Higher Beetle Diversity in Native Vegetation Than in Stands of the Invasive Arundo, *Arundo donax* L., along the Rio Grande Basin in Texas, USA

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Abstract

Within the cattle fever tick quarantine zone along the Rio Grande, a steady displacement of native vegetation by *Arundo donax* L. has been occurring for over a century. Arundo rapidly grows to a height of 3–6 m creating a dense wall of vegetation impeding surveillance and interception of stray cattle breaching the cattle fever tick quarantine from Mexico. Additionally, arundo monocultures may decrease the number and diversity of predatory beetles feeding on cattle fever ticks. To compare predatory beetle abundance and diversity within and between arundo and native vegetation, beetles were trapped at 10 locations twice a month for 16 mo (=38,400 trap nights) in the cattle fever tick quarantine zone along the Mexico–American border between Brownsville and Del Rio, TX. In total, 766 beetles were trapped, which included 34 genera and 43 species. Native vegetation provided more beetles, greater species richness, and increased biological diversity. Thus, greater beetle diversity was found in the more complex native vegetation compared with arundo stands. However, because predatory beetle sample numbers were modest, it is unlikely these mostly polyphagous, opportunistic arthropod predators would apply much pressure on tick populations, leading us to conclude that beetle predation would have little effect on tick populations in native vegetation or within stands of arundo.

Key words: pitfall trap, Coleoptera, Tenebrionidae, Carabidae, Hill number

Cattle fever ticks, *Rhipicephalus* (=*Boophilus*) spp., have been moving north through the U.S. quarantine zone along the Rio Grande on white-tailed deer, *Odocoileus virginianus* (Zimmermann) (Artiodactyla: Cervidae) and exotic ungulates in increasing numbers over the last decade leading to the initiation of research of contributing habitat changes. One major change along the Rio Grande is the rampant spread of *Arundo donax* L. (Poales: Poaceae). Arundo (giant river reed or Carrizo cane) originated from the Mediterranean to North Africa and parts of south Asia. *Arundo donax* has become a problem along streams and rivers in the southern United States including the cattle fever tick quarantine zone along the Rio Grande at the Texas–Mexico border (DiTomaso and Healy 2003, Yang et al. 2009, Yang et al. 2011). Arundo removal has been proposed to prevent the concealment of movement of deer and humans crossing quarantine zone (Goolsby et al. 2010, Moran and Goolsby 2010, Seawright et al. 2010).

Some beetles and ants are predators of arthropods including ticks (Showler and Reagan 1987, Samish and Rehacek 1999, Samish and Alekseev 2001, Velez-Bonner et al. 2013, Osbrink et al. 2017). Ground beetles are species rich and numerous in most terrestrial habitats and thus good indicators of community diversity. Also, as ambulatory ground dwellers they are adequately sampled by the pitfall trap method. Two families of ground beetles were surveyed, carabids (Carabidae) and tenebrionids (Tenebrionidae). Carabids are generalist predators of other arthropods and are vagile, active hunters and thus are likely to be transient in a community increasing their likelihood of being found in habitats supporting lower arthropod prey populations such as the arundo monoculture habitat with inferior refugia for most arthropods. In contrast, darkling beetles (Tenebrionidae) are flightless saprophores. Hence, their presence, even in low numbers, indicates that they are resident in the communities where they are trapped, providing a reliable measure of community diversity and thus environmental health. The objective of this study was to evaluate beetle diversity inside and outside arundo stands along the quarantine zone.

We expect greater beetle diversity in native vegetation than arundo stands because the former is a more complex habitat. Vegetational diversity provides an environment supporting greater variation in beetle due to increased niches for prey and therefore greater food availability for these highly active, mostly polyphagous, invertebrate predators compared with a stand of arundo monoculture (Altieri et al. 1977, Showler and Reagan 1991).
Materials and Methods

Study Sites
Beetle samples were obtained from 10 research sites north of the Rio Grande along the Texas–Mexico border (Table 1, Fig. 1) between Los Indios (Cameron county) to the east and Del Rio (Maverick county) to the west. At each location, two sites were compared, a site with native riparian vegetation and a site with a near monoculture of giant reed, Arundo donax.

