Research Article

Poorly Vetted Conservation Ranks Can Be More Wrong Than Right: Lessons from Texas Land Snails

Kathryn E. Perez,[1,4] Benjamin T. Hutchins,[2] and Jeffrey C. Nekola[3]

[1]Department of Biology, University of Texas Rio Grande Valley, 1201 W. University Dr., Edinburg, TX 78539
[2]Edwards Aquifer Research & Data Center, Department of Biology, Texas State University, 601 University Dr., San Marcos, TX 78666
[3]Department of Botany and Zoology, Masaryk University, Kotlářská 2, CZ-611 37 Brno, Czech Republic

[4]Corresponding author: perezke@gmail.com; 956-665-7145

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ABSTRACT

Setting priorities for scarce conservation dollars requires an accurate accounting of the most vulnerable species. For many invertebrates, lack of taxonomic expertise, low detectability, and funding limitations are impediments to this goal, with conservation ranks usually based on expert opinion, the published literature, and museum records. Because of biases and inaccuracies in these data, they may not provide an accurate basis for conservation ranks, especially when compared to de novo field surveys. We assessed this issue by comparative examination of these data sources in re-ranking the conservation status of all 254 land snail taxa reported from Texas, USA. We confirmed 198 land snail taxa, including 34 new state records. Our assessment of the entire land snail fauna of Texas resulted in (1) a near doubling of recommended Species of Greatest Conservation Need (SGCN) and (2) a 79% turnover in the makeup of SGCN taxa. Field sampling strongly outperformed museum and literature data in the encounter rate of both the entire fauna and all SGCN species, with the latter two demonstrating bias toward larger-bodied species. As a result, conservation priorities based solely on expert opinion and museum and literature records may be more wrong than right, with taxon-appropriate, targeted sampling required to generate accurate rankings.

Index terms: conservation status assessments; Gastropoda; natural heritage inventory; sampling bias

INTRODUCTION

While numerous criteria have been used to set natural resource protection and management priorities (Asaad et al. 2017), a central focus continues to be the conservation of imperiled species. Setting rare-species conservation and management targets, however, requires an accurate accounting of the most vulnerable species (Kirchhofer 1997; Beissinger et al. 2000; Salafsky et al. 2008). In the United States, the NatureServe Conservation Status assessment (NatureServe 2015) is the primary tool used by Natural Heritage Programs to assess species vulnerability. Similar to the IUCN Red List of Threatened Species assessment, it provides a consistent methodology for incorporating rarity measures (e.g., range extent, area occupied, number of populations), trends, and threats to evaluate conservation status (de Grammont and Cuarón 2006). The ranking process minimizes data-deficient/unrankable designations (Lewis and Senior 2011) to prevent genuinely imperiled but data-deficient (DD; or unrankable, NU) species from being overlooked during conservation planning. However, a data-deficient designation could be preferable to erroneous rankings if the underlying data is insufficient. Our study investigates the accuracy of initial ranks and the most efficient way to develop an evidence base for accurate rankings of a diverse invertebrate group.

For the diverse invertebrate species that feature prominently on rare species lists, low detectability (Kellner and Swihart 2014), lack of taxonomic expertise, and lack of funding for systematic field surveys (Cardoso et al. 2011) are impediments to data-driven conservation assessments. As a result, initial conservation assessments in these groups often rely on expert opinion, museum records, and published literature. Unfortunately, such data have a high potential for significant error and bias. Expert opinion can be problematic in terms of conscious or unconscious biases related to both motivation (e.g., favoring "pet" taxa or species restricted to loved habitats and regions) and research accessibility (Martin et al. 2012), and is derived, at least in part, from museum and literature data. And, while museum collections represent an enormous investment of time and effort from curators and collectors, lots are often misidentified, with error rates approaching 70% for some groups (Goodwin et al. 2015). As a result, naïve use of museum records without expert verification can produce inaccurate estimates of species abundance and distribution (Nekola et al. 2019). Museum records are also subject to geographic bias with sampling often being more prevalent in proximity to the institution or adjacent to highways and other access points (Palmer 1995; Soberón et al. 2000). Body size bias is also present with large, easily visible taxa overrepresented (Nekola et al. 2019).

The use of de novo (new) field surveys conducted to minimize bias across the entire range of available habitats within a given geographic region may make conservation rankings more robust but can be costly in terms of both funding and person-hours. Are such costs warranted? Is additional field work a justifiable expense in the conservation ranking process? To address this issue, we reassess the conservation status of all Texas land snails (e.g., Figure 1), based not only on literature surveys and

