PERSISTENCE OF *CYCLONAIAS NECKI* (BIVALVIA: UNIONIDAE) IN THE BLANCO RIVER, TEXAS: FIRST LIVE RECORD IN OVER 40 YEARS

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Cyclonaias necki (Burlakova et al. 2018) is a newly described freshwater mussel (Bivalvia: Unionidae) species recently split from *Cyclonaias petrina* (Gould 1855) (formally described as *Quadrula petrina*; Williams et al. 2017), which prior to the split was considered endemic to the Colorado and Guadalupe-San Antonio (GSA) river basins. Following the split, *C. necki* is now considered endemic to the GSA. The historical range of *C. necki* in the Guadalupe River basin included the Guadalupe and Blanco rivers (Strecker 1931; Horne & McIntosh 1979; Johnson et al. 2018). In the San Antonio River basin, *C. necki* was believed to occur in the San Antonio and Medina rivers, and Salado Creek; however, evidence from shell material to support this is limited (Johnson et al. 2018). Recent observations of live individuals suggest that *C. necki* currently occurs in the upper Guadalupe River upstream of Canyon Lake and lower Guadalupe River downstream of the San Marcos River confluence (Tsakiris & Randklev 2016; Randklev et al. 2017; Bonner et al. 2018). Recent surveys found that *C. necki* also presently occupies the lower San Marcos River near Luling, Texas, expanding its known range (Burlakova et al. 2012). *Cyclonaias necki* is listed as threatened by the Texas Parks and Wildlife Department (TPWD 2020) and is presently a candidate for federal listing under the Endangered Species Act (ESA) (USFWS 2019). Currently, the U.S. Fish and Wildlife Service (USWFS) presents that *C. necki* has experienced range curtailment in the Guadalupe and San Marcos rivers, and is presumed to be extirpated from the Blanco River (USFWS 2018).

The Blanco River lies within the Guadalupe River drainage of central Texas. It originates west of Blanco, Texas, predominantly flowing through karst landscapes of the Edwards Plateau, and shortly traverses the Blackland Prairie just east of the Balcones Escarpment

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before its confluence with the San Marcos River near San Marcos, Texas (Smith et al. 2015). The Blanco River within the Edwards Plateau exhibits strong groundwater-surface water interactions (Wierman & Hunt 2010; Smith et al. 2015). Karst features dictate whether water drains subsurface or is discharged into the river, which results in gaining and losing reaches (Smith et al. 2015). Gaining reaches are fed by multiple springs within the Edwards-Trinity Aquifer (e.g., Pleasant Valley and Jacob's Well springs; Smith et al. 2015). Further, the Blanco River is an important groundwater contributor to San Marcos and Barton springs as it flows into the Edwards Aquifer recharge area along the Balcones Fault Zone (Johnson et al. 2012; Smith et al. 2012). When discharge is high enough, water will continue to flow past the Balcones Fault Zone where the river enters the Blackland Prairie before its confluence with the San Marcos River (Smith et al. 2015). Freshwater mussel surveys and distributional records in the Blanco River basin are currently limited. Live *C. necki* (described as *Q. petrina*) were observed in the 1970s during a study conducted in a 6 km stretch of the lower Blanco River, downstream of the Balcones Fault Zone near the San Marcos River confluence (Horne & McIntosh 1979). During this study, *C. necki* mean densities ranged from 0.0 to 1.3 individuals m^{-2}, and were predominantly observed in areas with current velocities of 1.0 m sec^{-1} or greater, with cobble, gravel, and boulder substrates (Horne & McIntosh 1979). More recently, qualitative surveys at eight locations in the upper Blanco River, upstream of the Balcones Fault Zone, were conducted in the 1990s and early 2000s (Howells 1994; 1995; 1996; 2005). Although no live mussels were observed during these surveys, a single relic *C. necki* (described as *Q. petrina*) was observed in 1993 near Wimberly, Texas (Howells 1995), supporting that *C. necki* historically occurred in the upper Blanco River. Howells (1995) also conducted a survey in the lower Blanco River within the study area of Horne & McIntosh (1979), but did not observe any live mussels or shell material. The lack of live mussels detected by Howells (1994; 1995; 1996; 2005), combined with extensive drying of much of the Blanco River during recent droughts (Smith et al. 2015; Magnelia et al. 2019), has left the status of *C. necki* in the Blanco River uncertain.

