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Review

A large-scale conservation perspective considering endemic fishes of the North American plains

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ABSTRACT

Regions with unique habitats often harbor endemic taxa associated with temporally stable habitats. We identified such habitats that sustain endemic fishes in the plains of North America. We also summarized threats to their conservation and identified remnant habitats that still harbor endemic fishes (refuges) based on post-1989 surveys. Major springs, smaller, spring-fed streams, larger rivers, and euryhaline habitats were associated with a total of 49 endemics. Endemism was attributable to climatic refugia associated with each habitat type and dispersal limitation among major river drainages and springs. Forty-one endemic fishes (84%) were declining or extinct. Dewatering, habitat fragmentation, and habitat degradation were main causes of declines, often present together. Pollution and non-native species were also threats in many cases. Evidence for 53 existing refuges was found. We considered 34 refuges to be "high-quality" because they harbored three or more endemics. Twenty of these (those with available data) maintained consistent streamflow regimes for at least 50 years up to 2009. Case studies suggest high stream length, more natural flow regimes, and fewer direct human impacts are features of high-quality refuges, but extinction thresholds are unquantified and extinction debts of refuges are unknown. Limited information on past extinctions suggests drought, a natural feature of the plains, combines with other threats to eliminate remnant endemic populations. Long-term conservation planning requires identification, protection, and restoration of high-quality refuges to reduce extinction risk, especially during future drought periods. Planning should be integrated with regional water resource planning, given scarcity of water in the region.

Contents

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1. Introduction

Long-term processes create and maintain biodiversity (Callicott, 2002; Willis and Birks, 2006) and unique landscapes and climates that persist over time promote regionalization of faunas (Morrone, 2009). Endemic taxa arise within discrete habitats where extinction rates are low (Diamond, 1984; Oberdorff et al., 1999). Regions with unique environmental conditions and histories tend to harbor assemblages of associated, endemic taxa if suitable habitats are persistent (e.g. Reyjol et al., 2007; Brown et al., 2009). Patterns of human disturbance tend to be regional in nature as well. Entire regional endemic biotas are threatened when regional-scale disturbances degrade suitable habitats and climatic refugia (e.g. Deacon et al., 2007; Williams et al., 2009a).

The plains region of North America (henceforth, "the plains") provides unique aquatic habitats characterized by periodic or sporadic precipitation, highly erosive (sandy) soils, high evaporation relative to precipitation, and abundant and diverse connections with large aquifers (e.g. Matthews, 1988; Hubbs, 1995; Fausch and Bestgen, 1997). A suite of fishes well adapted for life in these habitats exhibits endemism, with distributional boundaries more or less congruent with the boundaries of the plains (e.g. Brunger Lipsey et al., 2005; Hoagstrom et al., 2007c). Efforts to conserve endemic fishes have ensued within the last 40 years (e.g. Ono et al., 1983; Cross and Moss, 1987) and literature suggests their regional status is poor, yet patterns of endemism and species status have received modest study and existing reviews either do not consider the entire region (e.g. Fausch and Bestgen, 1997; Hubert and Gordon, 2007) or are out of date (e.g. Cross et al., 1986). Here, we survey literature on endemic plains fishes to (1) summarize endemic fish diversity and describe associated habitats in the context of long-term persistence of unique taxa (endemism), (2) summarize the status of endemics, and (3) compile a list of refuges (areas recently inhabited by endemics) to focus future conservation efforts. Our approach provides an example of a preliminary analysis for preservation of regional endemics that have received modest levels of study despite widespread declines.

2. Methods

2.1. The plains

The plains include the Great Plains and Osage Plains regions (Fig. 1), which contain mostly un-glaciated, semi-arid, grasslands that encompass roughly 20° of latitude, including portions of eight major river drainages (Matthews, 1988). Three major drainages are tributary to the Gulf of Mexico via the Mississippi River (Missouri River, Arkansas River, Red River) and five are direct tributaries to the Gulf of Mexico (Brazos River, Colorado River, San Antonio Bay rivers, Nueces River, and Rio Grande). The Rocky Mountain and Basin and Range regions bound the plains on the west. Mountains in these regions contain headwater streams of major rivers of the plains. Headwaters of some smaller rivers originate in highlands of the plains or as springs. The Glaciated Central Lowlands, Ozark–Ouachita Uplands, and Coastal Plain regions bound the plains on the east and south. Rivers of the plains flow into these more humid regions upon exiting the plains.

