



Prioritizing sites for conservation based on similarity to historical baselines and feasibility of protection

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Abstract: *The concept of shifting baselines in conservation science implies advocacy for the use of historical knowledge to inform these baselines but does not address the feasibility of restoring sites to those baselines. In many regions, conservation feasibility varies among sites due to differences in resource availability, statutory power, and land-owner participation. We used zooarchaeological records to identify a historical baseline of the freshwater mussel community's composition before Euro-American influence at a river-reach scale (i.e., a kilometer stretch of river that is abiotically similar) in the Leon River of central Texas (U.S.A.). We evaluated how the community reference position and the feasibility of conservation might enable identification of sites where conservation actions would preserve historically representative communities and be likely to succeed. We devised a conceptual model that incorporated community information and landscape factors to link the best conservation areas to potential cost and conservation benefits. Using fuzzy ordination, we identified modern mussel beds that were most like the historical baseline. We then quantified housing density and land use near each river reach identified to estimate feasibility of habitat restoration. Using our conceptual framework, we identified reaches of high conservation value (i.e., contain the best mussel beds) and where restoration actions would be most likely to succeed. Reaches above Lake Belton were most similar in species composition and relative abundance to zooarchaeological sites. A subset of these mussel beds occurred in locations where conservation actions appeared most feasible. Our results show how to use zooarchaeological data (biodiversity data often readily available) and estimates of conservation feasibility to inform conservation priorities at a local spatial scale.*

Keywords: applied zooarchaeology, conservation feasibility, freshwater mussels, river conservation, shifting baselines

Priorización de Sitios para la Conservación basada en la Similitud con Líneas de Base Históricas y la Viabilidad de la Protección

Resumen: *El concepto de líneas base cambiantes en la ciencia de la conservación implica la defensa del uso del conocimiento histórico para informar a estas líneas base, pero no toca el tema de la viabilidad de la restauración de sitios hacia esas líneas base. En muchas regiones, la viabilidad de la conservación varía entre sitios debido a las diferencias en la disponibilidad de recursos, el poder legal y la participación de los terratenientes. Usamos registros zooarqueológicos para identificar una línea base histórica de la composición de la comunidad de mejillones de agua dulce antes de la influencia euro-americana a escala de alcance de río (es decir, un tramo de un kilómetro de río que es similar en componentes abióticos) en el río Leon del centro de Texas (E.U.A.). Evaluamos cómo la comunidad referencia la posición y cómo la viabilidad de la conservación puede permitir la identificación de sitios en donde las acciones de conservación preservarían comunidades representativas históricamente y que tengan probabilidad de tener éxito. Diseñamos un modelo conceptual que incorporó la información de la comunidad y los factores de paisaje para vincular las mejores áreas de conservación a los beneficios de conservación y costo potencial. Con el uso de ordenación difusa*

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identificamos lechos modernos de mejillones que tenían mayor probabilidad de parecerse a la línea de base histórica. Después cuantificamos la densidad de viviendas y el uso de suelo próximos a cada uno de los ríos identificados para estimar la viabilidad de la restauración del hábitat. Con nuestro marco de trabajo conceptual identificamos los alcances de río con alto valor para la conservación (es decir, que incluyera los mejores lechos de mejillones) y en dónde las acciones de restauración tendrían mayor posibilidad de ser exitosas. Los alcances por encima del lago Belton fueron los más similares a los sitios zooarqueológicos en cuanto a composición de especies y abundancia relativa. Un subconjunto de estos lechos de mejillones se registró en localidades en las que las acciones de conservación parecían ser más viables. Nuestros resultados muestran cómo usar los datos zooarqueológicos (datos sobre biodiversidad que comúnmente ya están disponibles) y las estimaciones sobre la viabilidad de la conservación para informar las prioridades de conservación a una escala espacial local.

Palabras clave: conservación de ríos, líneas de base cambiantes, mejillones de agua dulce, viabilidad de la conservación, zooarqueología aplicada

Introduction

Conservation of ecological communities is impaired when the collective idea of the natural baseline shifts due to cultural perceptions (Humphries & Winemiller 2009; Papworth et al. 2009; Radeloff et al. 2015). Thus, incorporating historical knowledge, including zooarchaeological data, in ecological baselines is important (Lyman 2012; Scharf 2014). The use of zooarchaeological data at landscape scales to conserve animal communities requires well-preserved zooarchaeological remains that represent localized animal communities; knowledge of current animal communities; and an understanding of the costs, benefits, and feasibility of potential conservation actions. We explored this approach for managing freshwater mussels in a river with methods applicable to other taxa that meet these requirements.

