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DATA ARTICLE

# The importance of open data describing prey item species lists for endangered species

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## Abstract

1. Open data and code can be transformative tools in supporting evidence-informed solutions for stakeholders. Data can take many forms of evidence in the discipline of applied ecology including tables, lists, maps and visualizations to name a few.
2. Endangered and listed species are often a catalyst for research, conservation and planning. Here, a novel, open data set summarizing all the reported diet and prey items for all endangered, terrestrial dryland species listed in central California is provided as a case study. These data highlight the critical need for sharing data rapidly and transparently to support ecological solution science.
3. Systematic review practices were used, data were compiled and the resulting data set was published in an open access, federated data repository using ecological metadata language and FAIR principles. The goal is to show that these data can now be used and analysed by applied ecologists and stakeholders to identify not only the habitat and spatial needs for the endangered species but to widen the conservation protection net to include prey species.
4. Conserving viable habitat with higher likelihoods of prey presence will better support conservation of endangered species, and data describing reported species are a crucial first step. Interactive tables, local species lists and maps are simple tools that can now be developed regionally with open data such as these.

**KEYWORDS**
conservation, diet, endangered species, open data, prey items, synthesis science

## 1 | INTRODUCTION

Location, location, location. Conservation and at times restoration ecology is often founded on the principle assumption that we must protect habitats. Protecting areas with relatively high activity and presence patterns of endangered species can be highly effective (Berigan et al., 2012). Protecting and designating core zones within conservation areas can also capture suitable habitats that meet the needs of many species including flagship and endangered species (Wang et al., 2021). Finally, the size of protected habitats and local conditions can positively outweigh other drivers of change in many of the taxa that we work to conserve (Bosco et al., 2023; Thebault et al., 2014). Nonetheless, habitat-focussed efforts for single or focal species can at times overlook the multiscale and multidriver nature of ecological solutions and the depth of evidence that we likely need to inform applied research and stakeholders (McNeil et al., 2020). This is not to say that we should not protect habitat, but it does suggest that exploring a shift in filters or in the definition of needs

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for species within a region can generate novel evidence and methods to inform conservation and data collection (Groves et al., 2002; Hanson et al., 2020). Here, we propose that compiling data on the reported diet and prey items for endangered species within a region will provide a high-level alternative and/or augmentation to describing habitat needs based on other ecological measures. Extending the habitat directly needed to support endangered species to the indirect habitat needs for prey species is a critical applied ecological challenge in many ecosystems.

In the central drylands of California, land conservation and restoration is a challenge. Synthesis evidence strongly suggests that protecting lands based primarily on vegetation can be effective, particularly when active restoration is used for a site (Lortie et al., 2018; Miguel et al., 2020). The local plant species richness was also shown to be an effective assay tool across many studies at different sites in central California (Lortie et al., 2022). Understanding the reported diet and prey items is a critical next step and an important form of evidence for conservation and potentially restoration because it will add important evidence to justify conservation. This paradigm can thus blend the best of both worlds using endangered species as a starting point for understanding both habitat but also the relative importance of other species within a region or at sites that can support them. Drylands encompass arid and semi-arid ecosystems (Yirdaw et al., 2017) and comprise 41% of the terrestrial surface of the planet while directly supporting 38% of humans and 44% of global croplands (Maestre et al., 2021). Prey items for the dryland, terrestrial endangered species in California are often terrestrial arthropods and will have different sensitivities, dispersal and movement patterns and in turn shifted vegetation needs than the endangered consumer species (Tobisch et al., 2023). Consequently, tools that reuse and populate lists of IUCN threatened species for a region for instance (Lee et al., 2019) or translocations efforts that are unsuccessful (Berger-Tal et al., 2020) can extend the evidence used in these models to include open, compiled data that lists reported prey items. We do not necessarily need to build food webs for all endangered species within a region (Heleno et al., 2020), but we do at a minimum need species lists to support decision-making for some of the associated species in addition to plant species that can provide habitat. The pressing question regionally is hence 'how can we even begin to conserve endangered species within this highly disturbed region if we do not know what they consume?' The terrestrial arthropods that support endangered vertebrate species are germane to planning because management for some of these species within croplands can occur adjacent to conservation and natural areas and likely have significant negative spillover effects that undermine conservation efforts (Braun & Lortie, 2019; Montoya et al., 2021; Zamorano et al., 2020), for example, a grasshopper is conceptualized as pest in one field, prey in another (Ralf, 2001; Rand et al., 2006; Schmitz, 2005). The motivation for the data collection here is thus to support a deeper understanding of the species that we need to describe for conservation of focal species within an ecological region. The key question addressed through data compilation is 'what prey items are reported to support endangered species with the central drylands of California, a diverse and highly fragmented, mixed use ecosystem' (Germano et al., 2011).