Beetle Sampling
Beetles were sampled using pitfall traps. A trap comprised of an embedded 11-cm-diameter PCV cylinder buried flush to the ground surface, with a close-fitting insert, a 470-ml polypropylene container (Redi-tainer, Clear Lake, MN; 10.5 × 9.9 × 7.0 cm [height by top diameter by bottom diameter]). A square masonry tile (30.5 × 30.5 cm) provided shelter from rain and was supported ≈5 cm above the trap by metal stakes driven in the ground. Each trap contained a 50:50 mixture of propylene glycol and water as a capture fluid and preservative (Thomas 2008). Traps were serviced every 2 wk (weather permitting) at which time the insert was removed, capped, and replaced with a new cup and fresh fluid. In the laboratory, the catch was sorted to separate target specimens that were preserved in isopropyl alcohol for later identification and counting.

Four traps were located 10 m apart within an arundo stand, and four traps were similarly placed in native vegetation at each of the 10 locations. Collections were conducted for 16 mo, from April 2014 to July 2015 (=38,400 trap nights). Beetle identification was conducted with a stereoscopic microscope using taxonomic beetle keys (Hinton 1948, Davis 1980, Papp 1981, Bosquet 1996, Aalbu et al. 2001, Ball and Bosquet 2001, Aalbu 2005, Triplehorn et al. 2009, Bosquet 2012, Triplehorn and Thomas 2013). A survey of vegetation was conducted with incidence recorded along four 20-m transects from trap locations to provide plant diversity information at each native vegetation site.

Table 1. Beetle sample study site locations along the Rio Grande, TX

| Location                              | County        | Latitude, Longitude |
|---------------------------------------|---------------|---------------------|
| Los Indios                            | Cameron       | 26.05, −97.74       |
| North American Butterfly Association (NABA) | Hildalgo    | 26.180243, −98.364973 |
| Bentsen Rio Grande State Park         | Hildalgo      | 26.1731300, −98.3825200 |
| San Ygnacio                           | Zapata        | 27.048175, −99.430788 |
| Laredo Community College (LCC)        | Webb          | 27.5084, −99.5214   |
| La Bota Ranch                         | Webb          | 27.6161258, −99.5569872 |
| Comanche Ranch                        | Maverick      | 28.643901, −100.444024 |
| Rosita Ranch                          | Maverick      | 28.643901, −100.444024 |
| Sycamore Creek                        | Kinney        | 29.4410659, −100.1228475 |
| Del Rio                               | Val Verde     | 29.3709, −100.8959  |

Fig. 1. Study sites in the cattle fever tick quarantine zone along the Texas–Mexico border.
graphs included in this study. The program iNEXT (Colwell et al. 2012, Chao et al. 2014) was used to plot sample-size-based rarefaction and extrapolation sampling curves where this curve plots the species richness estimates for a rarefied and extrapolated sample with respect to sample size following bootstrapping 100 times. Additionally, iNEXT was used to calculate coverage-based rarefaction and extrapolation curves where species richness estimates for rarefied and extrapolated samples to determine suitability of our sample coverage for the provided estimates and to calculate sample completeness curves plotting the sample completeness (as measured by sample coverage) with respect to sample size with representative graphs included in this study.

Calculated Hill numbers unify the reported biological diversity parameter such that a Hill number of 0, near 1, and 2 provides the communities’ species richness, exponent of Shannon index, and inverse of Simpson index, respectively, with representative graphs included in this study. More weight is given to dominant species as the Hill number increases (Chao et al. 2014). Coverage-based rarefaction and extrapolation sampling curve provides species richness estimates for rarefied samples and extrapolated samples with sample coverage up to double the reference sample size.

