Ichthyology & Herpetology 113, No. 1, 2025, 94–103

Long-Term Changes in Fish Assemblage Structure Associated with Hydrological Alteration in the Lower Rio Grande/Rio Bravo del Norte (USA/Mexico)

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The lower Rio Grande watershed below Falcon Dam has been 95% developed for agriculture, urban, and industrial uses. The river has been extremely altered to make this possible, with the addition of two more downstream dams, a series of five rock weirs, and numerous water diversions. This regulation has resulted in an extremely altered flow regime and fish fauna since the early 1950s. There has been a significant general retreat and decline of primary freshwater fishes over time, and we identified three significantly different faunal groups across the fragmented watercourse. However, the overall species richness of the region did not change significantly over time, likely due to an ongoing upstream intrusion of estuarine and marine-derived taxa, as well as the increase in the number and spread of non-native taxa. Despite no overall change in species richness within the region, we identified a significant trend in the species richness of the two most diverse primary freshwater fish families, Leuciscidae and Centrarchidae. Leuciscid richness significantly declined and centrarchid richness significantly increased over the 68-year period. Fluvial native leuciscid species that require a natural flow regime became extirpated or extinct, while lentic-adapted native and introduced centrarchids have thrived. The flow regime of the lower Rio Grande has been severely altered since impoundment of Falcon Reservoir. Median monthly flows have declined for all months, maximum flows and high flow pulses have declined, and base flows have increased. Also noteworthy were the increased number of hydrograph reversals post-impoundment. The streamflow regime is of central importance in sustaining the ecological integrity of rivers, and its disruption in the lower Rio Grande corresponds to a vastly different contemporary fish fauna than what historically occurred.

THE composition of riverine fish assemblages and the persistence of fish species are closely linked with environmental conditions. River flow regimes can act as master variables controlling water quality, food resources, fish habitat, and can mediate biotic interactions (Poff et al., 1997). The alteration of flow regimes through damming and impoundment converts lotic ecosystems to lentic ecosystems, changes sediment transport, and reduces habitat and substrate diversity (Bunn and Arthington, 2002). These effects can result in significant changes to resident fish assemblages, including loss of biodiversity, species replacement, species extirpations/extinctions, and proliferation of introduced species (Vörösmarty et al., 2010; Tickner et al., 2020). Meta-analysis has shown that species richness and diversity decline in tropical and temperate rivers post-impoundment and there is a general increase in non-native and generalist species (Turgeon et al., 2019). Specialist species such as broadcast or substrate spawning fishes that require a natural flow regime or coarse substrates have been shown to decline in rivers post-impoundment (Perkin and Bonner, 2011; Taylor and Mayes, 2022). Lotic specialists (Taylor and Mayes, 2022) and diadromous fishes requiring river corridor connectivity (Gehrke et al., 2002) are vulnerable to extinction in impounded river systems due to loss of habitat and alteration of flow conditions.

The Rio Grande system drains a bi-national basin and forms an approximately 2000 km international border across Texas and northern Mexico. It is considered one of North America's most endangered river ecosystems due to extensive alteration of flow regimes and degradation in water quality, quantity, and habitat (Dettinger et al., 2015; Taylor et al., 2019). The lower Rio Grande delta region, from the Falcon Reservoir to the mouth of the river, is now 95% developed for agricultural, urban, and industrial uses, with few minimally impacted areas remaining intact (Contreras-Balderas et al., 2002). The lower Rio Grande is a low gradient river, dropping on average 0.18 m/km over its run and changing little in width or depth (Contreras-Balderas et al., 2002). The International Boundary Water Commission (IBWC) reported that discharge at the river delta in the 1990s was 32% that of the 1960s (Contreras-Balderas et al., 2002). The habitat in this region once commonly contained riffles, gravel, and sand banks in the 1950s, but this habitat is being lost due to siltation caused by flow regulation (Contreras-Balderas et al., 2002). In addition to habitat changes, water quality has changed drastically. Water quality at the confluence of the Rio San Juan has changed most notably in conductivity and dissolved ions of calcium, sodium, and chloride as a result of changes in rainfall, stream flow, and from saltwater encroachment from the delta (Contreras-Balderas et al., 2002). Flow dynamics, including the frequency

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Submitted: 11 March 2024. Accepted: 10 January 2025. Associate Editor: M. P. Davis.
 DOI: 10.1643/i2024024 Published online: 6 March 2025