An applied ecological researcher or stakeholder can search for reported prey items or diet needs for endangered species. However, search term sensitivity (Lefebvre et al., 2019), access to publications and reporting of prey or diet can present challenges. It can be time consuming to search or even access publications and other resources to develop a comprehensive or at least representative list for even one focal species, and mentions of diet can be within a publication but not described in the title, abstract or as the main focus of a paper. Consequently, many of the challenges of limited opportunity to engage with open science tools (Lowndes et al., 2017) in addition to access to synthesis science tools and approaches to build evidence and data (Halpern et al., 2023) can impede an accurate, high-level assessment of prey and diets similar to other endeavours working to advance ecological knowledge (Halpern et al., 2020). To this end, a formal systematic review approach was adopted to develop a comprehensive list of all prey items for endangered terrestrial vertebrate species within central California drylands into one data set for the region for this specific group as proof of concept on the importance of these data.

## 2 | MATERIALS AND METHODS

The general workflow to collect data included identifying endangered species within a region from former syntheses of status listings, queries of a bibliometrics tool to then retrieve publications that listed diet and prey for these species, followed by formal systematic review practices to extract a list of prey for every endangered species, compile and publish openly for reuse. First, a list of reported endangered species previously compiled for this region (Germano et al., 2011) and then re-examined and updated in an additional synthesis explicitly testing for restoration opportunities (Stewart et al., 2019) were used to validate a robust list of focal conservation species. An exhaustive list for a total of 41 species were published alongside the restoration opportunities listing the species names, federal and California listing status, and persistence as extant, extirpated or unknown for this dryland region (Stewart et al., 2019). Using these data, we selected 18 endangered species that were vertebrates, listed federally or at state level and still reported as persistent within the region as of publication date. This dryland region is ecologically well described in spatial extent in the two former syntheses (Germano et al., 2011; Stewart et al., 2018), but the centred geolocation is 34.94, −119.69 in degrees decimals. A map is also provided to highlight where these data are most relevant to inform management and ecological solution science regionally (Figure 1).

Secondly, a total of 304 peer-reviewed publications were reviewed in detail for these 18 listed vertebrate species that reside in the region (Table 1). The bibliometrics resource ISI Web of Science was used to query the primary peer-reviewed research literature (Clarivate, 2023). The search terms included the Latin binomial for each listed species and the terms 'diet' and 'prey' listed anywhere

