Biodiversity, Biogeography, and Conservation of North American Desert Fishes

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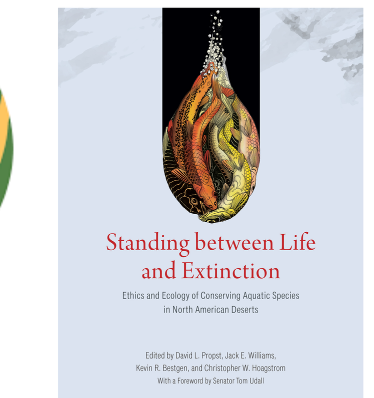

North America contains vast expanses of desert habitats that are home to several iconic endemic species (e.g., Saguaro cacti, Joshua trees, horned lizards, desert tortoises, roadrunners, etc.). Desert fishes are perhaps more overlooked, but nevertheless persist in many unique forms across desert landscapes and play important ecological roles in desert aquatic systems. Indeed, based on our literature review, North America hosts **336** desert-endemic fish lineages. These endemic desert fishes reside in a broad range of habitat types ranging from small springs to large rivers. A comparison of endemic-lineage distributions with modern and prehistoric drainage boundaries reveals **30** distinct areas of endemism (*sensu* Parenti & Ebach 2009; Fig. 1), with endemic lineages per area ranging from 1 (Tularosa, Solitary, Alvord) to 43 (Coahuila) (mean = 15 ± 11 s.d.). Faunal composition in each area of endemism is unique (Fig. 2). Thus, each unique assemblage, with its distinctive biogeographic history, should be considered as a discrete target for conservation.

A major biogeographic boundary subdivides the desert region into the Northern Great Basin-Colorado Plateau and Southern Desert-Eastern Steppes (with 13 and 17 areas of endemism, respectively; Fig. 1).

Only **3%** of desert-endemic fishes are distributed across this boundary. These either dispersed between the upper and lower Colorado River basins following formation of the Grand Canyon (Spencer et al. 2008), or crossed through Mono Lake, CA (Reheis et al. 2002).