Although the inclusion of zooarchaeological data typically improves historical baselines, this improvement does not always translate into improved management because conservation feasibility varies widely among sites. We defined “conservation feasibility” as the cumulative factors that increase the likelihood that management options will be undertaken and will be successful. These factors are related to social and government structure (Hobbs 2007; McBride et al. 2007; Mills et al. 2013), faunal biodiversity (Nel et al. 2009), site vulnerability and condition (Linke et al. 2007), and the presence of co-occurring stressors (Evans et al. 2011; Brown et al. 2013; Neeson et al. 2016). For freshwater systems, conservation feasibility varies widely because of the reliance of humans and riverine organisms on freshwater. Freshwater reserves can be difficult to establish because humans need stores of water (reservoirs) and riverine animals require stretches of flowing water without impediments (Strayer & Dudgeon 2010). For example, connectivity between headwater streams and the mouths of rivers is essential for some migrating fish, and reducing the number of impoundments reduces habitat alteration for stream organisms. Riverine communities also shift in

their species composition based on their location in a watershed because upstream and downstream habitats are quite different and harbor different species assemblages. River restoration often requires the participation of multiple conservation groups to restore natural stream habitat (Allan et al. 1997; Milt et al. 2017; Moody et al. 2017). Because feasibility aspects and reference uncertainty have been used to argue against reliance on historical baselines for conservation prioritization (Dufour & Piégay 2009), we propose a method to compare the 2 simultaneously.

Zooarchaeological assemblages, faunal remains found in archaeological settings, provide a representation of past environments for paleoecologists, wildlife managers, and conservation biologists (Lyman 2012). For freshwater mussels (*Bivalvia*: Unionidae; hereafter mussels), zooarchaeological research has focused on prehistoric extinctions (Williams & Fradkin 1999), extirpations (Ortmann 1909; Bogan 1990; Mitchell & Peacock 2014), and range shifts (Randklev et al. 2010; Peacock et al. 2016; Wolverton & Randklev 2016). Mussels have unique traits that make them excellent sources of zooarchaeological information. They have large, calcium carbonate shells that often preserve well (Parmalee & Klippel 1974). Native mussels are largely sedentary as adults and are constrained to particular habitats, thus archaeological shells reflect the past river environment (Matteson 1960; Peck et al. 2014). Finally, because mussels usually occur in multispecies aggregations (mussel beds), with densities 10 to 100 times higher than outside of beds (Strayer et al. 2004), they were likely collected indiscriminately within these beds by past human foragers (Peacock et al. 2012). Zooarchaeological records of freshwater mussels were likely deposited close to their collection site because mussels represent heavy, perishable packets of low caloric value (Peacock et al. 2012). To our knowledge, zooarchaeological data have not been used to prioritize specific reaches for conservation within a river system, which makes ours a novel technique for identifying areas for protection.

Freshwater mussels are a globally imperiled fauna (Lydeard et al. 2004). In North America, anthropogenic impacts have led to substantial declines; 70% of the mussel fauna is currently considered threatened (Haag 2012; Haag & Williams 2014). As long-lived, burrowing filter feeders, mussels provide ecosystem services by contributing to biofiltration, nutrient recycling and storage, providing and modifying habitat, and supporting food webs (Vaughn & Spooner 2007; Allen et al. 2012; Atkinson et al. 2013; Vaughn et al. 2015; Vaughn 2018). Because mussels are imperiled, improve riverine ecosystems, and are deposited near where they were collected, their archaeological shells may provide information that can inform conservation.

Zooarchaeological data can improve the two main approaches to freshwater mussel conservation, habitat and population restoration (Neves 1997; Freshwater Mollusk Conservation Society 2016), by allowing identification of river areas known to support diverse, healthy mussel beds. Population restoration is best performed after habitat restoration has insured a good place for the propagated or translocated to live (McMurray & Roe 2017), so we focused on habitat quality and potential restoration. Mussel beds are long-term features of a river that can remain in the same location for hundreds of years (Strayer 1999; Vaughn & Spooner 2004). In good conditions, the species composition of these mussel beds remains relatively unchanged over long periods (Vaughn et al. 1996). Such persistence of mussel communities likely means habitat conditions are good for these communities, and shifts in community structure may reflect large-scale habitat change (White 1977; Vaughn et al. 1996).