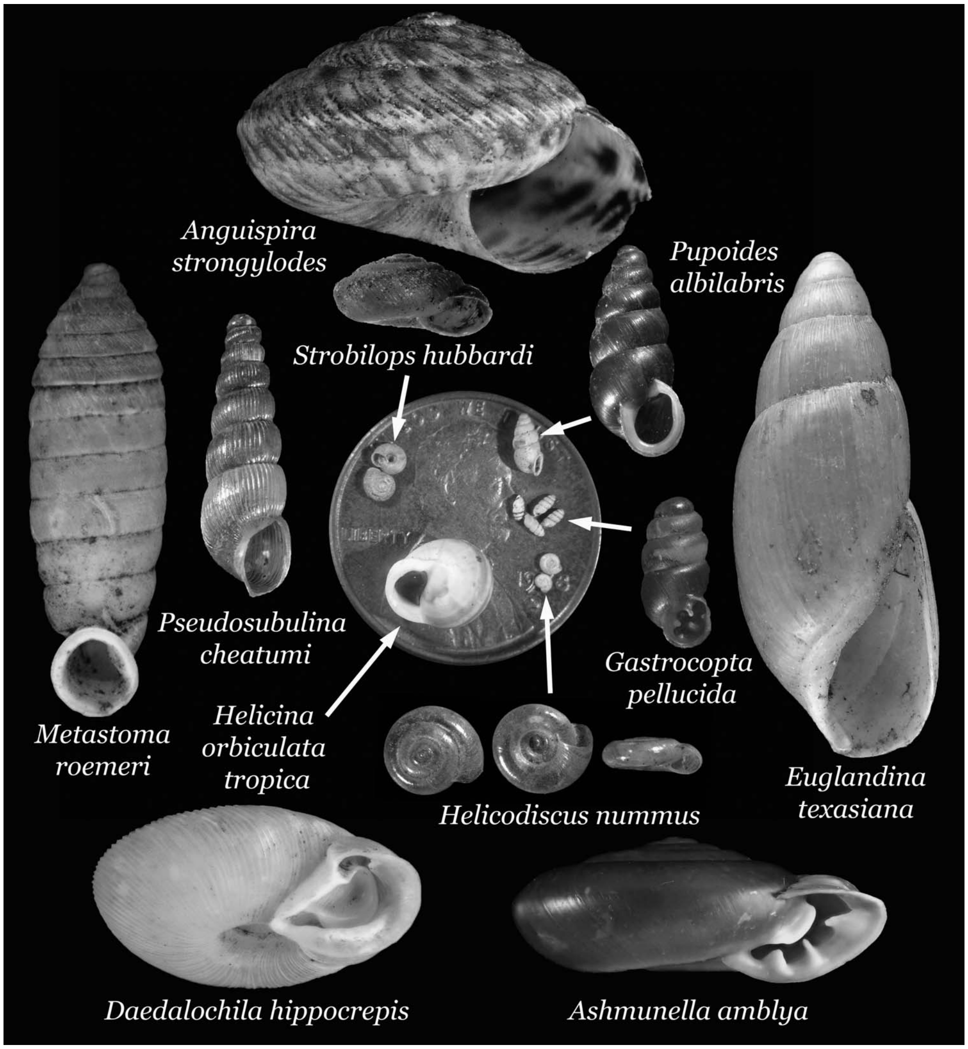

Figure 1.—Examples of land snail species found in Texas displaying a variety of sizes and shapes. A few of the smallest land snails are presented on a U.S. penny (19.05 mm in diameter) to provide context for their size. *Gastrocopta pellucida*, *Helicodiscus nummus*, *Pupoides albilabris*, and *Strobilops hubbardi* are in the minute category (<5 mm). *Helicina orbiculata tropica* and *Pseudosubulina cheatumi* are in the small category (5–10 mm). *Anguispira strongylodes*, *Ashmunella amblya*, *Daedalochila hippocrepis*, and *Metastoma roemeri* are in the medium category (10–20 mm). *Euglandina texasiana* is in the large category (20–40 mm).

reverification of all available holdings from the two largest global repositories for Texas material, but also on new field surveys from over 200 sites across the state. Based on these data, we examine the magnitude of proposed changes to the Texas land snail rankings, SGCN list, as well as the relative importance of expert opinion, literature and museum records, and new field surveys in evaluating existing ranks.

METHODS

Ranking Framework and Data

Much ranking activity in the USA is underwritten by the State and Tribal Wildlife Grant (STWG) program. To be eligible, a taxonomic group must be incorporated into a state wildlife action plan (WAP). The goal is to provide Species of Greatest Conservation Need (SGCN) with proactive protection so that regulatory intervention via state and federal endangered species law is never required. The process for establishment and evaluation of SGCNs within a WAP is (1) initial assessment based usually on expert input; (2) critical evaluation of this initial assessment based on literature, museum, and field data; (3) revision of ranks based on these data; and (4) removal of those species not warranting SGCN designation. This study is focused on steps 2 and 3.

While the first Texas WAP did not consider land snails, they were incorporated in 2005 (TPWD 2005). Initial ranks were based primarily upon expert interpretation of species accounts provided in The Aquatic and Land Mollusca of Texas series (Cheatum and Fullington 1971, 1973; Fullington and Pratt 1974) and solicitation of expert input on threats (KEP pers. comm.). These species were then tracked within the Texas Natural Diversity Database (TXNDD) of the Texas Parks & Wildlife Department (TPWD). In the subsequent 15 y, 14 land snail locality records have been entered into the TXNDD (Bob Gottfried, pers. comm.).

Historical Data: Collection of Museum and Literature Records

We considered two forms of historical data in our reassessment of Texas land snail conservation ranks: (1) verified museum records from the two largest global repositories of Texas material combined with (2) selected literature reports.

