	12	Corridoni
60	2022	May	21	Corridoni
61	2022	May	27	L. Huber
62	2022	June	7	L. Huber
63	2022	June	14	L. Huber
64	2022	June	22	L. Huber
65	2022	June	30	L. Huber
66	2022	July	6	L. Huber
67	2022	July	17	L. Huber
68	2022	July	22	Corridoni
69	2022	July	30	L. Huber
70	2022	August	8	L. Huber
71	2022	August	13	L. Huber
72	2022	August	21	L. Huber
73	2022	August	26	L. Huber
74	2022	September	4	L. Huber
75	2022	September	13	L. Huber
76	2022	September	26	L. Huber

77	2022	October	10	L. Huber
78	2022	October	17	L. Huber
79	2022	October	24	L. Huber
80	2022	October	31	Garcia

APPENDIX G

Appendix G. All Bird Species Detected in Study. A comprehensive list of all bird species detected during point count surveys from 2006 through 2022, including the four-letter banding code used on datasheets and the scientific name, and grouped by taxonomic family.

Family:	Species common name:	Banding code:	Scientific name:
Accipitridae	Bald Eagle	BAEA	*Haliaeetus leucocephalus*
Accipitridae	Cooper's Hawk	COHA	*Accipiter cooperii*
Accipitridae	Golden Eagle	GOEA	*Aquila chrysaetos*
Accipitridae	Northern Harrier	NOHA	*Circus hudsonius*
Accipitridae	Red-shouldered Hawk	RSHA	*Buteo lineatus*
Accipitridae	Red-tailed Hawk	RTHA	*Buteo jamaicensis*
Accipitridae	Sharp-shinned Hawk	SSHA	*Accipiter striatus*
Accipitridae	Swainson's Hawk	SWHA	*Buteo swainsoni*
Aegithalidae	Bushtit	BUSH	*Psaltriparus minimus*
Alcedinidae	Belted Kingfisher	BEKI	*Megaceryle alcyon*
Anatidae	American Wigeon	AMWI	*Mareca americana*
Anatidae	Canada Goose	CAGO	*Branta canadensis*
Anatidae	Common Goldeneye	COGO	*Bucephala clangula*
Anatidae	Common Merganser	COME	*Mergus merganser*
Anatidae	Greater White-fronted Goose	GWFG	*Anser albifrons*
Anatidae	Green-winged Teal	GWTE	*Anas crecca*
Anatidae	Hooded Merganser	HOME	*Lophodytes cucullatus*
Anatidae	Mallard	MALL	*Anas platyrhynchos*
Anatidae	Ross's Goose	ROGO	*Anser rossii*
Anatidae	Ruddy Duck	RUDU	*Oxyura jamaicensis*
Anatidae	Snow Goose	SNGO	*Anser caerulescens*
Anatidae	Tundra Swan	TUSW	*Cygnus columbianus*
Anatidae	Wood Duck	WODU	*Aix sponsa*
Apodidae	Vaux's Swift	VASW	*Chaetura vauxi*
Apodidae	White-throated Swift	WTSW	*Aeronautes saxatalis*
Ardeidae	Great Blue Heron	GBHE	*Ardea herodias*
Ardeidae	Great Egret	GREG	*Ardea alba*
Ardeidae	Green Heron	GRHE	*Butorides virescens*
Ardeidae	Snowy Egret	SNEG	*Egretta thula*
Bombycillidae	Cedar Waxwing	CEDW	*Bombycilla cedrorum*
Cardinalidae	Black-headed Grosbeak	BHGR	*Pheucticus melanocephalus*
Cardinalidae	Lazuli Bunting	LAZB	*Passerina amoena*
Cardinalidae	Rose-breasted Grosbeak	RBGR	*Pheucticus ludovicianus*
Cardinalidae	Western Tanager	WETA	*Piranga ludoviciana*
Cathartidae	Turkey Vulture	TUVU	*Cathartes aura*
Certhiidae	Brown Creeper	BRCR	*Certhia americana*
Charadriidae	Killdeer	KILL	*Charadrius vociferus*

