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Endemic species: Contribution to community uniqueness, effect of habitat alteration, and conservation priorities

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ABSTRACT

The biodiversity crisis, particularly dramatic in freshwaters, has prompted further setting of global and regional conservation priorities. Species rarity and endemism are among the most fundamental criteria for establishing these priorities. We studied the patterns of rarity and the role of rare species in community uniqueness using data on freshwater bivalve molluscs (family Unionidae) in Texas. Due to the large size and gradients in landscape and climate, Texas has diverse and distinct unionid communities, including numerous regional and state endemic species. Analysis of the state-wide distribution and abundance of Unionidae allowed us to develop a non-arbitrary method to classify species rarity based on their range size and relative density. Of the 46 Unionidae species currently present in Texas, 65% were classified as rare and very rare, including all state and regional endemics. We found that endemic species were a critical component in defining the uniqueness of unionid communities. Almost all endemics were found exclusively in streams and rivers, where diversity was almost double that of lentic waters. Man's ongoing alteration of lotic with lentic waterbodies favors common species, and dramatically reduces habitat for endemics, contributing to homogenization of unionid fauna. We identified hotspots of endemism, prioritized species in need of protection, estimated their population size, and recommended changes to their current conservation status.

1. Introduction

Exponential human population growth is associated with a dramatic increase in pollution, habitat alteration, introduction of invasive species and other factors which have contributed to the sharp decline in biodiversity worldwide. As a result, many freshwater as well as terrestrial systems are inevitably going to be greatly simplified and homogenized (McKinney and Lockwood, 1999). This is especially true for freshwater ecosystems, which are among the most endangered on Earth, experiencing greater declines in biodiversity than many other ecosystems due to steeply rising human demands over the past century (Dudgeon et al., 2006; Revenga and Kura, 2003; Strayer and Dudgeon, 2010). More than half of the accessible continental runoff is now controlled and used by humans, and over half of world's major rivers are seriously polluted (Vörösmarty et al., 2005; World Water Commission, 1999). The biodiversity crisis that we are currently facing requires priority setting at global, regional, and local scales in order to concentrate limited resources on the most important conservation needs (Darwall and Vie, 2005; Groom et al., 2006; Knight et al., 2008; Mittermeier et al., 1998; Williams et al., 2002).

Species rarity, diversity, and endemism are among the most frequently cited criteria for establishing conservation priorities (Reid, 1998; Schmeller et al., 2008; Williams et al., 2002). High endemism is especially typical for freshwater habitats whose insular nature has led to the evolution of many species with small geographic ranges (reviewed in Strayer and Dudgeon, 2010). Habitat change,

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degradation, and destruction are the most important threats to endemics which are highly adapted to their specific environments. Rarity is the major determinant of a species' likelihood of extinction in both ecological and geological time (Gaston, 1994; Mace et al., 2008; Pimm, 1991), and species usually become rare before going extinct (Dobson et al., 1995). Therefore, endemic species that are characterized by limited spatial distribution (Anderson, 1994), and especially those that disperse poorly, can be expected to be the first candidates for extinction. Among the 62 extinct European taxa since 1500, only 11 were wide-ranging taxa, while all others were endemic to one country, or narrow-ranging endemics shared by two or three countries (Fontaine et al., 2007). Not surprisingly, endemism is an important criterion in most methods used to determine national conservation responsibilities (Schmeller et al., 2008). However, estimates of future extinctions are hampered by many factors, including limited knowledge of species' life history traits, niche, resource requirements, and location of hotspots of endemism, as well as the lack of suitable criteria to determine rarity (Kuussaari et al., 2009; Pimm et al., 1995).

Molluscs are among the most threatened group of animals on the planet: the number of mollusc extinctions worldwide is higher than the number of extinctions in all other taxa combined (Régnier et al., 2009). Freshwater bivalves in the order Unionoida are considered to be one of the most endangered groups of animals in North America (Bogan, 1993; Lydeard et al., 2004), with over 76% of the North American Unionidae and Margaritiferidae presumed extinct, threatened, endangered, or deemed of special concern (Williams et al., 1993). Among the main reasons for their decline are sensitivity to water and habitat quality, sedentary lifestyle, long life span, complex life cycle with parasitic larvae that require specific fish hosts, slow growth, and low reproductive rates (reviewed in Bogan, 1993; McMahon and Bogan, 2001; and Strayer et al., 2004, etc.).