All Texas lots were verified from two Texas museums: the Perot Museum of Natural History in Dallas, Texas, and the University of Texas El Paso (UTEP) Centennial Museum Collection in El Paso, Texas. These house the two most extensive land snail holdings in the world for Texas land snail material. Both were also assembled and curated by the most active Texas land snail taxonomists of the 20th century. We did not verify or incorporate museum records from other national collections because (1) they are very limited in terms of Texas material, with the vast majority representing duplicate lots from either the Perot or UTEP, or (2) they have been reported previously in the scientific literature. For example, almost all Texas specimens in the Academy of Natural Sciences at Drexel University holdings were published in Henry A. Pilsbry's papers.

We examined every individual in every lot in the Perot and UTEP collections and verified species identification of each. "Lots" are used in snail collections as a storage unit for one to many individuals of a single species of snail from a unique sampling instance (same time and place). In our dataset, we excluded lots that were indicated as "drift" because these cannot be confidently assigned to a specific population location or confidently related to extant vs. subfossil shells. We also excluded lots of fossil or subfossil shells as they do not contribute useful conservation data. Mixed lots (i.e., lots containing one or more misidentified individuals belonging to a different species) were split into multiple lots of single species. Verification of species identifications was conducted by the coauthor with taxonomic expertise for a given group (coauthors: JN, KEP, BH). If a single coauthor was unable to confidently assign an identity, we used group consensus.

A second dataset of localities was generated by extracting records from all published literature on Texas land snails. We omitted accounts that did not identify precise localities (e.g., "south Texas"). To minimize redundancy, we only encoded those literature records absent from the museum lot data. We were able to retrieve most of the county-occurrence data of Hubricht (1985) through incorporation of all Texas lot records in the Hubricht Collection at the Field Museum of Natural History.

We did not include the 14 records (9 species) from the Texas Natural Diversity Database because only two (one each for *Daedalochila hippocrepis* and *Euchemotrema leai cheatumi*) were not already included in the museum data. Additionally, the validity of their identifications could not be independently verified.

Ecological Data: De Novo Field Collections

De novo field collections were designed to (1) confirm persistence of SGCN populations at historical sites, and (2) document the snail fauna across the state from a wide range of habitat types. We attempted to sample at least one extant site for each previously listed SGCN species. While we were able to document ~2/3 of previously designated species, we were denied permission to visit historical locations for the remainder by the Texas General Land Office or private landowners.

Sites not previously surveyed for land snails were also investigated. We used the above database of historical records to identify gaps in sampling effort and, based on prior experience, prioritized regions and vegetative communities that were most likely to support diverse faunas. We also targeted unique/undersampled vegetative communities near the state border, especially when species not previously recorded from Texas occurred nearby. Our aim was to sample two examples of each identified vegetation community for land snail biodiversity from sites as widely separated as possible. We accomplished this though use of the TPWD Texas Ecosystem Analytical Mapper (TEAM; TPWD 2019). TEAM uses underlying geology, slope, remote-sensing data, and extensive field ground-truthing (>14,000 sites) to identify nearly 400 vegetation types across the state and is publicly accessible online (https://tpwd.texas.gov/gis/team/).

In each ecological community sample, the fauna was documented using the method of Cameron and Pokryszko (2005) in which high-quality microhabitats are nonrandomly targeted within a 0.1 ha region. Random sampling does not perform well for land snails because sites are mostly covered in inappropriate microsites supporting very low shell densities (Cameron and Pokryszko 2005). Unless appropriate microsites are targeted, too few shells will be encountered to provide a robust picture of community richness and abundance. To document the entire fauna, we used a combination of encounter methods, including eye and hand searching of coarse debris and woody cover, sweep netting of arboreal vegetation, and sieving of leaf litter. Protocols for the latter are outlined in Nekola and Coles (2010) and Nekola (2014a). All identifications were subjected to the same verification procedures as above for museum records.

Evaluation of Conservation Status Ranks

All land snail taxa previously reported or encountered in the state were considered. Nonnative species were automatically assigned an exotic status (SNA) and not further assessed. Taxonomic uncertainty precluded in-depth assessment of several other taxa, especially those whose species-concepts remain unresolved or which require soft-body anatomy for verification (e.g., Succineidae and all slugs). These species were assigned a "taxonomy uncertain" status. Taxa erroneously reported from the state (i.e., records derived from misidentifications or outdated or incorrect taxonomy), were assigned "not applicable" (not applicable at the state level). Species were given state-level ranks (S) unless they were endemic to Texas, in which case global ranks (G) were assigned.

All remaining valid taxa were ranked using the NatureServe Rank Calculator Version 3.186 (NatureServe 2015). This tool assigns ranks ranging from 1 (critically imperiled) to 5 (secure) using a point- and rule-based system that considers scaled and weighted trend, rarity, and threat factors. Population trend data is not available for any Texas land snail species and were thus not used. Species were initially ranked by the team member with taxonomic or regional expertise in the group. Rankings were then evaluated by the group and revised by group consensus.