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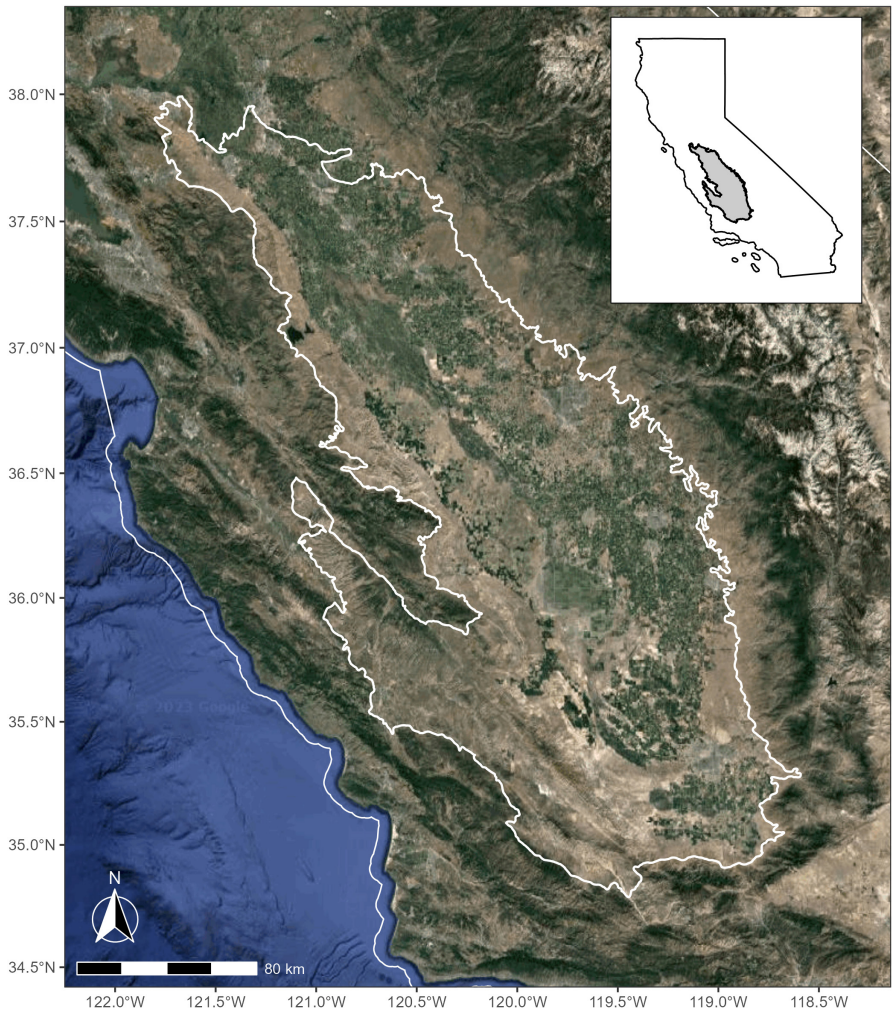


**FIGURE 1** A map of the Central Valley Ecoregion of California, United States. Extensive ecological and applied research has been done in this region with federally listed vertebrate species (see text for details). This region represents an instance of a spatially relevant ecological catchment for scientific synthesis of prey items for numerous species. This regional classification is from the US EPA Level IV ecoregion classification schema. Google was used to source the imagery, and the outline of California inset was developed by the US Census Bureau.

**TABLE 1** A synthesis of the reported prey and/or diet items in the peer-reviewed scientific literature for the listed and endangered vertebrate species within the central drylands of California.

| Listed species | No. of publications | No. of unique diet items |
|---|---|---|
| *Ambystoma californiense* | 8 | 7 |
| *Ammospermophilus nelsoni* | 3 | 33 |
| *Buteo swainsoni* | 26 | 147 |
| *Charadrius alexandrinus nivosus* | 2 | 15 |
| *Gambelia sila* | 8 | 25 |
| *Dipodomys ingens* | 14 | 11 |
| *Dipodomys nitratoides exilis* | 0 | 0 |
| *Dipodomys nitratoides nitratoides* | 5 | 0 |
| *Grus canadensis tabida* | 15 | 2 |
| *Haliaeetus leucocephalus* | 120 | 275 |
| *Neotoma fuscipes riparia* | 1 | 0 |
| *Rana draytonii* | 7 | 42 |
| *Riparia riparia* | 25 | 33 |
| *Sorex ornatus relictus* | 3 | 1 |
| *Sylvilagus bachmani riparius* | 11 | 16 |
| *Thamnophis gigas* | 12 | 12 |
| *Vireo bellii pusillus* | 19 | 5 |
| *Vulpes macrotis mutica* | 25 | 18 |

within publications. Additional queries were done using Google Scholar and all other reports, federal and regional, that were accessible were also reviewed (Gusenbauer & Haddaway, 2020). All salient elements supporting applied ecology that were reported consistently in publications and studies were included that list prey or diet items anywhere in the full text or tables (Lortie et al., 2022).

## 3 | USAGE NOTES

The purpose of these data was to provide an indication of the extent that a set of endangered species listed within a region can be used to develop a larger prey list, and thus, alternative lists of species can be developed for this or any other region using other criterion such as freshwater or feeding guild depending on the research or applied needs. Key variables in the data included were those relevant to reuse for terrestrial ecologists and other stakeholders within the region such as collection method for prey, taxonomic details, ecosystem and species life stages. Tidy data principles were used to structure the dataframe (Wickham, 2014); FAIR data principles were included in describing the published open data (Wilkinson et al., 2016); and Ecological Metadata Language 2.2.0 was used and published alongside the data (Jones et al., 2019). The repository