Columbidae	Band-tailed Pigeon	BTPI	*Patagioenas fasciata*
Columbidae	Eurasian Collared-Dove	EUCD	*Streptopelia decaocto*
Columbidae	Mourning Dove	MODO	*Zenaida macroura*
Columbidae	Rock Pigeon	ROPI	*Columba livia*
Corvidae	American Crow	AMCR	*Corvus brachyrhynchos*
Corvidae	California Scrub-Jay	CASJ	*Aphelocoma californica*
Corvidae	Common Raven	CORA	*Corvus corax*
Corvidae	Steller's Jay	STJA	*Cyanocitta stelleri*
Falconidae	American Kestrel	AMKE	*Falco sparverius*
Falconidae	Merlin	MERL	*Falco columbarius*
Falconidae	Peregrine Falcon	PEFA	*Falco peregrinus*
Fringillidae	American Goldfinch	AMGO	*Spinus tristis*
Fringillidae	House Finch	HOFI	*Haemorhous mexicanus*
Fringillidae	Lesser Goldfinch	LEGO	*Spinus psaltria*
Fringillidae	Pine Siskin	PISI	*Spinus pinus*
Fringillidae	Purple Finch	PUFI	*Haemorhous purpureus*
Hirundinidae	Barn Swallow	BARS	*Hirundo rustica*
Hirundinidae	Cliff Swallow	CLSW	*Petrochelidon pyrrhonota*
Hirundinidae	Northern Rough-winged Swallow	NRWS	*Stelgidopteryx serripennis*
Hirundinidae	Tree Swallow	TRES	*Tachycineta bicolor*
Hirundinidae	Violet-green Swallow	VGSW	*Tachycineta thalassina*
Icteridae	Brown-headed Cowbird	BHCO	*Molothrus ater*
Icteridae	Brewer's Blackbird	BRBL	*Euphagus cyanocephalus*
Icteridae	Bullock's Oriole	BUOR	*Icterus bullockii*
Icteridae	Hooded Oriole	HOOR	*Icterus cucullatus*
Icteridae	Red-winged Blackbird	RWBL	*Agelaius phoeniceus*
Icteridae	Western Meadowlark	WEME	*Sturnella neglecta*
Icteriidae	Yellow-breasted Chat	YBCH	*Icteria virens*
Mimidae	Northern Mockingbird	NOMO	*Mimus polyglottos*
Odontophoridae	California Quail	CAQU	*Callipepla californica*
Pandionidae	Osprey	OSPR	*Pandion haliaetus*
Paridae	Oak Titmouse	OATI	*Baeolophus inornatus*
Parulidae	Common Yellowthroat	COYE	*Geothlypis trichas*
Parulidae	Nashville Warbler	NAWA	*Leiothlypis ruficapilla*
Parulidae	Orange-crowned Warbler	OCWA	*Leiothlypis celata*
Parulidae	Wilson's Warbler	WIWA	*Cardellina pusilla*
Parulidae	Yellow Warbler	YEWA	*Setophaga petechia*
Parulidae	Yellow-rumped Warbler	YRWA	*Setophaga coronata*
Passerellidae	Brewer's Sparrow	BRSP	*Spizella breweri*
Passerellidae	California Towhee	CALT	*Melozone crissalis*
Passerellidae	Dark-eyed Junco	DEJU	*Junco hyemalis*
Passerellidae	Fox Sparrow	FOSP	*Passerella iliaca*

Passerellidae	Golden-crowned Sparrow	GCSP	*Zonotrichia atricapilla*
Passerellidae	Lark Sparrow	LASP	*Chondestes grammacus*
Passerellidae	Lincoln's Sparrow	LISP	*Melospiza lincolnii*
Passerellidae	Rufous-crowned Sparrow	RCSP	*Aimophila ruficeps*
Passerellidae	Song Sparrow	SOSP	*Melospiza melodia*
Passerellidae	Spotted Towhee	SPTO	*Pipilo maculatus*
Passerellidae	Swamp Sparrow	SWSP	*Melospiza georgiana*
Passerellidae	White-crowned Sparrow	WCSP	*Zonotrichia leucophyrs*
Passeridae	House Sparrow	HOSP	*Passer domesticus*
Phalacrocoraciae	Double-crested Cormorant	DCCO	*Nannopterum auritum*
Phasianidae	Wild Turkey	WITU	*Meleagris gallopavo*
Picidae	Acorn Woodpecker	ACWO	*Melanerpes formicivorus*
Picidae	Downy Woodpecker	DOWO	*Dryobates pubescens*
Picidae	Hairy Woodpecker	HAWO	*Dryobates villosus*
Picidae	Lewis's Woodpecker	LEWO	*Melanerpes lewis*
Picidae	Northern Flicker	NOFL	*Colaptes auratus*
Picidae	Nuttall's Woodpecker	NUWO	*Dryobates nuttallii*
Picidae	Red-breasted Sapsucker	RBSA	*Sphyrapicus ruber*
Podicipedidae	Pied-billed Grebe	PBGR	*Podilymbus podiceps*
Polioptilidae	Blue-gray Gnatcatcher	BGGN	*Polioptila caerulea*
Ptiliogonatidae	Phainopepla	PHAI	*Phainopepla nitens*
Rallidae	American Coot	AMCO	*Fulica americana*
Rallidae	Common Gallinule	COGA	*Gallinula galeata*
Rallidae	Sora	SORA	*Porzana carolina*
Rallidae	Virginia Rail	VIRA	*Rallus limicola*
Regulidae	Golden-crowned Kinglet	GCKI	*Regulus satrapa*
Regulidae	Ruby-crowned Kinglet	RCKI	*Regulus calendula*
Scolopacidae	Greater Yellowlegs	GRYE	*Tringa melanoleuca*
Scolopacidae	Spotted Sandpiper	SPSA	*Actitis macularius*
Scolopacidae	Wilson's Snipe	WISN	*Gallinago delicata*
Sittidae	Red-breasted Nuthatch	RBNU	*Sitta canadensis*
Sittidae	White-breasted Nuthatch	WBNU	*Sitta carolinensis*
Strigidae	Northern Pygmy-Owl	NOPO	*Glaucidium gnoma*
Sturnidae	European Starling	EUST	*Sturnus vulgaris*
Sylviidae	Wrentit	WREN	*Chamaea fasciata*
Trochilidae	Anna's Hummingbird	ANHU	*Calypte anna*
Trochilidae	Black-chinned Hummingbird	BCHU	*Archilochus alexandri*
Trochilidae	Rufous Hummingbird	RUHU	*Selasphorus rufus*
Troglodytidae	Bewick's Wren	BEWR	*Thryomanes bewickii*
Troglodytidae	Canyon Wren	CANW	*Catherpes mexicanus*
Troglodytidae	House Wren	HOWR	*Troglodytes aedon*
Turdidae	American Robin	AMRO	*Turdus migratorius*