Rarity factors included range extent (calculated as the minimum area convex hull required to encompass all museum and field sampling records) and number of occurrences (number of museum and field-based records from locations greater than 1 km apart). Area of occupancy was not used because of incomplete sampling across all habitats in the state. Because range extent likely overestimates coverage in patchily distributed organisms, our rankings may be more liberal than is warranted (e.g., being biased to assigning a less threatened status). However, a recent multi-taxon approach found little difference when comparing the use of range extent and area of occupancy at a landscape scale (Smith et al. 2020).

Threat factors were estimated for each region of the state and then applied to species found in those areas; these regional threat profiles are presented in Appendix 1 (online). Species-specific threats were also incorporated and were often related to habitat management, conversion, and alteration (e.g., prescribed fire, residential and commercial development, livestock farming, and timber production). Threat responses were based on literature (e.g., Nekola [2002] for fire) and the combined field experience of the authors. We attempted to identify the scope and severity of each threat assessed but acknowledge that few empirical studies document changes in abundance and distribution of land snails in response to specific threats. A small number of taxa also faced specific extralimital threats beyond the generic threats for a region, often related to the impact of global climate change.

Given that the most serious threats to land snails are land development and other direct human actions (Lydeard et al. 2004), we chose to adjust conservation ranks for those species that have large populations residing within well-protected properties, such as National Parks (indicated in Appendix 2 [online]). This aligns with the IUCN Red List (IUCN Standards and Petitions Committee 2019) species assessment approach in which small range endemism is not sufficient for critical conservation concern designation, although it may increase a species' sensitivity. Ranks were never adjusted more than one level from the recommended NatureServe calculator rank (e.g., S1 to S2, or S2 to S3) with no species being moved from S3 to S4. We anticipate this will allow conservation resources to be invested in species limited to more threatened private lands.

A small number of species reported from the state were not encountered in the museum surveys or field collections. For these, range extent and number of occurrences were inferred from the available literature.

Statistical Analysis

We determined whether each changed species rank was related to altered taxonomic concepts, museum lot misidentifications, new field observations, or a combination of these factors. We also evaluated the efficiency of museum, scientific literature, and ecological data to encounter (1) the entire fauna and (2) our updated list of SGCN taxa only. Separate datasets were assembled for all verified museum lots from the Perot and UTEP collections ($N = 3968$), unique literature records ($N = 2249$), and all lots from community samples made by the authors ($N = 2341$). For the entire snail fauna, each dataset was randomly sampled without replacement with 10,000 replicates to construct species accumulation curves with 95% confidence intervals. The species accumulation curves for each dataset were then compared using visual assessment of the 95% confidence envelopes. The process was repeated for accumulation of SGCN taxa only across the entire dataset. Analysis was conducted in R 3.5.2 (R Core Team 2015; code available on request).

To test for association between (1) snail species size and rank and (2) size and whether an account represented a new state record, we conducted a chi-square test of independence using updated ranks. Fisher exact tests of independence were used in instances of sparse data. Species that were unrankable due to insufficient data or taxonomic uncertainty were removed for assessment of conservation status rank by size, and species that were unrankable due to insufficient data were removed for assessment of new state record by size. Taxa were grouped by shell size (minute, small, medium, large, or minute-small, medium-large) using maximum shell dimension following the database of Nekola (2014b). Analysis was conducted in R 3.5.2 (R Core Team 2017).

RESULTS

Museum, Scientific Literature, and Ecological Records

Specimen records from both from museums and new field sampling ($N = 6309$) serve as the basis for this evaluation of conservation status ranks (database available upon request). Field sampling was conducted at 203 sites (Figure 2) representing 81 vegetation types, which were each sampled 1–10 times. Field sampling resulted in >100,000 individuals from 2341 specimen records. Materials from field sampling are vouchered at the Sam Houston State University Natural History Museum (SHSUSnail002626 – 003847) or in the collection of author JN. Georeferenced locality records were reported for eventual inclusion in the TNDD. Statewide patterns of species richness (and sampling intensity) are shown in Figure 3.

Evaluation of the Texas Land Snail Fauna and Conservation Status

Our assessment of 254 taxa resulted in a dramatic revision of Texas's documented land snails, including 34 new state records and removal of 13 previously reported taxa. Determinations of uncertain occurrence in the state (SU) and taxonomic uncertainty (TU) further altered the state list. In our study, we confirm 198 taxa (species and subspecies) from the state (excluding species ranked SU and TU), including 40 state-endemic species (20%) and 34 nonnative taxa (17%). Some historical records could not be confirmed from museum or field collections, and many species records were based on misidentified museum specimens perpetuated in published reports. Of the 198 rankable taxa (taxa that are extant in the state and not unrankable due to uncertain taxonomy or status) 173 (87%) received a new state conservation status rank (percentage of taxa in each rank category in Table 1). Rank changes included (1) taxa receiving a state rank for the first time, (2) taxa receiving a more or less imperiled rank, (3) rankings for extant taxa previously recorded by NatureServe as extinct or possibly extinct, and (4) additions or removals from the list of Texas species. Forty-three taxa (18%) were unrankable due to taxonomic ($N = 31$) or status ($N = 12$) uncertainty including six