Large-scale variation in habitat characteristics can be used to delineate appropriate mussel habitat. Mussels require stream channels that are stable, continually wet, and not subject to heavy sedimentation or eutrophication (Morales et al. 2006; Allen & Vaughn 2010; Osterling et al. 2010). Riparian forest restoration and reduction in nutrient loading can help achieve these habitat conditions (Haag 2012). Riparian restoration through cattle fencing and tree augmentation prevents bank collapse, reduces sedimentation, and prevents cattle from adding excessive nutrients to streams (Dosskey et al. 2010). These management actions can improve habitat for both resident and future propagated mussels, as well as other aquatic fauna.

We used zooarchaeological data and a landscape ecology approach to identify river reaches for habitat preservation based on their mussel community and feasibility of conservation actions (Peacock et al. 2016). We obtained data on present-day and pre-EuroAmerican mussel communities from a river in the southcentral United States. We used fuzzy ordination to identify reaches that should be conserved based on the similarity of their present-day community to the historical baseline. To establish feasibility of riparian restoration and nutrient loading

reduction, we quantified housing density and local land use. We used these analyses to explore which sites would be appropriate for conservation and whether restoring them to their pre-EuroAmerican baseline would be achievable.

Methods

Study Area

The Leon River is a fifth-order tributary of the Brazos River in central Texas. The area has hot, dry summers and wet winters (Rose & Echelle 1981), and the surrounding landscape is dominated by agricultural land. This river is moderately affected by anthropogenic change due to 2 small urban centers (Belton and Hamilton) and 3 water impoundments (Fig. 1). A recent quantitative survey documented 11 mussel species in the river. Over time species richness and abundance have declined (Randklev et al. 2013). Historically, the river harbored 3 mussel species of conservation concern: false spike (*Fusconaia mitchelli*), Texas fawnsfoot (*Truncilla macrodon*), and smooth pimpleback (*Cyclonaias houstonensis*) (Randklev et al. 2013; Williams et al. 2017; Popejoy et al. 2018). Only *C. houstonensis* persists in the river today, although all 3 are present in other Brazos tributaries.

Conservation Conceptual Model

To evaluate which river reaches represent the best conservation areas, we created a conceptual model that relates habitat quality and resident mussel communities to potential restoration costs and ecosystem service gains provided by mussels (i.e., conservation feasibility) (Fig. 2). The current community's similarity to historical communities is important because communities that are more similar to past communities likely contain remnant, endemic populations that are of high conservation concern. We defined "conservation feasibility" broadly as all economic, social, and political aspects that determine the likelihood of successfully implementing conservation. For example, high conservation feasibility could represent less cost in both effort and money. In our model, sites are on 3 tiers: tier 1, mussel beds that are easiest to preserve and likely have intact mussel-derived ecosystem services, such as biofiltration and nutrient cycling; tier 2, sites that require either work to restore the mussel community or to restore habitat but still have good ecological function; tier 3, sites where both mussel community and habitat need restoration (loss of ecological function). Tier 1 beds have a high similarity index (>0.5) and an above-average conservation feasibility. Tier 2 beds have either a high similarity index or low conservation feasibility or vice versa. Tier 3 beds have a similarity index <0.5 and a below-average conservation feasibility.