Turdidae	Hermit Thrush	HETH	*Catharus guttatus*
Turdidae	Varied Thrush	VATH	*Ixoreus naevius*
Turdidae	Western Bluebird	WEBL	*Sialia mexicana*
Tyrannidae	Ash-throated Flycatcher	ATFL	*Myiarchus cinerascens*
Tyrannidae	Black Phoebe	BLPH	*Sayornis nigricans*
Tyrannidae	Dusky Flycatcher	DUFL	*Empidonax oberholseri*
Tyrannidae	Hammond’s Flycatcher	HAFL	*Empidonax hammondii*
Tyrannidae	Pacific-slope Flycatcher	PSFL	*Empidonax difficilis*
Tyrannidae	Western Kingbird	WEKI	*Tyrannus verticalis*
Tyrannidae	Western Wood-Pewee	WEWP	*Contopus sordidulus*
Tyrannidae	Willow Flycatcher	WIFL	*Empidonax traillii*
Vireonidae	Cassin’s Vireo	CAVI	*Vireo cassinii*
Vireonidae	Hutton’s Vireo	HUVI	*Vireo huttoni*
Vireonidae	Warbling Vireo	WAVI	*Vireo gilvus*

APPENDIX H

Appendix H. Foraging Guilds.

Aerial Foragers	
Ash-throated Flycatcher	Pacific-slope Flycatcher
Barn Swallow	Tree Swallow
Black Phoebe	Vaux's Swift
Cliff Swallow	Violet-green Swallow
Dusky Flycatcher	Western Kingbird
Hammond's Flycatcher	Western Wood-Pewee
Northern Rough-winged Swallow	Willow Flycatcher
Peregrine Falcon	White-throated Swift

Ground/Open meadow	
American Crow	Killdeer
American Goldfinch	Lark Sparrow
American Kestrel	Lazuli Bunting
American Robin	Lesser Goldfinch
Brown-headed Cowbird	Lincoln's Sparrow
Brewer's Blackbird	Merlin
Brewer's Sparrow	Mourning Dove
Canada Goose	Northern Harrier
California Towhee	Northern Mockingbird