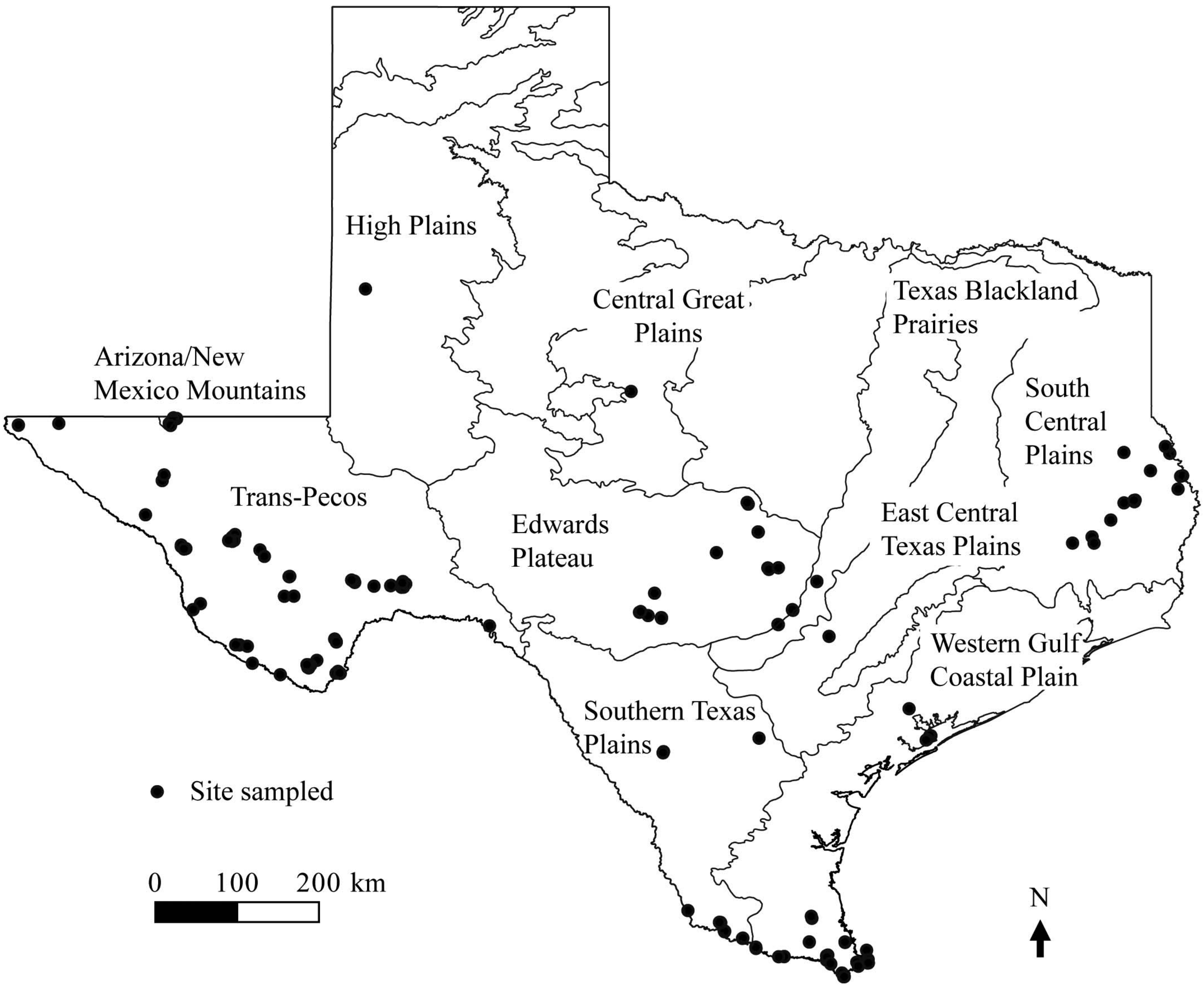

Figure 2.—Sites examined ($N = 203$) for single species or community samples. A full list of sites and vegetative communities sampled available upon request from the authors or the TPWD Nongame and Rare Species Program. The full TEAM vegetation maps are available here: https://tpwd.texas.gov/gis/team/.

species only recorded as dead shells in beach drift. Rank changes were unevenly distributed across families. In the two most commonly encountered families, Helicodiscidae (8 taxa) and Helicinidae (2 taxa), 100% of species underwent rank changes, and none of the 10 most species-rich families had fewer than 50% of species change rank (Table 2). In general, species were more likely to increase in ranking (i.e., less imperiled than previously thought) than decrease (Figure 4). Of the taxa evaluated, 60 ranks (25.4%) derived from the NatureServe rank calculator were further revised based on expert consensus. These were revised in three ways: 71.7% to a more secure status, 13.3% to reflect higher imperilment, or 15% to reflect uncertainty such as taxonomic uncertainty. Of rank changes, 6% were the result of museum collection validation, 33% new field collections, 28% both, and 22% due to revised taxonomy.

The previous Texas SGCN list included 36 land snail species. Our rankings increased that to 67 recommended taxa with 22 species removed from the list and 53 taxa added (Appendix 2 [online]). Only 14 of the previous SGCN species were retained. Thus our revisions produced a 79% turnover in the species included on the prior Texas SGCN list. Additions to the list include new state records, new species described since the last TPWD review, undescribed new species discovered during this study, subspecies encountered during this study and not previously tracked, and, most importantly, minute snails that had been under-sampled or overlooked in the ranking process. Species that we recommend be removed from the SGCN list include those that are more common than previously reported or likely represent invalid taxa.