Beetle species composition was compared across habitats and sites. A cluster analysis with a similarity profile test (SIMPROF, Clarke and Gorley 2015) was performed using Euclidean distance coefficient to identify significant differences (P ≤ 0.05) between the clusters. The dendrogram with group-average linkage was chosen to separate those with significant difference and cluster those with high similarity. A metric multi-dimensional scaling (mMDS) was applied with a cluster overlay and Shepard’s plot, using the stress level to determine adequacy of configuration in between variables. Shepard’s plot draws envelopes around cluster groups with high similarity levels. Data analysis was performed with PRIMER 7 (Clarke and Gorley 2015).

Results

After 16 mo, a total of 713 specimens of Tenebrionidae composed of 12 genera and 16 species, and 145 specimens with 22 genera and

Table 2. Census of Carabidae (Coleoptera) beetles captured in pitfall traps in tick quarantine zone

| Species                        | LI | NABA | SY | LCC | LB | CR | RR | SC | DR | BRG |
|--------------------------------|----|------|----|-----|----|----|----|----|----|-----|
| **Amara aenea** (De Geer)*      | 0  | 0    | 0  | 0   | 0  | 0  | 1* | 0  | 0  | 0   |
| **Apenes lucidula** (Dejean)*   | 0  | 0    | 0  | 1   | 1  | 0  | 0  | 0  | 0  | 4*  |
| **Apenes nebulosa** (LeConte)*  | 0  | 4    | 6* | 8*  | 0  | 0  | 1* | 0  | 0  | 3*  |
| **Apenes simule** (Say)*        | 0  | 6*  | 2  | 1*  | 1  | 0  | 0  | 0  | 1  | 2   |
| **Apreis subulatius** (Dejean)* | 0  | 0    | 0  | 0   | 2* | 0  | 0  | 0  | 0  | 0   |
| **Axinopalpis biaugulatus** (LeConte)* | 0  | 0    | 0  | 0   | 0  | 0  | 2* | 0  | 0  | 0   |
| **Calleida planulata** (LeConte)* | 0  | 0    | 2* | 0   | 0  | 0  | 0  | 0  | 0  | 0   |
| **Calosoma marginale** (Casey)* | 0  | 0    | 1  | 1*  | 1  | 2  | 1  | 0  | 1  | 1   |
| **Chlaenius azurescens** (Chaudoir)* | 0  | 0    | 0  | 2*  | 0  | 0  | 0  | 0  | 1* | 0   |
| **Chlaenius impunctifrons** (Say)* | 0  | 0    | 0  | 0   | 1* | 0  | 0  | 0  | 0  | 0   |
| **Colinus laticollis** (Say)*    | 0  | 1    | 0  | 0   | 0  | 0  | 0  | 0  | 1* | 0   |
| **Cicindela obsolenta** (Say)*  | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 1* | 0   |
| **Clivina dentipes** (Dejean)*  | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 1* | 0   |
| **Cymindus platycollis** (Say)* | 0  | 0    | 0  | 0   | 2* | 0  | 0  | 0  | 0  | 0   |
| **Dyschirius larochellei** Bosquet* | 0  | 0    | 0  | 0   | 0  | 0  | 1* | 0  | 1* | 0   |
| **Notiohia terminata** (Say)*   | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 2   |
| **Panageus salfasi** Chaudoir*   | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 1*  |
| **Passimachus californicus** (Chaudoir)* | 0  | 0    | 2  | 34* | 0  | 0  | 1  | 0  | 0  | 2   |
| **Pocelius chalcites** (Say)*    | 0  | 2*  | 1  | 0   | 1  | 0  | 0  | 0  | 1* | 0   |
| **Pterostichus sp.**             | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 1* | 0  | 0   |
| **Sclerites quadricipes** Chaudoir* | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 4* | 0   |
| **Selenophorus fatuus** (Chevrotat)* | 0  | 0    | 0  | 0   | 1* | 0  | 0  | 0  | 0  | 0   |
| **Selenophorus opalinus** (LeConte)* | 0  | 0    | 0  | 3   | 0  | 0  | 0  | 0  | 0  | 0   |
| **Selenophorus mexicana** (Chevrotat)* | 0  | 1*  | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0   |
| **Selenophorus ochraceus** (Say)* | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 1   |
| **Stenobreus californicus** (Menetries)* | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 0  | 0  | 0   |
| **Tetracha carolina** (L.)*     | 0  | 1*  | 0  | 1   | 0  | 0  | 0  | 0  | 7* | 0   |