From 2018 to 2020, I used visual and tactile search methods to conduct haphazard qualitative mussel surveys at the lower Blanco River in San Marcos, Texas near the location of previous live *C. necki* observations by Horne & McIntosh (1979). I collected shell material of four *C. necki* specimens on April 24, 2018 (29.898410° N, -97.901893° W; shell lengths: 48 and 60 mm) and May 6, 2018 (29.894669° N, -97.900101° W; shell lengths: 50 and 55 mm). On March 27, 2020, I observed a single live *C. necki* (29.894314° N, -97.899323° W; shell length: 41 mm; Fig. 1). Exterior shell characteristics of the shell material and live specimen aligned with recent taxonomic descriptions that included subquadrate shell outline, posterior corrugations, umbo sculpture with rows of nodules, and yellow to brown periostracum with broken green rays on the posterior slope or disc of several specimens (Burlakova et al. 2018; Johnson et al. 2018). Shell material collected was located 50 and 500 m upstream of the live specimen, and weathering was minimal for multiple specimens that maintained intact periostracum (outer layer), glossy nacre (inner layer), and attached hinge ligaments. The live specimen was located in a shallow (0.3 m water depth) glide with a mean water column velocity of 0.01 m sec^{-1}. Substrate composition was visually estimated to be 80% cobble and 20% gravel.

Figure 1. Live *Cyclonaias necki* observed at the Blanco River, San Marcos, Texas in March, 2020.

This is the first live record of *C. necki* in the Blanco River since previous observations by Horne & McIntosh (1979) over 40 years ago and indicates that *C. necki* is not extirpated from the Blanco River, extending the current distribution proposed by the USFWS (2018). The lack of weathering for several of the shell specimens collected suggests recent mortality and that *C. necki* also persists within areas upstream of the live observation, although the actual time since death cannot be quantified with confidence, and due to the Blanco River's extremely flashy flow regime (Smith et al. 2015; Furl et al. 2018), the actual locations of these specimens prior to mortality are uncertain and may have been farther upstream. It's also unclear whether *C. necki* has persisted in this reach of the Blanco River over the past 40 years. A combination of prolonged droughts and increased water harvesting have reduced spring flows that sustain surface flows of the Blanco River (Smith et al. 2015). For example, during the drought of 2011 the Blanco River was reduced to a sequence of stagnant pools in some areas, completely dry in losing reaches, and remained flowing in upstream reaches near the city of Blanco (Magnelia et al. 2019). The lower Blanco River near San Marcos remains wet during moderate drought conditions (Smith et al. 2015). Therefore, it is possible that *C. necki* has persisted in the Blanco River within areas that remained wet during periods of drought. Based on an age-growth model for *C. necki* in the Guadalupe River by Dudding et al. (2019), the potential age range of the live individual was about 8 to 10 years and the shell specimens were likely about 12 years or older. These age range estimates suggest *C. necki* most likely persisted during the 2011 drought and has always occupied the Blanco River, but was not detected during previous survey efforts. Alternatively, the live individual may have been a recent migrant from the San Marcos River. Freshwater mussels parasitize on a host fish during their larval stage (Barnhart et al. 2008), which can facilitate long range upstream dispersal and recolonization in unoccupied areas (Strayer 2008; Vaughn 2012). Long range upstream dispersal of mussels is typically a slow process (Strayer 2008) and the nearest known occurrence of *C. necki* in the San Marcos River is over 50 km downstream. Based on this, a potential recolonization event immediately after the 2011 drought is unlikely, supporting long-term persistence as the most parsimonious scenario.

Due to the lack of contemporary survey data, more robust sampling near this live record would help elucidate the current status of *C. necki* in the lower Blanco River. Longitudinal surveys within gaining reaches of the upper Blanco River are also needed to understand its current distribution throughout the system. For example, the Blanco River from Pleasant Valley Spring to 40 km downstream is a gaining reach (Smith et al. 2015) and is located within the vicinity of Howells (1995) relic *C. necki* observation. The presence of *C. necki* in the Blanco River also indicates that additional sampling is needed in areas deemed extirpated but lack recent survey data, such as the Guadalupe River from Canyon Lake Dam to the San Marcos River confluence (USFWS 2018). It is evident that areas deemed extirpated where data gaps exist may misrepresent the current distribution of *C. necki* and result in inaccurate estimates of range curtailment. Similarly, surface flow discontinuity is a natural phenomenon in the Blanco River with about 35 km of river identified as losing sections (Smith et al. 2015), which suggests that at least 30% of the river has likely never been persistent habitat for mussels. However, diminishing baseflows are expected to affect the hydrology and ecology of the Blanco River (Smith et al. 2015), which may unknowingly impact the mussel fauna if present in gaining reaches. Reductions in spring flows have been found to negatively impact mussel assemblages in several other Edwards Plateau drainages in the Colorado River basin (Randklev et al. 2018; Mitchell et al. 2019). For example, Mitchell et al. (2019) surveyed the Concho River before and after the drought of 2011 and observed a complete loss of the mussel community in areas sampled, including ESA candidate *C. petrina*. Based on this, further information on the distribution and population dynamics of *C. necki* in the Blanco River are needed to understand its current status and develop sound conservation strategies to protect this rare freshwater mussel species.

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