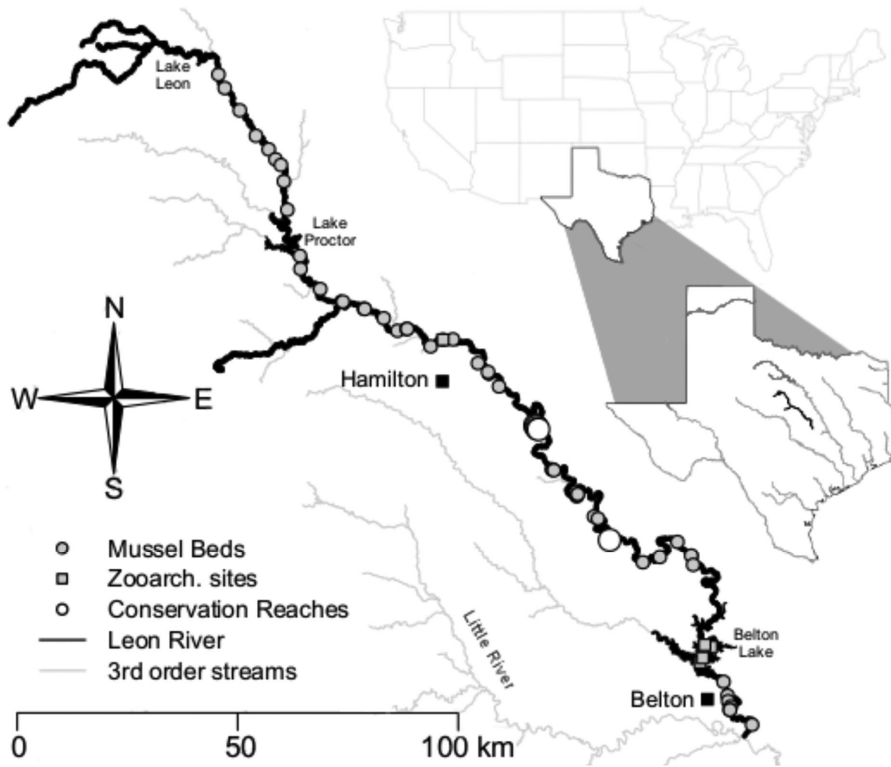


Figure 1. Leon River, extant mussel beds, locations of zooarchaeological mussel remains, identified conservation reaches (see Results), and relevant third-order tributaries of the Brazos River and all sixth-order streams in the state (inset). Map generated with code from the hydroMap R package (DeCicco & Blodgett 2017).

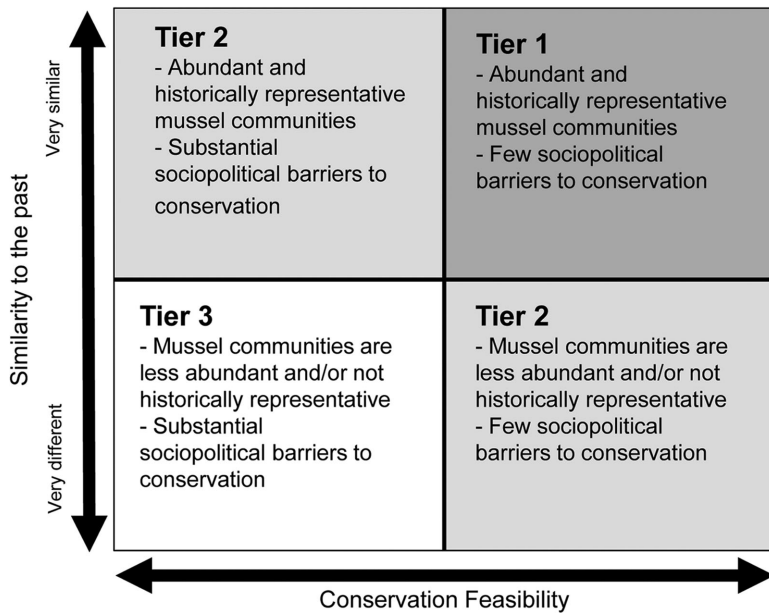


Figure 2. Conceptual model relating the similarity of extant mussel community to historical community and conservation feasibility to mussel-provided ecosystem services. The darker the shading, the better the conservation options in terms of community similarity and cost.

Locating Pristine Mussel Beds

We used data on present-day mussel communities from a 2011 systematic survey of the river by Randklev et al. (2013), who located 52 mussel beds from just below Lake Leon to the confluence of the Leon River with the Little River (Fig. 1). We used two pre-EuroAmerican zooarchaeological data sets to represent the late Holocene mussel community: the 41HM61 assemblage and the Belton Lake assemblages (Popejoy et al. 2018). The 41HM61 assem-

blage represents an upstream portion of the Leon River near Hamilton. The Belton Lake assemblages comprise remains from 18 separate cave sites that surround Belton Lake. These assemblages represent mussels collected and discarded by native peoples during the late Holocene (approximately 2000 years ago) (Weinstein 2015). We identified shell remains that contained a nonrepetitive element (umbo) to the lowest taxonomic category possible (Giovas 2009; Driver 2011; Harris et al. 2015). Based on

freshwater mussel ecology and their low caloric value, species exclusion within mussel beds by human predation is unlikely (Parmalee & Klippel 1974). But differential preservation between mussel species can alter the composition of the archaeological remains (Wolverton et al. 2010).