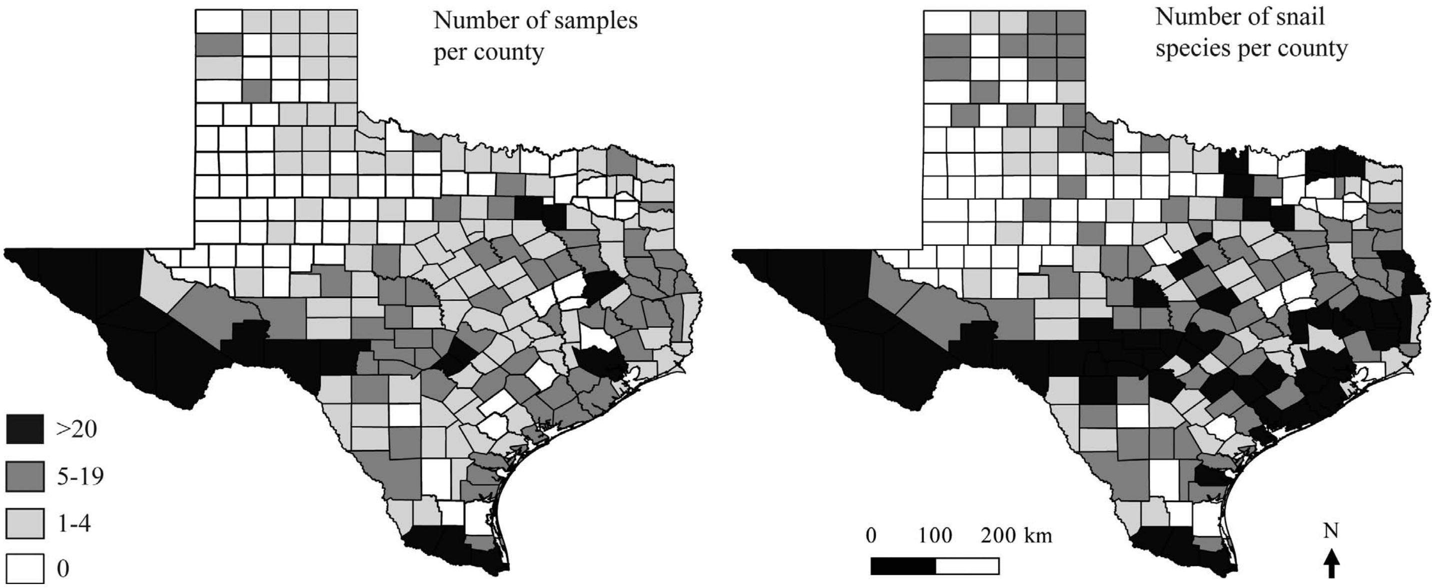

Figure 3.—Left: Number of unique sampling sites per county (museum records and new field collections). Right: Species richness per county (museum records and new field collections). Legend and scale apply to both images.

Efficiency of Historical Record Compilation vs. New Field Work

Of new state records, both native and nonnative, 32% were the result of museum collection validation, 55% field collections, and 12% both. Using the museum dataset as a basis for comparison we examined the efficiency of literature-derived and ecological sampling datasets in encountering the entire fauna and only SGCN species (S1–S3/G1–G3; Figure 5). For the first ~200 observations, literature records fall within the 95% CI for museum data, but then after 200–250 records, literature samples underperform museum samples for all species and for rare species. For the first ~500–700 records field sampling is within the 95% CI of museum records, but past that point ecological samples outperform museum samples for all species and rare species, becoming increasingly better as the number of observations increases.

Impacts of Snail Size on Status of Taxa

Whether or not a taxon represented a new state record was marginally correlated with shell size, with new records being more likely for small or minute taxa ($\chi^2 = 2.81$, df $= 1$, $N = 214$, $P = 0.094$). Similarly, species conservation rank was marginally correlated with shell size, with medium-large taxa being more likely to receive more imperiled status ranks ($\chi^2 = 7.93$, df $= 4$, $N = 154$, $P = 0.098$).

Table 1.—Percentage of heritage ranks assigned to Texas land snails. For simplicity, taxa with multiple plausible character states ($N = 9$) were assigned to the most imperiled plausible rank.

Heritage rank (S or G)	Number of taxa	% of Fauna
1	38	16%
2	29	12%
3	40	17%
4	32	13%
5	25	10%
SNA	34	14%
SU/ TU	43	18%

DISCUSSION

In this study, we evaluated a method for rapidly collecting the evidentiary basis needed for accurate, objective (well-vetted) rankings. Using a combination of validated museum records, accumulated scientific literature records, and a taxon-appropriate field sampling strategy that targets ecological communities rather than species, we re-ranked all Texas land snails. In the case of Texas land snails, museum and literature records give a relatively accurate picture of snail diversity in some ways (e.g., high diversity and endemism in sky-island mountains of the Trans-Pecos region). However, beyond broad strokes, the picture is less accurate (e.g., the underrepresentation of small-minute taxa and prevalence of misidentifications) and existing conservation status ranks were not supported. While we found that previously ranked taxa were, on average, less imperiled than

Table 2.—Status or conservation ranking change in the 10 most species-rich families in Texas. Changes include conservation status rank changes as well as addition or removal from species list, assignment of taxonomic uncertain or exotic status.