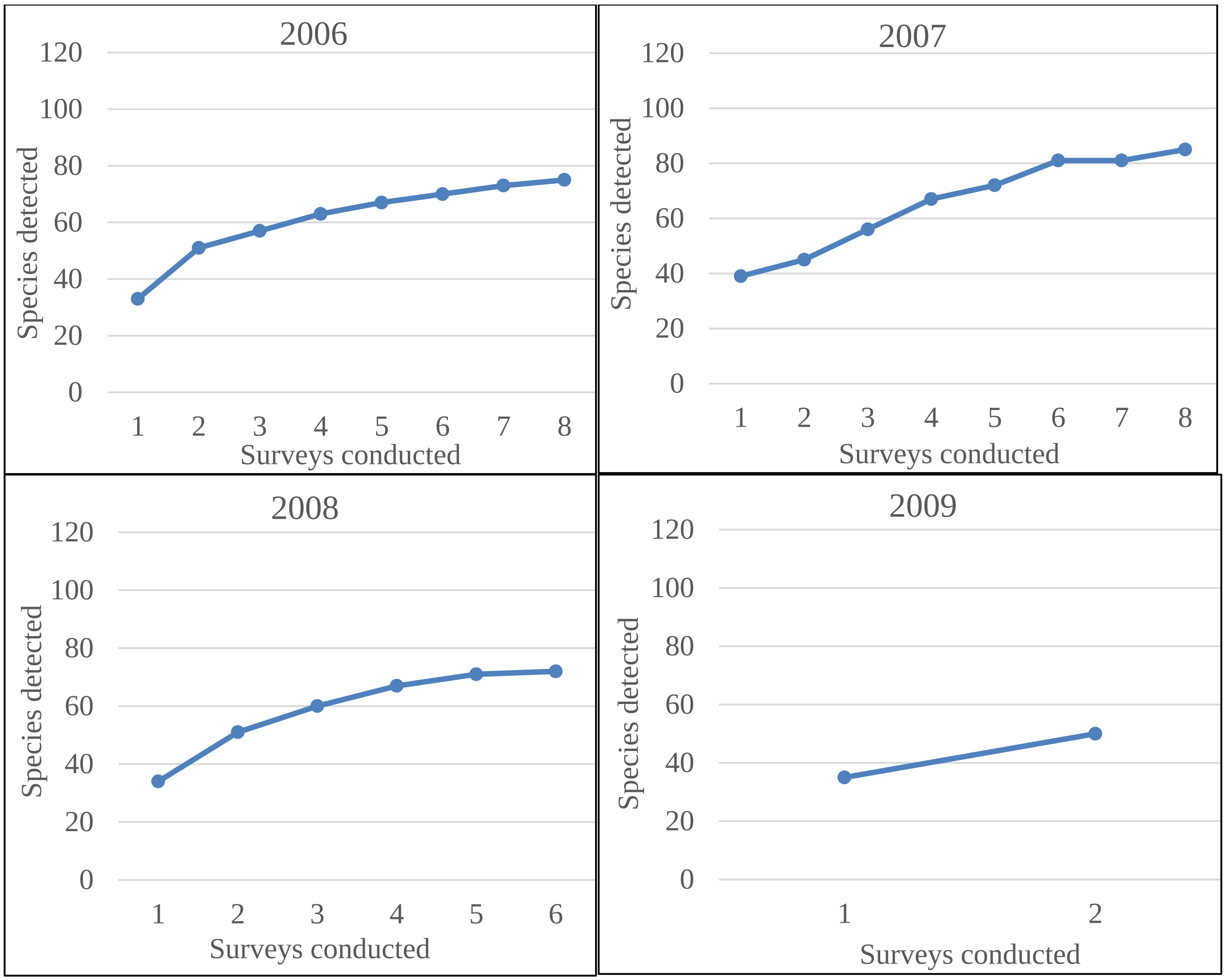
Canyon Wren	Rufous-crowned Sparrow
California Quail	Rock Pigeon
California Scrub-Jay	Red-winged Blackbird
Common Raven	Song Sparrow
Dark-eyed Junco	Spotted Towhee
Eurasian Collared-Dove	Swainson’s Hawk
European Starling	Swamp Sparrow
Fox Sparrow	Turkey Vulture
Golden-crowned Sparrow	White-crowned Sparrow
Golden Eagle	Western Bluebird
Hermit Thrush	Western Meadowlark
House Finch	Wilson’s Snipe
House Sparrow	Wild Turkey
Water-Associated	
American Coot	Green-winged Teal
American Wigeon	Hooded Merganser
Bald Eagle	Mallard
Belted Kingfisher	Osprey
Common Gallinule	Pied-billed Grebe
Common Goldeneye	Ross’s Goose
Common Merganser	Ruddy Duck