Archaeological shells have been subjected to multiple filters by the time they are identified (Lyman 2010); differential remains preservation and sampling adequacy are two pertinent filters to consider. Like bones, shell sphericity and density affect mussel-shell preservation (Wolverton et al. 2010). Because threeridge (*Amblema plicata*) has a robust and easily identifiable shell, it tends to dominate in zooarchaeological assemblages. The assemblages from Belton Lake are well preserved (7.1% unidentifiable shells) but samples are small. The 41HM61 assemblage is moderately well preserved (21.3% unidentifiable shells) and has a larger sample size than the Belton Lake assemblage (Popejoy et al. 2017). Because both assemblages include species that are unlikely to be preserved (Louisiana fatmucket [*Lampsilis bydiana*] and rock pocketbook [*Arcidens confragosus*]), we accepted that they represent the late Holocene mussel community.

Zooarchaeological samples are the amalgamation of multiple sampling events through time, and sample adequacy is important in any community-focused research (Woo et al. 2016). To ensure complete sampling of the late Holocene community, we used a rarefaction curve in R package *vegan* to eliminate samples that did not adequately represent community richness (R Core Team 2014; Oksanen et al. 2017). Based on our rarefaction curve (Supporting Information), we eliminated samples that contained <5 species. Thus, we used six zooarchaeological sites to represent the late Holocene freshwater mussel community and to establish a pre-EuroAmerican baseline.

We used species abundance data and spatial locations of mussel beds in a fuzzy ordination to determine which contemporary sites are most like the pre-EuroAmerican baseline in terms of mussel species richness and relative abundance. Mussel-bed location was the number of river kilometers upstream from the confluence of the Little and Leon Rivers. In fuzzy ordination, fuzzy set logic is used to compare the community composition of each site and assign them a fuzzy classification (Roberts 2009). Fuzzy set logic works well for archaeological data because the data contain inherent uncertainties, such as preservation bias (Hermon et al. 2004; Baxter 2009). The sites were assigned to two sets (A and B) based on location with values from 0 to 1. A third set (C) was constructed by finding the set anticommutative difference (sites that are similar to set A but are not similar to set B) of the other sets. This third set represented the predicted membership of sets A and B of the sites based on other variables. Sets A and B were based on the spatial location of the

sites. Set C was the predicted river-kilometer location of each sample based on mussel relative abundance. The correlation between actual location and predicted locations was used to determine whether the environmental gradient was appropriate for predicting community composition. Set C represented the similarity index of each bed between modern and prehistoric communities. We completed fuzzy ordination of the prehistoric and the modern mussel sites with R Core Software and the *fso* package (Roberts 2013; R Core Team 2014).

To ensure the similarity index represented current conservation goals, we ran a Spearman's ρ correlation to correlate the similarity index (μ) values to *C. boustoensis* abundance and to mussel density. Nonparametric statistics are most appropriate for zooarchaeological data due to uncertainty related to preservation; hence, we used fuzzy-set ordination and Spearman's ρ correlation (Driver 2011; Wolverton 2013).

Conservation Feasibility Analysis

To evaluate how feasible it would be to conserve the mussel beds that are most similar to the pre-EuroAmerican baseline, we assessed two common conservation actions: riparian forest preservation and improving land management in the area. To complete this spatial analysis, all 52 mussel beds were snapped to a shapefile of the mainstem of the Leon River, from the U.S. Geological Survey National Hydrologic Database, with the *maptools* package in R (Bivand & Lewin-Koh 2016). This shapefile contains line segments that represent hydrologically unique reaches of the river (U.S. Geological Survey 2016). We then reduced the length of these segments to areas of the river within a 300-m radius of the mussel bed. Reaches that contained the mussel beds had a mean length of 0.68 km (SD 0.31). We considered different approximations of anthropogenic factors that influence river ecosystems to evaluate conservation feasibility. Ideally, reaches that have communities similar to the pre-EuroAmerican baseline would be in areas with low housing density and few developed and crop land-use areas. Where mussel beds are in areas with relatively fewer houses and more forest and wetland, it may be easier to convince property owners to install cattle fences and reduce fertilizer use.

Evaluating Protection of Riparian Forests and Land use

Protecting riparian forests by augmenting vegetation or constructing cattle fences relies on landowner cooperation. Although trust between landowners and water managers increases the likelihood of conservation success, stakeholder involvement does not (Young et al. 2013). To minimize the number of stakeholders affected by riparian restoration, we identified reaches where the number of property owners was low. To do this, we estimated

the density of property owners based on the number of houses within U.S. census blocks that abutted each mussel reach (U.S. Census Bureau 2010). We compiled a set of census blocks that were within 100 m of the river and divided the number of houses within each block by the land area to determine housing density for that block. Housing density for all blocks surrounding the reach was then averaged to get a single value for each reach. The resulting value approximated the number of property owners near a mussel reach and provided an indirect measure of other anthropogenic impacts.