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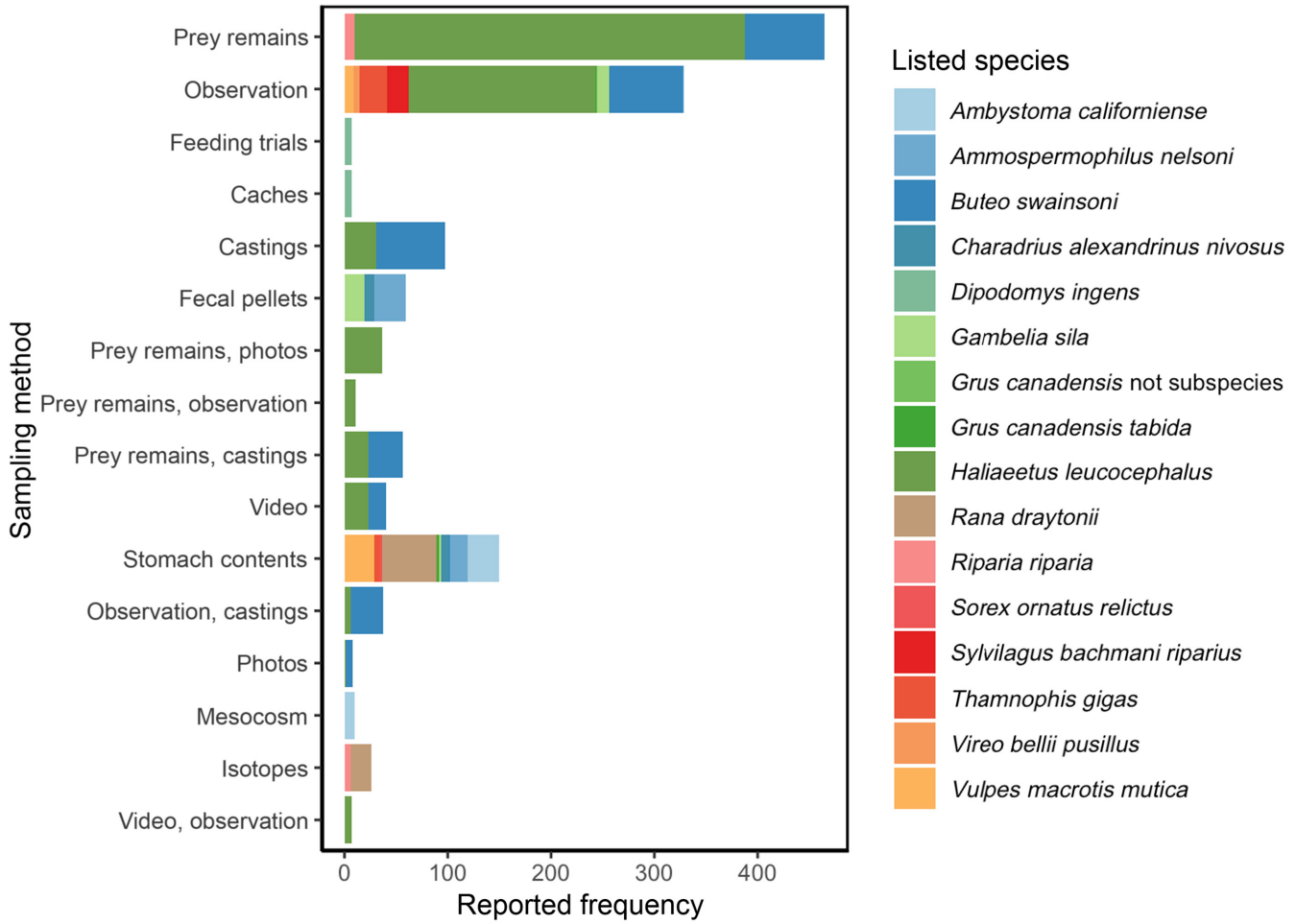


**FIGURE 2** The relative frequency of reported methods to describe prey items for listed and endangered terrestrial vertebrate species within the central drylands of California. These data were compiled in formal synthesis of the literature (see Section 2), and reported frequency is the number of independent instances a prey item was documented within studies.

Knowledge Network for Biocomplexity was selected for data sharing because it includes and supports biodiversity data, is well curated, indexed by other resources and provided a permanent digital online identifier (Lortie et al., 2022). Taxonomic naming and harmonization of differences in reporting between the primary publications were completed with the R package 'TAXIZE' (Chamberlain et al., 2022). The year listed was the date of primary publication; this was not necessarily the date of prey collection or ecological diet assessment.