Star (*) indicates that voucher specimens were preserved.
LI = Los Indios; NABA = North American Butterfly Association; SY = San Ygnacio; LCC = Laredo Community College; LB = La Bota Ranch; CR = Comanche Ranch; RR = Rosita Ranch; SC = Sycamore Creek; DR = Del Rio; BRG = Bentsen Rio Grande State Park.
27 species of Carabidae (Tables 2 and 3). Only 2 species were captured from all 10 locations, and 19 species were captured at a single location only (Tables 2 and 3). *Eleodes* (Tenebrionidae) was the most diverse genus represented by four species, and a single species, *Blapstinus fortis* (LeConte) (Coleoptera: Tenebrionidae), accounted for 47% of all beetles collected (Table 3).

Beetles of both families were more abundant in the native habitats than in the arundo by a ratio of about 3:1. For tenebrionids, 73% of captures were from native habitat, and similarly, carabids were more abundant in the native habitats (78% of captures). In terms of species diversity, all 16 species of tenebrionids were found in the native habitats but only 8 species were found in the arundo. However, whereas no species of tenebrionid was found in the arundo that was not also found in the native habitat, there were four species of carabids in the arundo that were not found in the native habitat. But, these were nearly all single specimen records. In comparison, there were seven single species records for the native habitat absent from arundo.

Combined then, greater abundances of beetles were captured, and more species were encountered, in the native vegetation than in arundo at each test site with at least 17 × more plant species occurring in the former (Tables 4 and 5). Estimates of biodiversity were greater in native vegetation than in arundo stands (Table 5).

Species accumulation curves indicate the least diverse sites plateaued earliest (Los Indios) by a factor of 5× or greater than sites with highest diversity (Laredo Community College, Del Rio, La Bota Ranch, and Bentsen Rio Grande State Park; Fig. 3). Species accumulation in the arundo habitat is still on an upward trend, whereas native habitat seems to have plateaued (Fig. 4). Composite curves for all sites combined by family and habitat indicate tenebrionid fauna shows overdominance whereas the carabids show more evenness (Fig. 5). Transforming the abundance data to log-normal causes the native habitat fauna to appear linear and diverse, which is typical for stable faunas (Fig. 6). The arundo faunas are seen as steep and curtailed, typical of disturbed or depauperated faunas (Fig. 6). As shown