Family	Number of taxa	Taxa with rank changes	Percent change
Polygyridae	41	39	95%
Gastrocoptidae	19	19	100%
Zonitidae	15	14	93%
Bulimulidae	10	10	100%
Urocoptidae	10	7	70%
Helicodiscidae	8	8	100%
Valloniidae	8	8	100%
Vertiginidae	8	8	100%
Humboldtianidae	7	4	57%
Pupillidae	6	6	100%

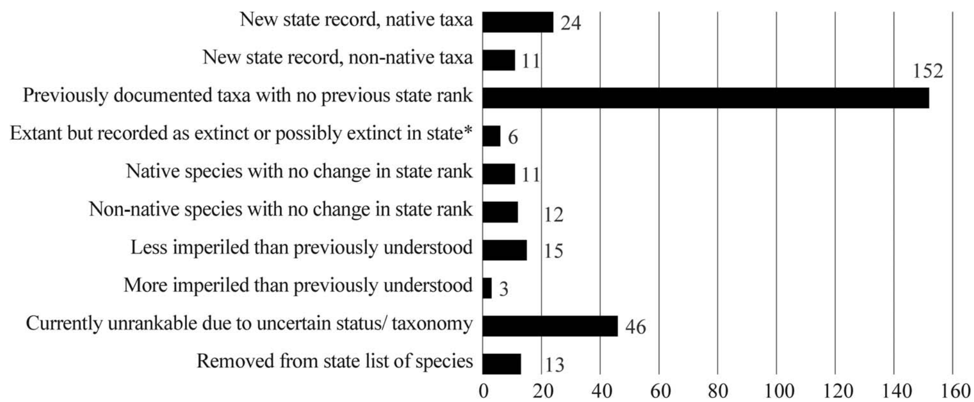

Figure 4.—Change in conservation status ranks for Texas land snails. Categories are not mutually exclusive. *As recorded by NatureServe.

previously thought, the lack of objective status assessments for most taxa resulted in a serious underestimation of the imperilment of the state's land snails as a whole: twice as many species warrant designation as species of greatest conservation need (SGCN) than was previously understood.

Evaluation of Conservation Status Ranks for Texas's Land Snails

Although the number of land snails recommended for SGCN designation increased by nearly 100%, the change does not appear to primarily represent an increase in the imperilment status of species since last evaluated, nor is it an artifact of a more conservative ranking methodology (i.e., assuming worst-case scenarios during the ranking process). Indeed, previously ranked taxa were more likely to receive a less imperiled status ranking, suggesting that the increased number of imperiled species resulted from a more comprehensive, less-biased assessment. The overrepresentation of large- and medium-sized snails and complete absence of minute snails on the previous SGCN list reflects a bias that was also recently documented in the major museum collections for this fauna (Nekola et al. 2019). The recommended, revised SGCN list includes 34% minute taxa; with different size classes now represented proportionally to their prevalence in the state fauna (Table 3). Even considering that larger snails are more likely to have small ranges and higher imperilment, this indicates that the SGCN list now better reflects snail diversity.

In the present study, 78% of the evaluated taxa previously lacked state-specific conservation status ranks, and over half of the species that did have preexisting ranks underwent status revisions. For a small number of taxa, status may have genuinely changed since ranks were initially calculated in the 1980s and 1990s, but the majority of changes are due to (1) information collected since original ranking, (2) changes in the criteria used to rank species, and (3) changes in taxonomy (sensu Butchart et al. 2005). We do not suggest that the land snail fauna of Texas is secure, but that the previous rankings were uninformative.

Given the incompleteness of land snail records, even in relatively well-sampled regions (Lydeard et al. 2004), documentation of new state records in Texas was not surprising. New state records were derived from (1) surveys at the periphery of the state for species with known ranges nearby (43% of new records), (2) documentation of introduced and/or anthropophilic species (30%), (3) sampling in sky-islands and/or historically under-sampled microhabitats (50%), and (4) rectification of unpublished or misidentified museum specimens (33%). Because new records can be assigned to more than one of these categories, the above percentages sum to >100%.

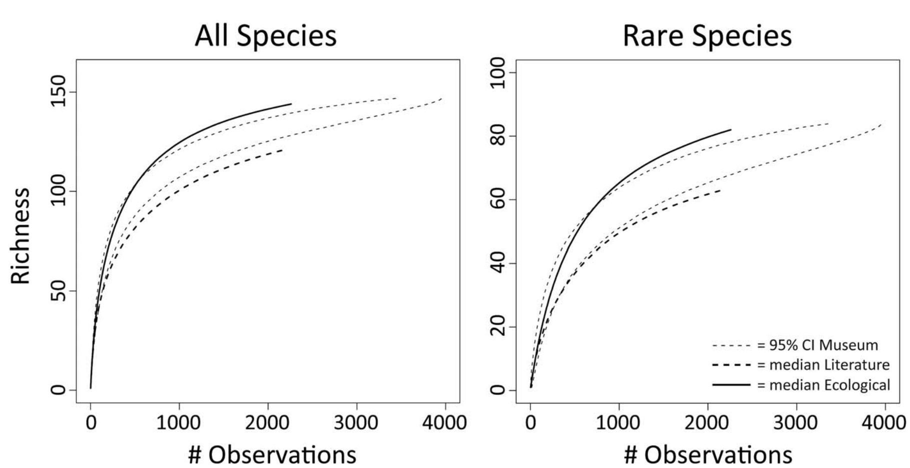

Figure 5.—Permutation tests showing 95% confidence intervals from museum records (dashed lines) with species accumulation from literature (bold dashed line) and ecological sampling from this study (solid line) for all species and rare species.