Improving land management across river basins can reduce nutrient loading, sedimentation, and anthropogenic chemical input (i.e., herbicides and pesticides) in rivers (Allan et al. 1997). Local improvement of land management directly influences habitat quality in stream reaches. Thus, we used land-use raster data from the U.S. Department of Agriculture to evaluate the proportion of land area under different uses within 1 km of each mussel bed (Atkinson et al. 2012; Homer et al. 2012). The relative abundance of forest and wetland within the area surrounding the river was used to predict the feasibility of protecting or supplementing existing forest near river reaches.

Results

The ordination with mussel community composition and river kilometer was significant ($r = 0.64$, $p < 0.01$), indicating river kilometer predicted community composition. This ordination ordered the sites based on their species composition and returned their set C (μ) value that indicated the probability of belonging to either end of the river continuum spectrum (Fig. 3). The μ values, indicating similarity between modern and prehistoric communities, ranged from 0.376 to 0.627. This ordination showed a shift from sites dominated by *A. plicata* (late Holocene) to sites dominated by lentic species (yellow sandshell [*Lampsilis teres*] and fragile papershell [*Lepetodea fragilis*]).

The mussel community at the AW site was most similar to the prehistoric community because it was dominated by *A. plicata* (Fig. 3). The AW site had a low catch-per-unit-effort (CPUE) and abundance of mussels: 8 *A. plicata* and 4 *C. bostonensis*. Thus, it was not the ideal bed for conservation. The AE site had a community with the highest μ of 0.58. This bed had both high mussel CPUE and abundance of *C. bostonensis*.

The similarity index was correlated with *C. bostonensis* abundance ($\rho = 0.71$, $p < 0.001$) and mussel density ($\rho = 0.66$, $p < 0.001$). Because the similarity index matched past community structure and modern conservation goals, we used this value to identify beds that contained a resident mussel community suitable for conservation.

Generally, mussel beds with species composition similar to the late Holocene mussel assemblages were in reaches that had a low density of houses in adjacent census blocks (Fig. 4a). The average number of houses at each reach ranged from 1 to 55, and the average census block area ranged from 0.19 to 18.29 km² (Supporting Information). This resulted in 0.05–19.70 houses/km² and a mean of 3.16 houses/km² (SD 4.88). Mussel beds that were most similar to the pre-European baseline were also in areas with low housing density. Sites AG, AH, and AD had 0.48 houses/km² and site AE had 0.67 houses/km² (Fig. 4a).

Reaches with more forest and wetlands had mussel beds more similar to historical communities (Fig. 4b). Pasture was the highest land use surrounding the reaches, followed by shrubland and grain crops (Supporting Information). Mussel beds that were most similar to the late Holocene baseline were often surrounded by forest. Site AD had 49.9% forest cover, and site AO and AE had 48.3% forest cover (Fig. 4b).

Based on our conceptual model, we identified multiple options for conserving mussel beds in the Leon River. Eight of the 52 known mussel beds contained mussel communities similar to those in the past and were in areas of low housing density and high relative abundance of forest, making them tier 1 in our conceptual model.

Discussion

We found that zooarchaeological and landscape data can be combined to identify mussel beds of high conservation priority and areas where conservation may be most feasible. We also provided potential solutions for protecting high-quality reaches and rehabilitating habitat based on land-use change and similarity of current beds with the past mussel community. Our study is an example of the use of unconventional data sets to further conservation of aquatic species. It also highlights the role zooarchaeological data can play in mussel conservation, beyond measuring temporal changes in faunal assemblages.

Freshwater mussels and aquatic systems are under multiple threats in the Leon River. Climate change and anthropogenic water use often exacerbate harsh water conditions in southern rivers (Vaughn et al. 2015). By ensuring sufficient water during critical life-history phases, water managers can mitigate harm caused by anthropogenic water use (Gates et al. 2015). Zebra mussels (*Dreissena polymorpha*), a new invasive species in the river system (Olson 2016), adversely affect native mussels through food and space competition (Strayer & Malcom 2007). The beds that represent the best conservation opportunities are upstream of current zebra mussel locations (Lake Belton) and thus are potentially protected because zebra mussel larvae are poor dispersers against flow (Stoeckel et al. 1997). By considering the multiple threats aquatic