### Table 3. Census of Tenebrionidae (Coleoptera) beetles captured in pitfall traps in tick quarantine zone

| Species                  | LI | NABA | SY | LCC | LB | CR | RR | SC | DR | BRG |
|--------------------------|----|------|----|-----|----|----|----|----|----|-----|
| *Araeoschizus decipiens* (Horn)* | 0  | 1    | 0  | 0   | 0  | 2  | 0  | 0  | 0  | 0   |
| *Armalia texana* (LeConte)* | 1  | 0    | 2  | 6   | 1  | 0  | 0  | 0  | 0  | 6   |
| *Asbolus mexicanus* (Champion)* | 0  | 0    | 0  | 1*  | 2  | 3  | 0  | 3  | 0  | 0   |
| *Blapstinus fortis* (LeConte)* | 7  | 84   | 103| 18* | 4  | 24 | 43 | 5  | 70 | 5   |
| *Blapstinus fuscus* (Casey)* | 4* | 6    | 22 | 3   | 1  | 17 | 6  | 3  | 3  | 3   |
| *Combus rotundicollis* (Linell)* | 0  | 0    | 0  | 0   | 0  | 0  | 1* | 0  | 0  | 0   |
| *Eleodes goryi* (Solier)* | 0  | 4    | 4  | 0   | 0  | 1  | 4  | 0  | 11*| 0   |
| *Eleodes gracilis* (LeConte)* | 0  | 0    | 0  | 0   | 0  | 8  | 0  | 1  | 0  | 0   |
| *Eleodes pedinoides* (LeConte)* | 0  | 0    | 0  | 1*  | 1* | 0  | 0  | 0  | 0  | 0   |
| *Eleodes spinipes* (Solier)* | 0  | 0    | 0  | 0   | 0  | 3  | 4  | 17 | 0  | 2   |
| *Hymenorus* sp.* | 0  | 0    | 0  | 0   | 0  | 0  | 0  | 1* | 0  | 0   |
| *Metaponium politum* (Casey)* | 0  | 0    | 0  | 14  | 0  | 0  | 0  | 26*| 0  | 0   |
| *Opatrius aciculatus* (LeConte)* | 1  | 4    | 8  | 0   | 2  | 0  | 6  | 0  | 7  | 12* |
| *Tricholium castaneum* (Herbst)* | 0  | 0    | 0  | 2   | 4  | 1  | 2  | 0  | 0  | 0   |
| *Triorophus nodiceps* (LeConte)* | 0  | 0    | 0  | 12* | 0  | 0  | 2  | 0  | 0  | 0   |
| *Ulus elongatulus* (Casey)* | 0  | 0    | 0  | 1*  | 0  | 0  | 0  | 0  | 0  | 0   |

Star (*) indicates that voucher specimens were preserved.

LI = Los Indios; NABA = North American Butterfly Association; SY = San Ygnacio; LCC = Laredo Community College; LB = La Bota Ranch; CR = Comanche Ranch; RR = Rosita Ranch; SC = Sycamore Creek; DR = Del Rio; BRG = Bentsen Rio Grande State Park.
in the metric MDS plot along with a Shepard's plot (Fig. 7), 7 out of the 10 arundo location sites were clustered by a green envelope representing similarity. Rosita arundo habitat overlapped in similarity with the main green envelope. In contrast, native habitats had three out of the ten presented as outliers showing dissimilarity with the rest of the group. Bensten arundo and Sycamore native habitat had

### Table 4. Presence or absence of plants and EFNs at 10 sample sites along the Rio Grande in Texas Jan–Dec 2014

| Species                  | EFN | Common name        | LI | NABA | BRG | SY | LCC | LB | CR | RR | SC | DR |
|--------------------------|-----|--------------------|----|------|-----|----|-----|----|-----|----|----|----|
| Prosopis glandulosa      | +   | Mesquite           | +  | 0    | 0   | +  | +   | +  | +   | +  | +  | +  |
| Celtis laevigate         | 0   | Hackberry          | 0  | +    | +   | 0  | 0   | +  | +   | +  | +  | 0  |
| Ulmus crassifolia        | +   | Cedar elm          | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Acacia spp.              | +   | Acacia             | 0  | +    | +   | 0  | 0   | +  | 0   | +  | 0  | +  |
| Acacia rigidula          | +   | Blackbrush         | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Celtis pallida           | +   | Spiny hackberry    | +  | 0    | +   | 0  | +   | +  | 0   | 0  | +  | 0  |
| Acacia smallii           | +   | Huisache           | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Mimosa pigra            | 0   | Mimosa             | 0  | 0    | +   | +  | 0   | +  | +   | +  | 0  | +  |
| Opuntia indistincta      | +   | Prickly pear cactus| +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Triadica sebifera        | +   | Chinese tallow     | +  | +    | 0   | +  | +   | 0  | +   | +  | +  | +  |
| Ricinus communis         | 0   | Castor bean        | 0  | 0    | 0   | +  | 0   | 0  | +   | +  | +  | +  |
| Cenchrus ciliaris        | +   | Buffel grass       | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Panicum maximum          | +   | Guinea grass       | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Triadica sebifera        | +   | Chinese tallow     | +  | +    | 0   | +  | +   | +  | +   | +  | +  | +  |
| Ricinus communis         | 0   | Castor bean        | 0  | +    | +   | 0  | +   | 0  | +   | 0  | +  | 0  |
| Cenchrus ciliaris        | +   | Buffel grass       | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |
| Panicum maximum          | +   | Guinea grass       | +  | +    | +   | +  | +   | +  | +   | +  | +  | +  |