Table 3.—Size distribution of land snail species from 28 sites from across Texas compared to the size distribution of the previous SGCN list and the SGCN list provided in this report. The new SGCN list is more representative of the fauna.

Size class	Size value	Percent of taxa in Texas faunal sample	Percent of taxa in previous SGCN list	Percent of taxa in updated list
Minute	(<5 mm)	36.3	0	34.3
Small	(5-10 mm)	18.7	10	13.4
Medium	(10-20 mm)	28.5	46.6	34.3
Large	(20-40 mm)	14.5	43.3	17.9
Very Large	(>40 mm)	2	-	-

Considering incomplete sampling across most regions of the state (Figures 2, 3) and the failure of rarefaction curves to reach an asymptote (Figure 5), additional state records seem likely. However, we also rectified several erroneous and unsupported (by museum specimens) state records, and given the number of remaining taxa with uncertain taxonomy or status, future studies, particularly those employing molecular techniques to resolve uncertain taxonomy, will likely result in additional removals from the state species list. We also demonstrated there is unknown diversity to be discovered.

Conservation Status Rankings for Invertebrates: Lessons Learned

Conservation biology has long been considered a "crisis discipline" (Soulé 1985) as time-sensitive conservation decisions are made with imperfect or incomplete data. Setting species targets remains a central focus in biological conservation, requiring an accurate accounting of the vulnerability of species. Comprehensive status assessments for groups of taxa are an important step in the conservation process. Particularly for invertebrate groups that contain high numbers of imperiled taxa but receive relatively little conservation attention, status assessments may be an effective tool for bringing attention to these groups (Hutchins 2018). But however critical, initial conservation status assessments are most often based on expert opinion, museum data, and primary literature (e.g., Taylor et al. 2007; Clausnitzer et al. 2009; Johnson et al. 2013), and inaccurate ranks based on errors and biases endemic to these data sources may result in the misdirection of limited resources away from true species of greatest conservation need.

Conservation status rankings conducted with incomplete or inaccurate data may still catalyze valuable conservation effort, drawing attention to knowledge gaps or spurring more detailed assessment by taxonomic experts. Our work indicates that potential Wallacean (lack of distributional data) and Hutchinsonian (lack of ecological/environmental tolerance data) shortfalls (Cardoso et al. 2011) should be considered to determine whether available data is sufficiently unbiased and accurate to estimate conservation status. We propose that assigning an initial conservation status rank of data-deficient (DD) is preferable to assigning a rank from extremely incomplete data. Otherwise, conservation status ranks, and more importantly, conservation priorities based on those ranks, may more likely be wrong than right.

We argue that data-deficient, unrankable, and taxonomic uncertainty (TU) designations are concerning enough to warrant additional assessment through targeted surveys, taxonomic work, and life history evaluations. As the sixth mass extinction continues (Dirzo et al. 2014), there is no a priori reason to assume that data-deficient species are secure, particularly in taxa with inherently high rates of imperilment like mollusks. Indeed, rarity and endemism (both of which are major contributors to imperilment) are parsimonious explanations for data deficiency.

Conclusion

The comparison of museum, literature, and new field collection datasets illustrates that literature can be an important source for single-taxon records but does not accurately inform whole fauna or rare species analyses. So long as potential sources of error and bias are recognized, museum collection validation adds valuable information for updating state lists and species ranks and informs field sampling efforts. But for the land snails of Texas the most effective way to evaluate both the entire fauna and rare species was to conduct a strategically designed field campaign, sampling across major biogeographic provinces and targeting under-sampled areas including disjunct/peripheral habitats. We propose this method has wide applicability to other poorly known invertebrate and plant groups.

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Kathryn E. Perez received a BS and MS in Biology from Angelo State University and PhD in Biological Sciences from the University of Alabama. She is an Associate Professor at the University of Texas Rio Grande Valley and works on land and freshwater snails.

Benjamin T. Hutchins received his BS in Biology from Western Kentucky University, MS in Biology from American University, and PhD in Aquatic Resources from Texas State University. He is Assistant Director of Research and Education at the Edwards Aquifer Research and Data Center. His research focuses on the ecology and biodiversity of groundwater invertebrates.

Jeffrey C. Nekola received his PhD in Ecology from the University of North Carolina at Chapel Hill. He is an Associate Professor in the Department of Botany and Zoology at Masaryk University. His works span the range of biodiversity studies, from molecular genetics to macroecology and general theory.

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