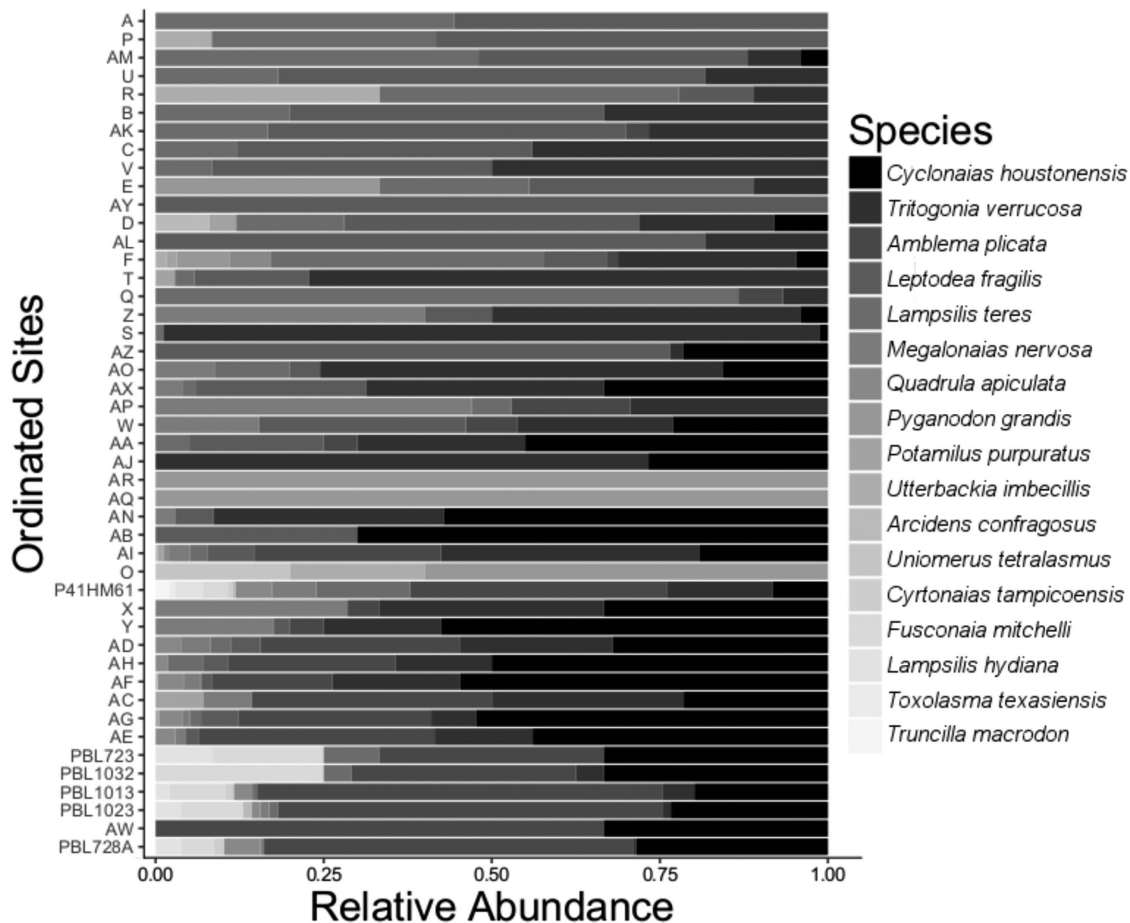


Figure 3. Mussel species composition at sampled sites ordered by past similarity to historical communities (μ) (y -axis). Zooarchaeological sites are generally at the bottom and their names start with the letter P, whereas names of modern sites are 1–2 letters. Species ordered in legend by modern abundance (top, highest abundance).

systems face, conservation biologists can better concentrate resources to improve return on investment.

By restoring mussel beds, both humans and aquatic organisms benefit. Freshwater mussels can improve water quality because their filtering action removes bacteria from the water column (Faust et al. 2009; Othman et al. 2015). This filter feeding improves stream clarity and increases macroinvertebrate resources in the river (Vaughn 2018), which could potentially increase the recreational value of the river. By working with successful management groups to enact species conservation efforts, conservationists can improve the river for recreation purposes. The Leon River Watershed Protection Program, a local management group, successfully engaged stakeholders through outreach to improve the river's water quality to state and federal standards (Koch & Cawthon 2014). By working with this stakeholder-engagement program, it may be possible to implement more species-centric conservation actions.

We suggest managers focus their efforts on tier 1 beds because they represent the best opportunities for conservation. Tier 1 beds contain irreplaceable mussel com-

munities that are likely providing important ecosystem services. They also represent cost-effective opportunities for conservation: less money would need to be spent restoring the habitat or the mussel population. Beds in tier 2 also represent viable conservation options, depending on available resources and stakeholder receptiveness. By working with current stream-management structures and considering two looming threats to the river, the Leon River and its stakeholders would benefit from conserving freshwater mussels.