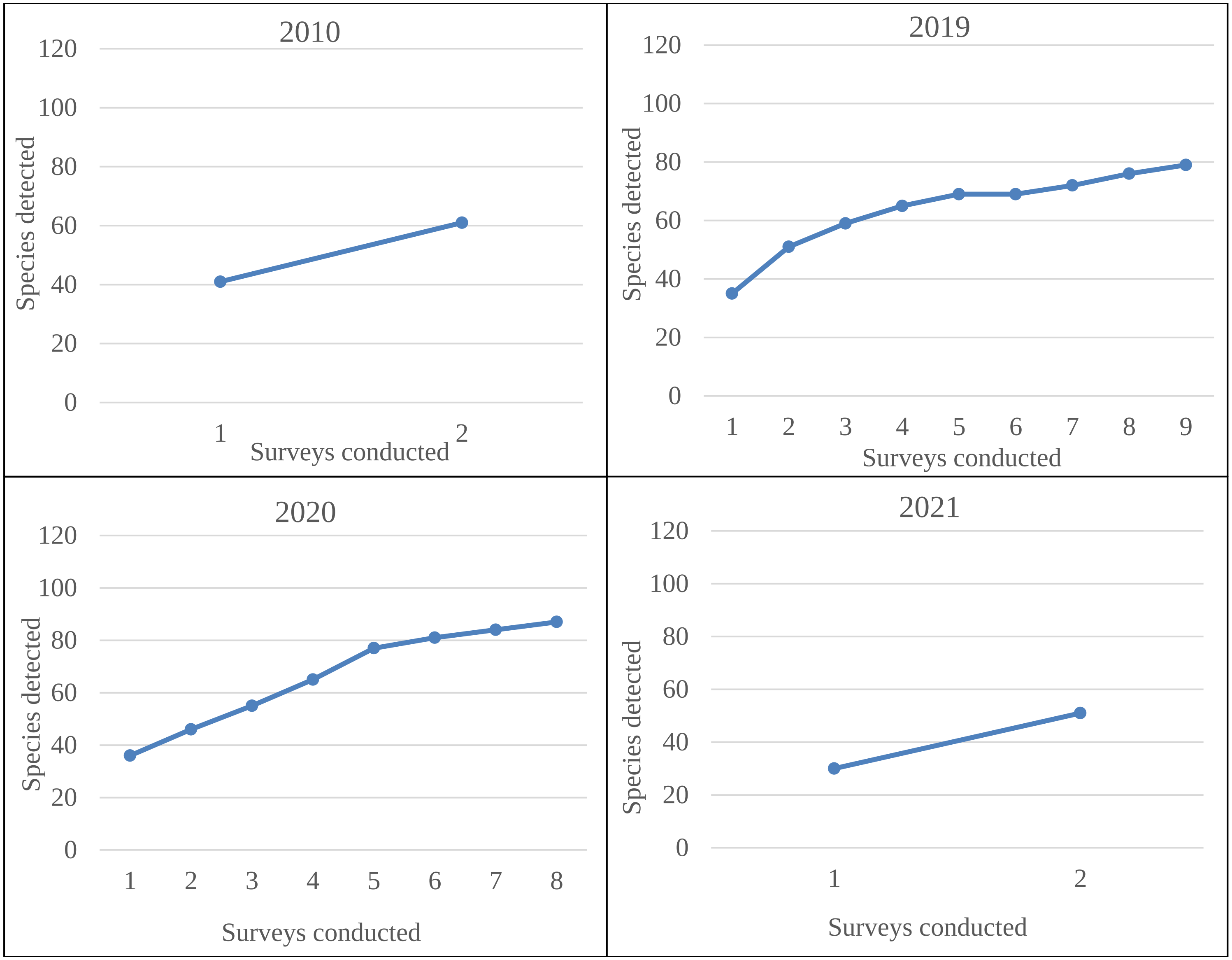
Common Yellowthroat	Snowy Egret
Double-crested Cormorant	Snow Goose
Great Blue Heron	Sora
Great Egret	Spotted Sandpiper
Green Heron	Tundra Swan
Greater Yellowlegs	Virginia Rail
Greater White-fronted Goose	Wood Duck
Tree/Vegetation-Associated	
Acorn Woodpecker	Oak Titmouse
Anna’s Hummingbird	Orange-crowned Warbler
Black-chinned Hummingbird	Phainopepla
Bewick’s Wren	Pine Siskin
Blue-gray Gnatcatcher	Purple Finch
Black-headed Grosbeak	Rose-breasted Grosbeak
Brown Creeper	Red-breasted Nuthatch
Band-tailed Pigeon	Red-breasted Sapsucker
Bullock’s Oriole	Ruby-crowned Kinglet
Bushtit	Red-shouldered Hawk
Cassin’s Vireo	Red-tailed Hawk
Cedar Waxwing	Rufous Hummingbird