**EFN** = extrafloural nectaries; **LI** = Los Indios; **NABA** = North American Butterfly Association; **SY** = San Ygnacio; **LCC** = Laredo Community College; **LB** = La Bota Ranch; **CR** = Comanche Ranch; **RR** = Rosita Ranch; **SC** = Sycamore Creek; **DR** = Del Rio; **BRG** = Bentsen Rio Grande State Park.

### Table 5. Beetle biodiversity in arundo and native vegetation (±SE)

| Location          | Number of observed Sp. | Total number of beetles | Chao1 estimated Sp. richness | Exponential of Shannon index | Inverse of Simpson index |
|-------------------|------------------------|-------------------------|-----------------------------|-----------------------------|--------------------------|
| Los Indios        | Arundo                 | 2                       | 8                           | 3.0 ± 0.5a                  | 1.6 ± 0.1a               | 1.3 ± 0.1a               |
|                   | Native                 | 3                       | 29                          | 4.5 ± 1.3a                  | 1.7 ± 0.3a               | 1.3 ± 0.1a               |
| NABA              | Arundo                 | 3                       | 20                          | 4.5 ± 1.3a                  | 2.1 ± 0.3a               | 1.7 ± 0.2a               |
|                   | Native                 | 8                       | 94                          | 12.2 ± 3.4b                 | 3.9 ± 0.4b               | 2.8 ± 0.2b               |
| San Ygnacio       | Arundo                 | 3                       | 72                          | 6.5 ± 1.3a                  | 3.4 ± 0.3a               | 2.8 ± 0.2a               |
|                   | Native                 | 8                       | 81                          | 12.2 ± 3.4b                 | 5.0 ± 0.5b               | 3.6 ± 0.3a               |
| LCC               | Arundo                 | 6                       | 29                          | 15.9 ± 11.5a                | 3.3 ± 0.7a               | 2.0 ± 0.3a               |
|                   | Native                 | 12                      | 81                          | 12.4 ± 17.0a                | 7.1 ± 0.7b               | 4.7 ± 0.5b               |
| La Bota           | Arundo                 | 2                       | 5                           | 3.0 ± 0.5a                  | 1.5 ± 0.2a               | 1.2 ± 0.1a               |
|                   | Native                 | 13                      | 19                          | 31.3 ± 10.5b                | 7.4 ± 1.3b               | 2.9 ± 0.5b               |
| Comanche Ranch    | Arundo                 | 2                       | 20                          | 4.0 ± 0.5a                  | 2.3 ± 0.2a               | 1.8 ± 0.2a               |
|                   | Native                 | 7                       | 38                          | 14.4 ± 7.1b                 | 4.8 ± 0.6b               | 2.8 ± 0.4a               |
| Rosita Ranch      | Arundo                 | 4                       | 43                          | 11.0 ± 3.7a                 | 4.7 ± 0.5a               | 3.2 ± 0.4a               |
|                   | Native                 | 9                       | 50                          | 18.2 ± 7.5a                 | 5.7 ± 0.8a               | 3.7 ± 0.5a               |
| Sycamore Creek    | Arundo                 | 2                       | 3                           | 3.5 ± 1.3a                  | 1.3 ± 0.2a               | 1.1 ± 0.1a               |
|                   | Native                 | 4                       | 12                          | 5.0 ± 0.5a                  | 2.3 ± 0.3a               | 1.6 ± 0.2b               |
| Del Rio           | Arundo                 | 6                       | 33                          | 21.3 ± 16.9a                | 3.6 ± 0.6a               | 2.4 ± 0.3a               |
|                   | Native                 | 10                      | 100                         | 20.0 ± 11.6a                | 4.7 ± 3.9b               | 3.2 ± 3.0b               |
| Bentsen R.G.      | Arundo                 | 4                       | 12                          | 8.0 ± 1.8a                  | 2.8 ± 0.4a               | 1.8 ± 0.2a               |
|                   | Native                 | 11                      | 39                          | 44.6 ± 39.2a                | 5.5 ± 0.4b               | 3.0 ± 0.4b               |