## 4 | GENERAL PATTERNS

The primary goal was to provide a comprehensive, regional prey item species list that can function as a resource for reuse, replication and simple 'look-ups'. Two immediate opportunities to better support data reuse and interactivity were evident that facilitated general pattern assessments. A table that directly supported user-defined filtering was published (https://edata.shinyapps.io/prey_app/) using the RStudio Shiny app (Chang et al., 2023). Search and sort are enabled and accessible in any web browser. Using the same online tool, a simple interactive bar plot was also published to visualize the relative frequency of prey items, by class, reported for every listed species (https://edata.shinyapps.io/prey_app/). These tools enabled interaction with the open data but do not replace published open data for more detailed reuse. From an applied synthesis science perspective, the relative extent that prey items were reported in publications and the number of unique diet items that directly listed diet and prey is also a key finding because it illuminates gaps and suggests strength of evidence (Table 1). The most common ecological methods to estimate prey items were inspection of prey remains followed by direct observation of feeding (Figure 2, two of the listed species did not report prey items in sufficient detail, with methods, to compile into quantitative data). A total of 635 unique prey items were described. These findings strongly show that listed and endangered species within a region are directly supported by many other species as prey items and that open data summarizing these reported interactions will significantly enhance both the breadth of conservation strategies and the scope of restoration applications.

To make a cogent argument for diet data use to support more robust management decisions, a clear link between specific evidence and practice is useful. *Gambelia sila* or the blunt-nosed leopard lizard was one of the first federally listed vertebrate species in the United States

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and is endemic to this region (Germano et al., 2011; Service, 1998). Key habitat characteristics include shrubs (Westphal et al., 2018), abandoned burrows (Fields et al., 1999; Prugh & Brashares, 2012) and access to habitat that provides thermal heterogeneity to support its diverse behavioural needs (Gaudenti et al., 2021; Ivey et al., 2020). Consequently, restoration planning for *G. Sila* can thus encompass many niche dimensions (Stewart et al., 2019). Nonetheless, a total of 25 unique diet items have been reported for this endangered species (Table 1), and interaction with the online app developed rapidly shows that while most prey items are reported at least once, there are three species, all insects, that are more frequently and independently reported. Fly, grasshopper and species of cricket are strongly influenced by the availability of herbaceous spring and summer vegetation and flowering plants (Ibanez et al., 2013; Reemer & Rotheray, 2009). These three insect prey items are also sensitive to pesticide practices in agricultural and human-use lands (Grégoire et al., 2022), and thus, negative spillover from crop management needs to be considered as a key rationale for diet data inclusion into planning decisions (Montoya et al., 2021). These data suggest that planning for habitat conservation and restoration with the endangered species *G. sila* as an indicator for the region must incorporate direct needs such as shrubs (for shelter) but also ensure that other vegetation is present to support its prey items (for their diets). Management strategies for crop pests within the region must also be considered (because they are also prey for this endangered species), and if this is immutable or challenging to reconcile, the practice of planning conservation areas for *G. sila* with buffers or spatial separation from the negative impacts of active agriculture must be balanced against the benefits of flowering plants and increased prey availability. This landscape of choice is an opportunity to explore novel trade-offs and provides a broader palette of ecological management levers. Many of the listed species summarized herein also have less reported unique prey items. These linkage principles are thus profoundly relevant to the practice of solution science for species with less diet data available or more specialized feeding. We propose that the extent that a listed species samples the landscape and its foraging for the prey items identified through synthesis data be conceptualized as the 'food habitat' for a species in addition to direct habitat needs. Tangibly linking diet-to-habitat for a specific endangered species thereby provides a unique filter to planning and evidence-informed ecological management decisions.

## AUTHOR CONTRIBUTIONS

C. J. Lortie and Jenna Braun collected the data. Rachel King validated data and harmonized species nomenclature. All authors wrote the paper.

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## CONFLICT OF INTEREST STATEMENT

The authors have conflict of interest to declare.

## PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/2688-8319.12251.

## DATA AVAILABILITY STATEMENT

All data are openly archived at https://knb.ecoinformatics.org/view/doi:10.5063/F1TQ600D (Lortie et al., 2022).

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