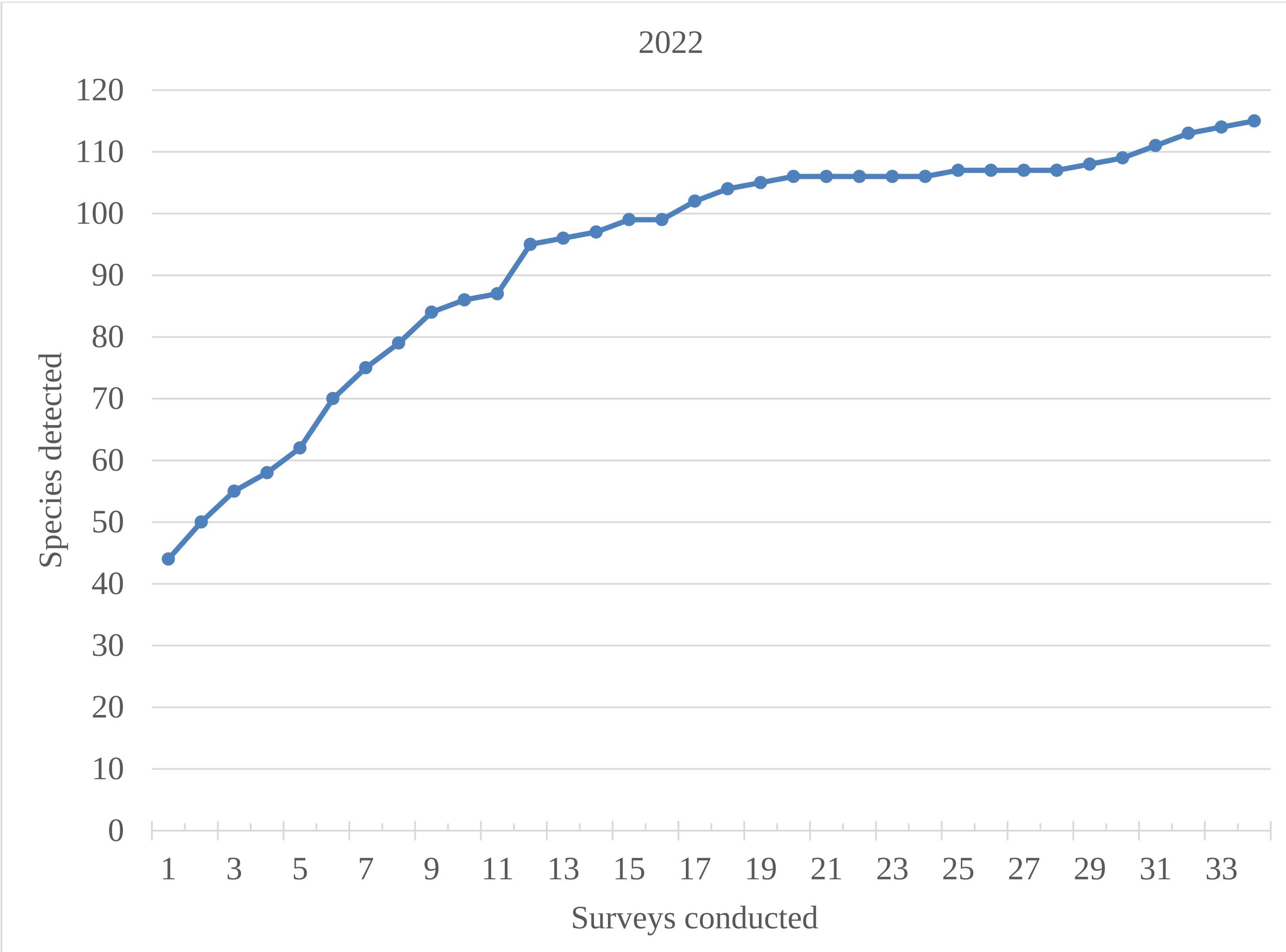
Cooper’s Hawk	Sharp-shinned Hawk
Downy Woodpecker	Steller’s Jay
Golden-crowned Kinglet	Varied Thrush
Hairy Woodpecker	Warbling Vireo
Hooded Oriole	White-breasted Nuthatch
House Wren	Western Tanager
Hutton’s Vireo	Wilson’s Warbler
Lewis’s Woodpecker	Wrentit
Nashville Warbler	Yellow-breasted Chat
Northern Flicker	Yellow Warbler
Northern Pygmy-Owl	Yellow-rumped Warbler
Nuttall’s Woodpecker	