In the plains, there is a continuum of aquatic habitats from those dominated by groundwater discharge (i.e. springs) to those dominated by surface runoff. Large springs have nearly constant environmental conditions (e.g. temperature, discharge) due to the constancy of groundwater chemistry and discharge (Hubbs, 1995, 2001). Aquifers are also a main source of base flow in perennial streams and rivers (e.g. Sophocleous, 2003; Dodds et al., 2004; Hoagstrom, 2009). Groundwater seepage may comprise the majority of streamflow in smaller streams. Narrow meandering channels, relatively stable substrates, grassy riparian zones, and riffle-pool habitat patches characterize these habitats (Cross and Moss, 1987; Dodds et al., 2004). Larger streams are increasingly influenced by surface runoff as drainage area increases. Much of the plains landscape is covered with sandy soils, so runoff into larger streams delivers abundant sand to the river bed and facilitates channel migrations. This creates wide river channels with high width-to-depth ratios and shifting sand substrata. Open-water habitats are relatively shallow (usually only a few meters, often much less, except in the largest rivers) and perpetual sand transport creates a dynamic habitat mosaic (e.g. Polivka, 1999; Hoagstrom et al., 2008a). Rivers of the plains have wide floodplains, often forested with galleries of trees (e.g. *Populus* spp.), and may include various transient and spring-fed aquatic habitats (Hoagstrom and Brooks, 1999; Dodds et al., 2004). Periodic foods connect floodplains with riverine habitats.

Extreme climatic fluctuations (i.e. alternation between warm, dry and cool, wet periods) have strongly influenced native fish faunas of the plains for several million years (Cross, 1970; Newbrey and Ashworth, 2004; Hoagstrom and Berry, 2006). The grassland environment has extended to the east during warm, dry periods (e.g. King, 1981), at which time conditions in the western plains were more arid (Meltzer, 1999). Fishes endemic to the plains likely extended their range to the east during these times, but simultaneously may have declined from the western plains due to widespread desiccation. However, areas with substantial connections to aquifers likely sustained endemic fishes because groundwater responds relatively slowly to climate change, buffering climatic fluctuations (Smith et al., 1997; Chen et al., 2003). High endemism in major springs of the region is a result of extreme, long-term environmental stability (e.g. Longley, 1981).

Main human disturbances to aquatic habitats of the plains are associated with arid-land agriculture, the dominant land use in the region (Parton et al., 2007). In certain areas, urban and industrial developments also cause disturbance (e.g. Johnson and Hubbs, 1989). Dewatering (Cross and Moss, 1987), damming (Poff et al., 2007), and physical habitat modification (e.g. channelization; Dodds et al., 2004) are widespread. Non-native fishes (Gido et al., 2004) and pollution (Hoagstrom, 2003, 2009) also impact endemic fishes in some areas. These impacts are interrelated and often associated with irrigated agriculture, urbanization, mining, and other land uses.

2.2. Endemic fishes, habitat types, and refuges of the plains

We reviewed literature to compile a list of endemic fishes of the plains with an assessment of their status. Our review was focused on peer-reviewed articles because they are the best and most accessible long-term record of fish assemblage studies, but we supplemented our search with distributional reviews, theses and dissertations, and government agency reports to determine the status of all endemics.

We defined endemic fishes as those with distributions centered in the plains. Some taxa ranged into adjacent regions, but all were characteristic of typical plains habitats and, when present in adjacent regions, were restricted to plains-type habitats. We summarized patterns of endemic diversity among river drainages (beta diversity) by calculating percent of unshared taxa between neighboring river drainages (Hoagstrom et al., 2007c) and noted introductions to drainages outside their native range.

We used our entire library to group endemic taxa into four "status" categories: (1) declining (range or abundance less than historically documented), (2) stable (range unchanged), (3) increasing (existing throughout historical range and expanding via invasions), or (4) unknown. We grouped factors contributing to declines into