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## ABSTRACT

Freshwater mussels are declining globally, and effective conservation requires prioritizing research and actions to identify and mitigate threats impacting mussel species. Conservation priorities vary widely, ranging from preventing imminent extinction to maintaining abundant populations. Here, we develop a portfolio of priority research topics for freshwater mussel conservation assessment. To address these topics, we group research priorities into two categories: intrinsic or extrinsic factors. Intrinsic factors are indicators of organismal or population status, while extrinsic factors encompass environmental variables and threats. An understanding of intrinsic factors is useful in monitoring, and of extrinsic factors are important to understand ongoing and potential impacts on conservation status. This dual approach can guide conservation status assessments prior to the establishment of priority species and implementation of conservation management actions.

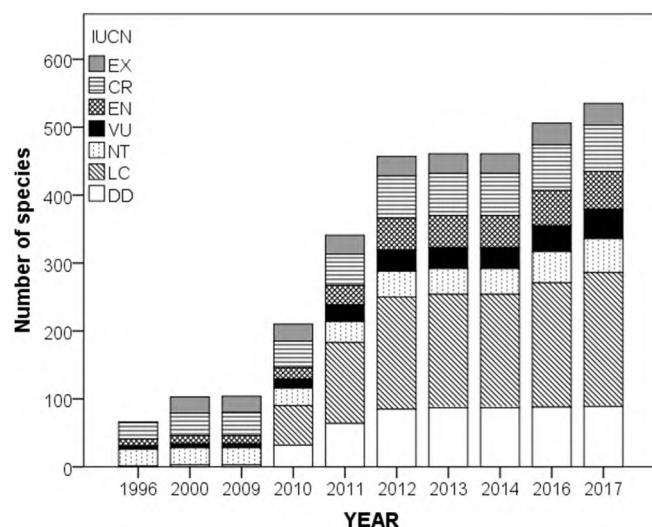
## 1. Introduction

Freshwater mussels (Mollusca: Bivalvia: Unionida) are benthic macroinvertebrates that use their muscular foot and shell to burrow into the sediment (Allen and Vaughn, 2009). Adults filter-feed on particles from the water column and interstitial space using cilia-generated water currents (Vaughn et al., 2008; Walker et al., 2014). They have a unique life cycle in which the larva (glochidia, lasidinia, or haustoria) must attach to a vertebrate host, usually a fish, and subsequently metamorphose into a juvenile mussel (Wächtler et al., 2001).

Scientific interest in freshwater mussels has grown dramatically since the 1970s (Strayer et al., 2004; Lopes-Lima et al., 2014) when the first modern extinctions were recognized (Stansbery, 1970, 1971). As currently defined, the Order Unionida, the freshwater mussels, comprises six nominal families and around 800 described species, although the exact number fluctuates as new species are described and taxonomic revisions to existing taxa are made (Williams et al., 2017; Graf and Cummings, 2018). In this context, accurate taxonomic identification plays a key role in species conservation, and modern phylogenetic information is a critical component of conservation biology (Morrison III et al., 2009). Freshwater mussels are globally imperiled (6% of known species having recently become extinct; IUCN, 2017), with declines in distribution and abundance related to a variety of factors including habitat modification, water quality degradation, climate change, introduction of non-native species, declines in fish hosts, and over-exploitation (Strayer et al., 2004; Walker et al., 2014; Lopes-Lima et al., 2018). Of 535 freshwater mussel species assessed by the International Union for Conservation of Nature (IUCN, 2017), 217 were categorized as Near Threatened, Vulnerable, Endangered, or Critically Endangered, and 89 species were classified as Data Deficient (Fig. 1). Given these high levels of imperilment, establishing research priorities that support more accurate determination of a species' status is critical. Here we summarize the most important research needs for assessing the conservation status of freshwater mussels (Table 1) and discuss how

practitioners can leverage this information to improve the development and implementation of effective conservation and management strategies.

Characters used to assess the conservation status of a given group of organisms can be subdivided into intrinsic and extrinsic factors (following Williams et al., 2008; Dawson et al., 2011; Fig. 2). Intrinsic factors are measures of a species' condition and provide valuable information about demographic trends (e.g., abundance, distribution, and viability of extant populations) and population health status (e.g.,



**Fig. 1.** Number of assessed freshwater mussel taxa and distribution of IUCN Red list status in recent years. DD, Data Deficient; LC, Least Concern; VU, Vulnerable; NT, Near Threatened; EN, Endangered; CR, Critically Endangered; EX, Extinct. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)