Chao1 estimation of species richness is equivalent of diversity of order 0; exponential of Shannon index is equivalent of diversity of order 1; inverse of Simpson index is equivalent of diversity of order 2 (Chao et al. 2015). Means in a column from the same location pair followed by the same letter are not significantly different as indicated by overlap of 95% confidence intervals.

NABA = North American Butterfly Association; LCC = Laredo Community College; Bentsen R.G. = Bentsen Rio Grande State Park.
highly similar assemblages of species despite the distance between the sites. Rosita native and Laredo CC native species makeup was highly similar as well with two native habitats in the same envelope. In the dendrogram (Fig. 8), two examples in which the determinant for similarity was based on geographic proximity were Rosita and San Ygnacio. Both examples were on the same node and envelope in the MDS plot signifying high similarity. The main conclusion, despite those two exceptions, is that the native assemblages were dissimilar to one another as well as to the arundo. The arundo habitats were, in general, similar to one another.

Discussion

Trapping using pitfalls is a well-established method of monitoring beetles (Kharboutli and Mack 1991, Reng-Moss et al. 1998). The numbers and diversity of beetles trapped inside and outside the arundo stands reflect the response of species to the different available resources such as food and harborage (Beier and Albuquerque 2016). Basically, ground beetles in arundo habitats are incursions from populations in the surrounding native habitat. Beetles wander into arundo, but no beetle species was more abundant or preferred arundo over the native habitat.

At North American Butterfly Association (NABA), for example, extrapolated empirical calculations indicate greater diversity in native vegetation. Greater species richness in NABA’s natural vegetation than in the arundo stand is indicated by nonoverlap of confidence limits of the sample-size-based rarefaction and extrapolation sampling curves. NABA’s sampling completeness curve shows that the number of samples taken was adequate for coverage of study area as indicated by the plateauing of the curve. Similar comparisons were conducted for all study sites. In contrast, Laredo Community College, with overlapping confidence limits, did not demonstrate species richness differences even though sampling was adequate.

It is notable that although tenebrionids were more common than carabids by about a 4:1 margin, there were many more species of carabids by nearly 2:1. This pattern of species diversity reflects, in part, a basic ecological difference between tenebrionids and carabids. The carabids are true ground beetles in that they are predators that hunt for prey by searching actively at ground surface level. They are highly vagile insects with essentially all of the species being alate. Thus, it is not surprising that a high proportion of the carabid species were represented by single species records. Singletones are present in essentially all faunal surveys.

The sites varied both in the number of individuals captured and in the number of species represented. Two of the sites (Los Indios and Sycamore Canyon) were faunally poor in both numbers of species and numbers of individuals. At 8 of the 10 sites, there were greater numbers of individuals captured in the native habitat than in the arundo (at one site they were essentially the same, 7 vs 8). At 8 of the 10 sites, there were greater numbers of species in the native habitat than in the arundo (at one site they were the same, 11 species). The Shannon diversity was greater in the native habitat at 9 of the 10 sites, but essentially the same at the 10th site. The Simpson diversity index was greater for the native habitats than for the arundo habitats in 8 of the 10 sites (essentially the same at one site). The arundo site with greater Simpson diversity, BRG, had fewer species and far
**Fig. 4.** Accumulation of species by habitat. The arundo habitat is still on an upward trend, whereas the native habitat seems to have plateaued.