APPENDIX I

Appendix I. Annual Species Accumulation Curves

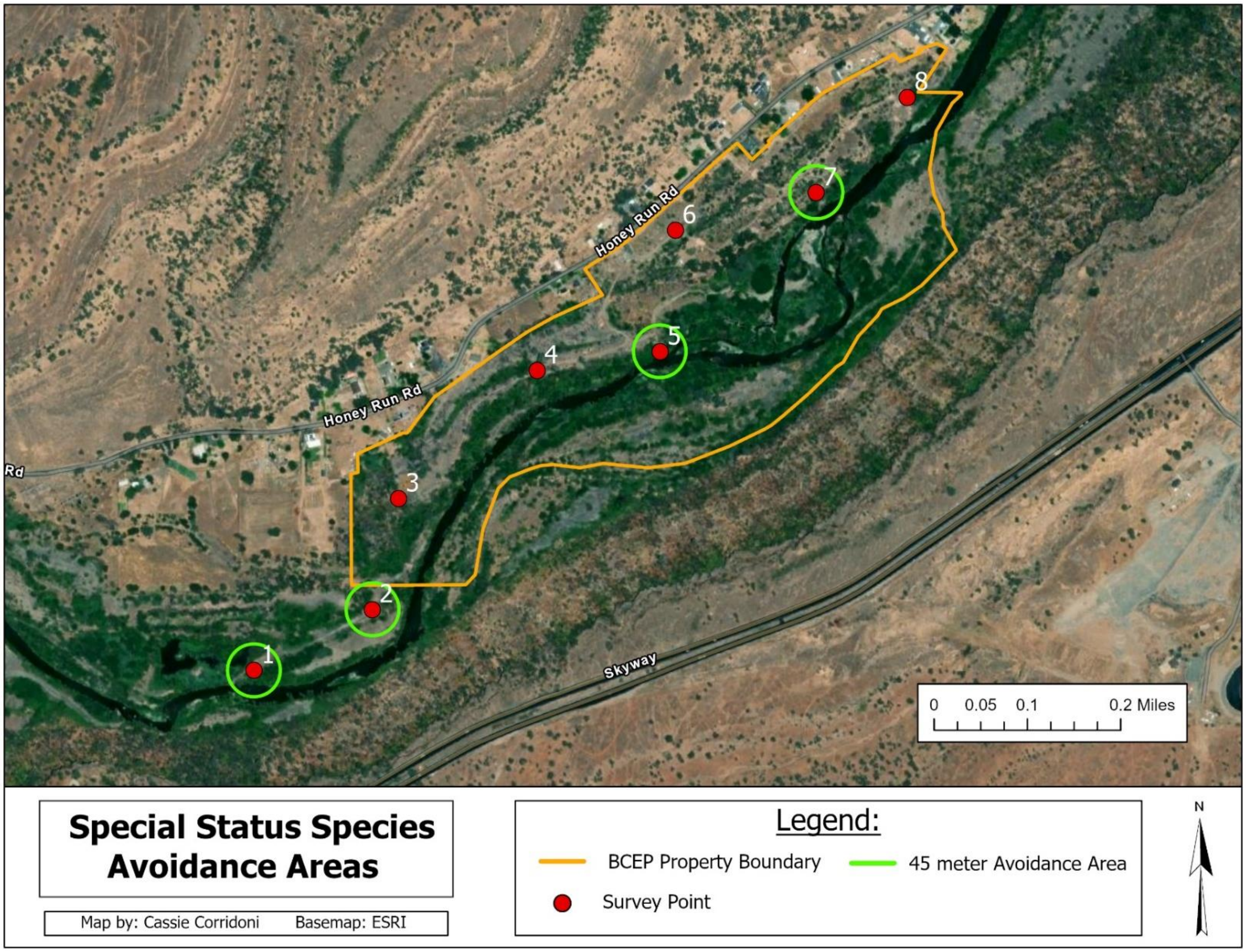



2010
Species detected
Surveys conducted
2019
Species detected
Surveys conducted
2020
Species detected
Surveys conducted
2021
Species detected
Surveys conducted


2022
120
110
100
90
80
70
60
50
40
30
20
10
0
Species detected
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Surveys conducted

APPENDIX J

Appendix J. Special Status Species Avoidance Areas



APPENDIX K

Appendix K. GPS Coordinates of Survey Points

Point	Latitude	Longitude
1	39.71045	-121.72839
2	39.71137	-121.72600
3	39.71307	-121.72543
4	39.71503	-121.72262
5	39.71530	-121.72013
6	39.71718	-121.71978
7	39.71772	-121.71694
8	39.71920	-121.71508

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APPENDIX L

Appendix L. Total annual detections for each species. Appendix L contains total annual detections for each species for each survey year. The four-letter species codes can be referenced in Appendix G.

Species	2006	2007	2008	2009	2010	2019	2020	2021	2022	Total
ACWO	20	25	53	21	11	86	79	16	738	1049
AMCO		2	4	3				2	2	13
AMCR	4	14	3		3	3	5	7	1	40
AMGO	16	36	46	3	3		4		7	115
AMKE									11	11
AMRO	37	51	18	22	13	28	68	13	164	414
AMWI		5		2						7
ANHU	24	11	13	2	10	13	22	5	185	285
ATFL	20	14	19		6	31	17		101	208
BAEA		1	2			3		1	9	16
BARS	5									5
BCHU			2							2
BEKI	8	13	6	4	11	11	16	3	22	94
BEWR	61	52	49	9	12	15	15	10	237	460
BGGN		4								4
BHCO	37	36	31		4	15	19	1	128	271
BHGR	40	29	27		3	22	20		106	247
BLPH	21	28	44	11	3	28	32	11	160	338
BRBL	30	34	44		34	21	7	25	76	271
BRCR	1	1				3				5
BRSP									1	1
BTPI		11		50	14				46	121
BUOR	23	8	6		6	13	5	1	66	128
BUSH	30	15	94	54	13	28	7	2	127	370
CAGO	3	17	2	12	6	30	65	22	207	364
CALT	16	9	13	2	5	25	9		55	134
CANW							1		6	7
CAQU	12	25	34	3	13	33	34	18	475	647
CASJ	15	28	31	26	10	67	63	9	386	635
CAVI		1	1							2
CEDW	15	18	7		6		46	17	185	294
CLSW	2220	76	52			1	5		14	2368
COGA	1	13	16		1				32	63
COGO							9		5	14
COHA	1	1					2		2	6

