

A multi-state mark-recapture-recovery model to estimate rates of severe injury and cause-specific mortality in North Atlantic right whales

Recent decline of North Atlantic right whales over the past decade has been attributed to high rates of mortality and low rates of reproduction. The former has been driven by human-related causes including entanglement and vessel strike, though cause-specific mortality rates have been difficult to estimate due to uncertain variation in carcass detection and a large proportion (>60%) of cryptic mortality. Here we present a multi-state mark-recapture-recovery model that leverages the sightings of individuals with severe injuries and recovered carcasses of known individuals to estimate rates of injury and mortality during 1990–2019. Annual variation and decadal trends in injury and mortality rates were accommodated, as well as the effect of mature females recovering from the physiological stress of reproduction. Model results suggest that while just under half of vessel strike mortalities may result in recovery, entanglement mortalities are recovered at a much lower rate. Population-wide apportionment of mortality suggests a ~2:1 ratio of entanglement to vessel strike deaths. Females with a recently weaned calf had higher rates of severe injury and, consequently, a higher proportion of mortalities due to entanglement. By integrating observations of severe injuries with carcass recoveries, our modeling approach provides a novel framework for estimation of cause-specific mortality.