**Fig. 5.** Abundance curves. The tenebrionid fauna shows overdominance, whereas the carabids show evenness.

**Fig. 6.** Transforming the abundance data to log-normal causes the native habitat fauna to appear linear and diverse, which is typical for stable faunas. The Arundo faunas are seen as steep and curtailed, typical of disturbed or depauperate faunas. The carabid-arundo fauna is not plotted because it is dominated by singletons and ln = 0.
fewer individuals than the native habitat. A characteristic, and some would say a flaw, of the Simpson index is that it emphasizes evenness over species richness.

Species richness is the simplest measure of diversity but is considered biased in that rare species can be missed (Colwell et al. 2012). Our sampling was large and equal for both habitats (38,400 trap nights each). Moreover, the sampling covered all seasons of the year and included spring-summer samples over 2 yr. In the species accumulation curves for each site (Fig. 3), it can be seen that species accumulation has essentially plateaued at 6–8 mo, halfway through the study. When comparing the habitats however (Fig. 4), a difference appears. Species accumulation in the native habitat appears to have plateaued, whereas the species accumulation curve for the arundo habitat is still on a slight upward trend. One method to compare species richness for populations of unequal numbers is by subsampling the richer habitat to a sample standard. For example, for the arundo habitat, there was a total of 245 specimens representing 23 species of beetles. For the native habitat, there was a total of 42 species, but there were 521 specimens. Using species accumulation data when the 150th beetle was captured in the native habitat, there were 26 species. This compares to the 23 species in the arundo when the first 150 individuals were collected, suggesting that the arundo habitat is a similarly diverse but a rarefied version of the native habitat. On the other hand, according to Chao and Jost (2012), an interpolation based on sample size is not a ‘fair’ comparison because it is a linear compression of the data and the coverage under accumulation curves is not linear. They opine that percent ‘coverage’ rather than sample size can be used to obtain a less biased estimate of species richness. A traditional way to estimate coverage is by Turing’s estimator (Chao and Jost 2012), \( 1 - f/n \), where \( f \) is the number of singleton species. Applying this to the arundo habitat data with eight singletons, the coverage is estimated to be 0.652, whereas the native habitat with 12
singletons is estimated to be 0.684. Hence the complete ground beetle faunas of the arundo and native habitat can be estimated at 80 and 175 species, respectively, if coverage is the key factor.

Rank abundance curves can be used to characterize community structure. Fig. 5 provides composite curves for all sites combined by family and habitat. The tenebrionid curves show an inflection indicating that there is a lack of evenness in species abundance. The two species of Blapsinus dominated at all of the sites. Transforming the rank abundance data to a log-normal scale produces a straight line (Fig. 6) at least for the beetles in the native habitat. Species abundance curves are expected to be, and typically are, log-normal in natural communities (Williamson and Gaston 2005). In contrast, the log-normal transformed curve for the arundo habitat is sigmoidal and truncated. The steep sigmoidal curve results from the ‘common’ species being uncommon, a situation often associated with disturbed, transitional, nonmature communities (May 1974) with the truncation reflecting an incomplete census or, because in this case with an equal sampling rate, a depauperate fauna (MacArthur 1957). The data for the carabids in the arundo habitat does not appear because it consisted of mostly singletons and ln 1 = 0.

In sum, the native riparian habitats along the Rio Grande support a diverse beetle fauna with variable species composition. These faunas are as unlike one another as they are unlike the arundo faunas. In contrast, only a small subset of the beetle fauna from the native vegetation is able to thrive and survive in the arundo habitat.

Compositions of beetle fauna differed between the native vegetation that provides greater niches for food and haborage and the less diverse arundo. Reestablishment of native vegetation replacing arundo would increase the beetle diversity. Because carabid sample numbers were modest, it is unlikely these mostly polyphagous, opportunistic arthropod predators would apply much pressure on tick populations; thus, beetle predation would have little effect on tick populations in native vegetation or within stands of arundo (Samish and Rehacek 1999).

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