COME	21	16	12	1		21	25		37	133
CORA	11	10	7	1		13	22	3	121	188
COYE		1				5			5	11
DCCO						2	1		23	26
DEJU			1	1	1	1	9		4	17
DOWO	11	10	11	1	4	12	5	3	56	113
DUFL					1					1
EUCD						38	57	9	199	303
EUST	15	14	14	5	7	104	177	18	619	973
FOSP	2	2				2	2		19	27
GBHE	1	5	2			5	4	5	15	37
GCKI							1			1
GCSP	9	9	1	3		36	29	12	123	222
GOEA		1		1						2
GREG		1				3	3		16	23
GRHE	3	2	3		1	5	2	2	14	32
GRYE		3					1			4
GWFG		125							115	240
GWTE			6							6
HAFL					2					2
HAWO	3	15		2		4	1		15	40
HETH	8	7	4	5	2	6	5		28	65
HOFI	84	90	65	17	13	28	56	13	242	608
HOME					1				2	3
HOOR									22	22
HOSP		9	5	2		6	1		92	115
HOWR	21	13	9		8	28	44	3	104	230
HUVI	5	6	1	1					1	14
KILL	2	6	1		1	1			7	18
LASP		1					1		64	66
LAZB					1	21	10		14	46
LEGO	115	232	96	74	51	119	188	2	179	1056
LEWO									19	19
LISP	1					2	3	1	6	13
MALL	6	30	28	14	2	25	15	13	138	271
MERL							1		1	2
MODO	34	17	18		1	20	14	1	79	184
NAWA	1	2								3
NOFL	6	15	8	7	4	36	24	4	171	275
NOHA									2	2
NOMO			1	1		4	2	1	37	46
NOPO		1								1
NRWS	6	10	2	4	22	8	5	2	75	134

NUWO	14	27	29	7	5	36	30	10	145	303
OATI	13	27	21	7	13	43	71	10	183	388
OCWA	25	30	12	6	20	12	9	3	5	122
OSPR							5		12	17
PBGR		6	3	1			2		3	15
PEFA			2			1			2	5
PHAI	6	5	15		1		25		139	191
PISI						6			32	38
PSFL	1		2		2	2	1		2	10
PUFI						6	1		6	13
RBGR									1	1
RBNU	1									1
RBSA						1	1		1	3
RCKI	6	20	8	10	1	40	35	4	80	204
RCSP									3	3
ROGO									16	16
ROPI						1	1			2
RSHA	5	4	6	2	1	7	3	6	36	70
RTHA	1					1	1		36	39
RUDU			2							2
RUHU					1				6	7
RWBL	4	13	10	1	2	1	20	14	258	323
SNEG							1			1
SNGO		100				375	375		932	1782
SORA									5	5
SOSP	21	23	8	2	2	12	10	4	36	118
SPSA	3		3						1	7
SPTO	34	39	20	3		50	28	8	125	307
SSHA									1	1
STJA	1		20	5		3				29
SWHA									1	1
SWSP	1									1
TRES	104	174	76	11	33	95	42	81	328	944
TUSW		300					271		63	634
TUVU	24	54	26	4	19	58	63	34	517	799
VASW									1	1
VATH									1	1
VGSW	16	38	43		40	10	23	206	275	651
VIRA							4	3	17	24
WAVI		1			2	1			2	6
WBNU	13	10	15	7		10	19	1	64	139
WCSP	7	3	3	1	5	47	95	20	237	418
WEBL			16	6			25		25	72

WEKI	6	4	7			2	3	4	30	56
WEME			1						1	2
WETA	8	6	21		3	4	3		23	68
WEWP	14	7	11			20	6		28	86
WIFL	1	1	2				1		42	47
WISN									1	1
WITU	8	2	4		2	1		1	17	35
WIWA	14	1	3		7	7			13	45
WODU	5	31	26	17	3	25	38	1	70	216
WREN			17	1	2		2		50	72
WTSW									1	1
YBCH	34	19	28		9	41	19		89	239
YEWA	9	9	17		3	17	7		49	111
YRWA	32	16	4	5	6	26	7	4	36	136
Total	3456	2201	1393	460	491	1992	2505	669	10265	23432