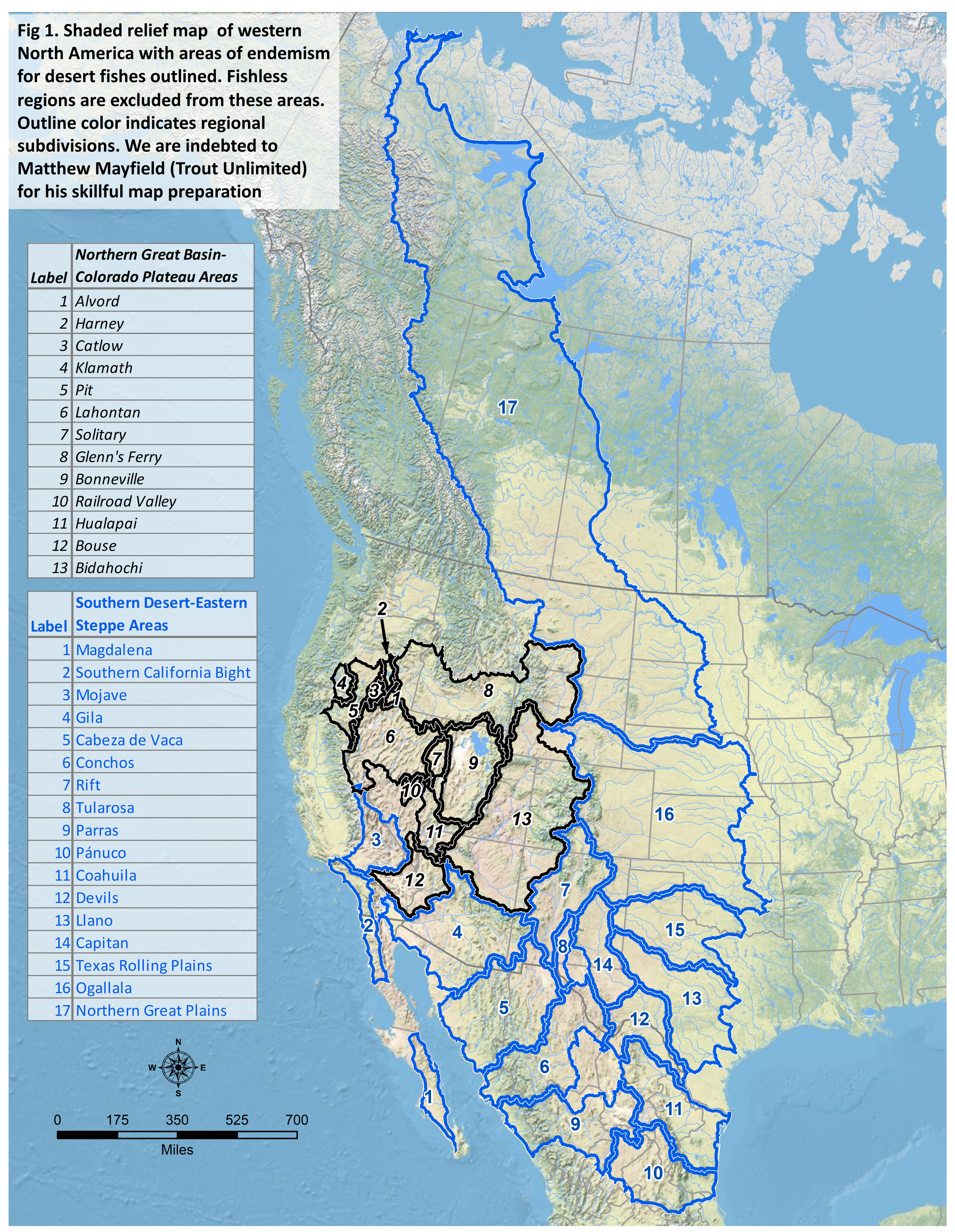

Fig 1. Shaded relief map of western North America with areas of endemism for desert fishes outlined. Fishless regions are excluded from these areas. Outline color indicates regional subdivisions. We are indebted to Matthew Mayfield (Trout Unlimited) for his skillful map preparation

While some 'widespread' endemics occupy multiple areas of endemism, **82%** are restricted to single areas, and none occupy more than 5 (Fig. 3). Areas with shared lineages have histories of interconnectedness, particularly in modern drainages that are conglomerates of distinct pre-historic river basins (e.g., Colorado River, Rio Grande).

North American desert endemic fishes represent 53 clades from 14 families. Estimates of lineage origins are mostly asynchronous, with desert-endemic fish diversity accumulating over ~23 million years (Table 1).

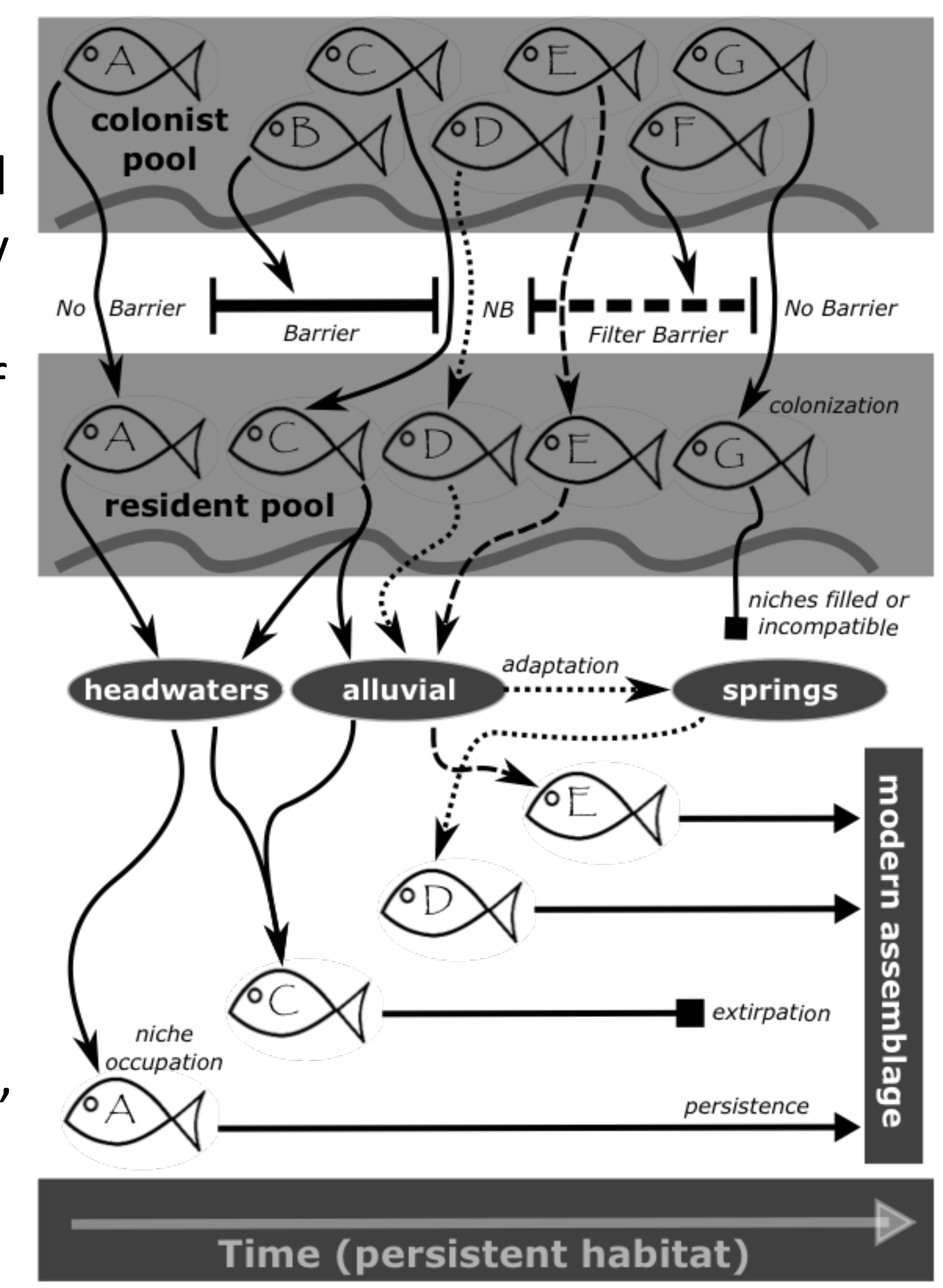

Fig. 4. Conceptual model of faunal assembly.