We studied the patterns of rarity and the role of rare species in community structure using data on Unionidae in the state of Texas. Due to its large size, geographical location, and gradients in landscape and climate, Texas has diverse and distinct unionid communities, including numerous endemic species (Abell et al., 2000; Howells et al., 1996; Neck, 1984). Since 1800, over 1.2 million acres of artificial lakes have been created in Texas, including 200 major reservoirs and ~1000,000 small ponds, that have dramatically altered the hydrology of the state which historically had no natural lentic waters (Estaville and Earl, 2008; Masser and Schonrock, 2006). The purpose of this paper is to discriminate among common and rare Texas unionid species, determine the role of endemic species in community uniqueness, compare species composition in lotic and lentic environments, and prioritize species in need of protection.

2. Methods

2.1. Study area

We conducted a state-wide survey of unionids in Texas (latitudes 98°32–99°30, longitudes 102°08–93°31) from 2003 to 2009 (Fig. 1). This area encompasses several climate zones, from humid to arid, with mean annual precipitation decreasing from 140 cm on the east to less than 38 cm on the west (Estaville and Earl, 2008). There are 11,247 named streams and rivers in Texas that belong to two major drainage basins, the Mississippi River (Red River and Arkansas basins) and the Gulf of Mexico Coastal drainage basin (Dahm et al., 2005). Most East Texas watersheds are predominantly forested (>60% of total watershed area) with little urbanization (<8%). In contrast, Central Texas drainage basins are mostly rangeland (>50%) and very urban (up to 25%). Three quarters of the Rio Grande River drainage basin is scrubland and grassland (Dahm et al., 2005). Drastic differences in climate, soils, and landscapes contribute to differences among the rivers. Rivers flowing in the wet climate of East Texas are characterized by pine-covered banks and slow-moving currents. Central Texas rivers cut through hilly terrain and have steep gradients. Rivers in West Texas traverse extremely arid landscapes with high bluffs and canyons. Considering these differences, the studied areas were divided into four biogeographical regions (with regards to unionids) according to Neck (1982) (Fig. 1). Following Parmalee and Bogan (1998), we will refer to them as "provinces". Northern Texas, including the Canadian, Red, Sulphur, and Big Cypress Bayou river systems, is referred to as the Texoma Province – a part of Interior Basin, or Mississippian Province. The Sabine province includes the eastern part of Texas (Sabine, Neches, Trinity, and San Jacinto river basins). The Central Province includes the Brazos, Colorado, Guadalupe, San Antonio, and Nueces river basins, and coastal plain streams feeding into the Baffin Bay system (Neck, 1982). The Rio Grande Province consists of the Rio Grande River drainage basin.

2.2. Survey sites

Mussels were surveyed at 139 sites, distributed in 66 waterbodies, belonging to 11 major drainage basins of Texas (Fig. 1). Most of the sites were sampled once, however, 19 sites were sampled several times. Due to the prevalence of private land in Texas, where only 2% of the lands remain in public ownership (Texas Parks and Wildlife Department, 1974), survey sites were often selected within state parks, near public boat ramps, or based on accessibility from roads that either crossed or approached a waterbody. A Landowner Permission for wildlife research was acquired from each property owner before entering their property, if the land was private. The work was carried out with an appropriate Scientific Research Permit issued by the Texas Parks and Wildlife Department (TPWD).

Sampling was completed via hand collection of both live and dead mussels, by wading in low water, and by snorkeling. Due to poor visibility, tactile searches (running fingers over the sediment and checking up to 15 cm depths, depending on substrate) were used at all sites. Reconnaissance sampling (timed searches) was used to reveal the presence of mussels and species diversity (Strayer et al., 1997; Vaughn et al., 1997) at each site. If mussel assemblages were present, quantitative methods (randomly placed 0.25 m^2 quadrats, area searches, or systematic strip transects with a random start (Smith, 2006)) were used for assessments of density and population size (Dunn, 2000; Strayer and Smith, 2003). All collected live mussels and shells were taxonomically identified, counted, and measured with calipers to the nearest mm. Live mussels after measurements were carefully rebedded into the sediment from which they were taken. Shell condition of dead mussels was recorded for each specimen. Shells were considered recently dead if they contained tissue remains and/or internal and external colors were not faded. Shells with most or all of the internal coloration and gloss faded, shell epidermis absent, or aged and flaking, were considered long dead and were excluded from data analysis. Specimens were identified using published taxonomic keys and descriptions (Cummings and Mayer, 1992; Howells et al., 1996; Johnson, 1998; Oesch, 1995; Strayer and Jirka, 1997). Live specimens were preserved in 200 proof ethyl alcohol; dead shells were cleaned and dried. We deposited voucher specimens into the Great Lakes Center Invertebrate Collection (Buffalo State College, Buffalo, NY). Each specimen was labeled with a unique number, and cataloged in database with the following information: specimen number, species name, name of person who collected and identified the specimen, date of collection, and detailed site information. Specimens were also deposited in the North