The Leon River case study demonstrates the real-world utility of zooarchaeological data, which is rarely used by mussel conservationists in management and recovery planning. Although we focused on a threatened mussel fauna in a small tributary in Texas, our approach could be extended to other animals, as long as both conservation and zooarchaeological constraints are considered. Animals must produce archaeological signatures through harvest by hunter-gatherers and the preservation of hard body components in middens. Zooarchaeological data must be local (long-distance transport would eliminate local spatial data) and be a good representation of the

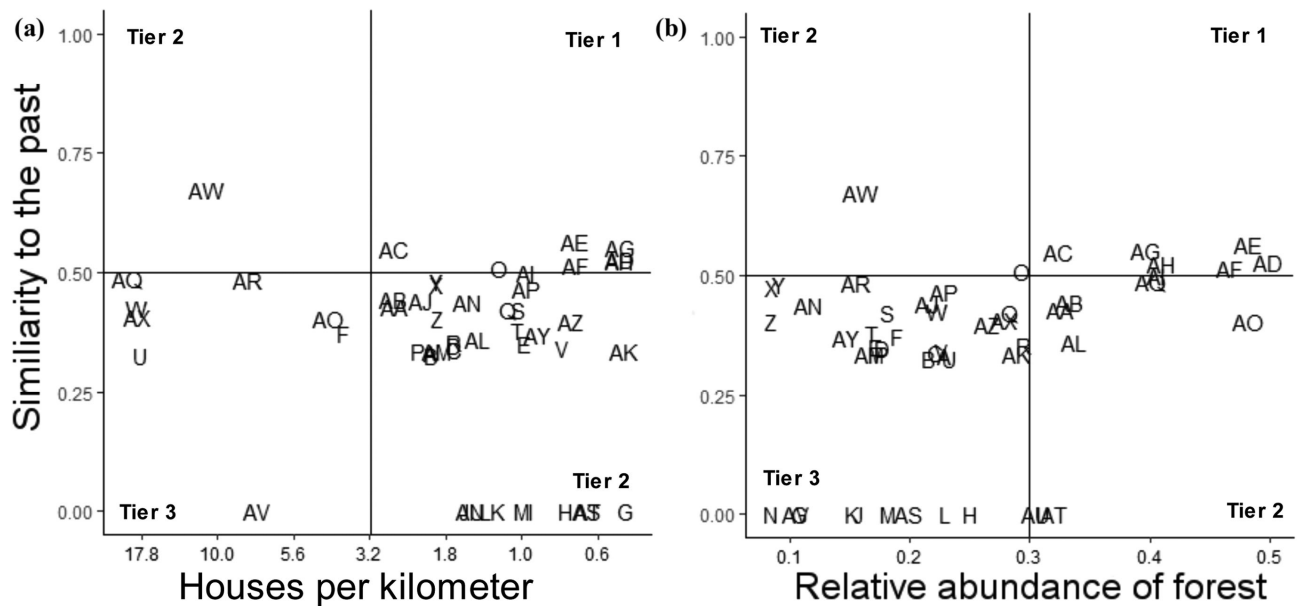


Figure 4. Similarity of extant mussel beds to the historical baseline and conservation feasibility of each bed (y-axis [μ], result of the fuzzy ordination; x-axis variables, feasibility of conservation [the fewer houses, the fewer property owners, and the more trees the better functioning the riparian forests]; tiers, conceptual model [Fig. 2] identifying which beds are ideal for conservation; letters, individual extant mussel beds on the Leon River; the farther to the top and right the more cost-effective the conservation effort [larger, extant mussel beds in areas ideal for conservation]).

local faunal community. Last, a good understanding of zooarchaeological data quality is essential for applying the data to conservation applications. Because zooarchaeological data are often collected during archaeological excavations, it represents a potentially inexpensive and irreplaceable source of historical ecological data. Although there are obstacles to applying this method to all fauna in archaeological deposits, we have shown that it is a useful approach that can inform conservation.

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Supporting Information

Rarefaction curves for the archaeological samples (Appendix S1), Mussel bed information, location and housing information (Appendix S2), and land use data (Appendix S3) are available online. The R Code is avail-

able online on Github (<https://github.com/TraciPopejoy/ZooarchConservFeasibility>). The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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