Our conceptual model of faunal assembly (Fig. 4) illustrates a multi-step process wherein an incipient desert endemic lineage can diverge at any time. An area may provide habitats in headwaters, alluvial streams, or springs.

1. Founders colonize areas of endemism via passive (barrier formation) or active (dispersal) mechanisms.
2. Persistence, possibly with adaptation, establishes residency. Areas with endemics become 'centers of survival' (*sensu* Cowman & Bellwood 2013).
3. Over time, areas accumulate diverse faunas through periodic colonization and/or *in situ* diversification. Areas accruing faunas become 'centers of accumulation' (*sensu* Cowman and Bellwood 2013), and areas with *in situ* diversification become 'centers of origin' for desert fish diversity.

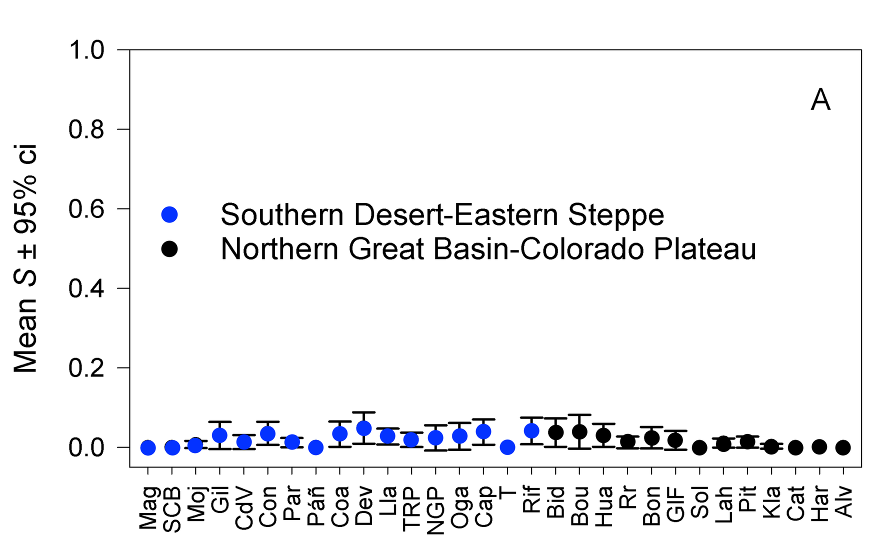

Fig. 2. Mean ± 95% confidence intervals for pairwise comparisons of the Sorenson Coefficient of Similarity (S; 0=no similarity, 1=total similarity) among 30 areas of endemism for assemblages of desert-endemic fishes. Symbol color indicates regional subdivisions.

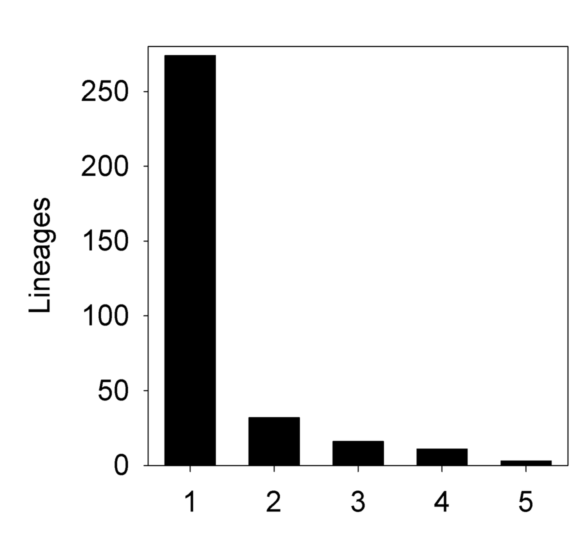

Fig. 3. Number of desert endemic fishes native to 1, 2, 3, 4, or 5 areas of endemism (n=333). No lineage is native to > 5 areas.

Table 1. Time period for initiation of desert endemism for 39 of 53 endemic-producing clades (based on available estimates)

EPOCH	TIME PERIOD	CLADES
Early Miocene	23-16 MYA	1
Middle Miocene	16-12 MYA	9
Late Miocene	12-5 MYA	17
Pliocene	5-2.6 MYA	8
Quaternary	2.6 MYA - PRESENT	4

More details available from the recently published volume: *Standing Between Life & Extinction*. DL Propst, JE Williams, KR Bestgen, & CW Hoagstrom (eds). University of Chicago Press. (Cover image pictured top-right.)

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