Honey, I Ate the Kids: Strategic Cannibalism by Invasive *Mnemiopsis leidyi*

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Increased industry and globalization continue to rapidly shift the distribution of biodiversity and structure of ecosystems through the introduction of invasive species into habitats they would not naturally occupy. The early 1980s marked the beginning of *Mnemiopsis leidyi's* reign of terror; their accidental introduction to the Black Sea and subsequent invasion of Eurasian waters has devastated local ecosystems and fisheries. *M. leidyi* are extraordinarily efficient predators that effectively empty prey fields and disrupt food webs reliant on zooplankton. It takes an *M. leidyi* a mere 13 days to grow from an embryo to an adult; their extraordinary growth rate paired with their bloom-and-bust population dynamics (long periods of high population growth and subsequent crash in population) and ability to self-fertilize contribute to *M. leidyi's* success (Sasson and Ryan, 2016). These mechanisms alone, however, do not explain the survival of *M. leidyi* populations in northern latitudes of their non-native range in Eurasian waters. Here they experience much longer low-feeding periods (late seasons) compared to their native habitat along the Atlantic coastline of North and South America. Individual *M. leidyi* do not have large nutrient reserves, and risk starvation during extended late seasons at northern latitudes. Despite the importance of nutrient reserves to adult survival over the late season, mature *M. leidyi* invest an immense amount of resources into reproduction during the late seasons! Investment into reproduction does not serve to expand the population; larvae produced during the late season experienced a high mortality rate, starvation, and stunted growth. Investing precious resources into reproduction during periods of great scarcity may seem counterintuitive, and yet *M. leidyi* are able to survive long, inhospitable winters. This raises the question to the purpose of *M. leidyi's* anomalous reproductive behaviour.

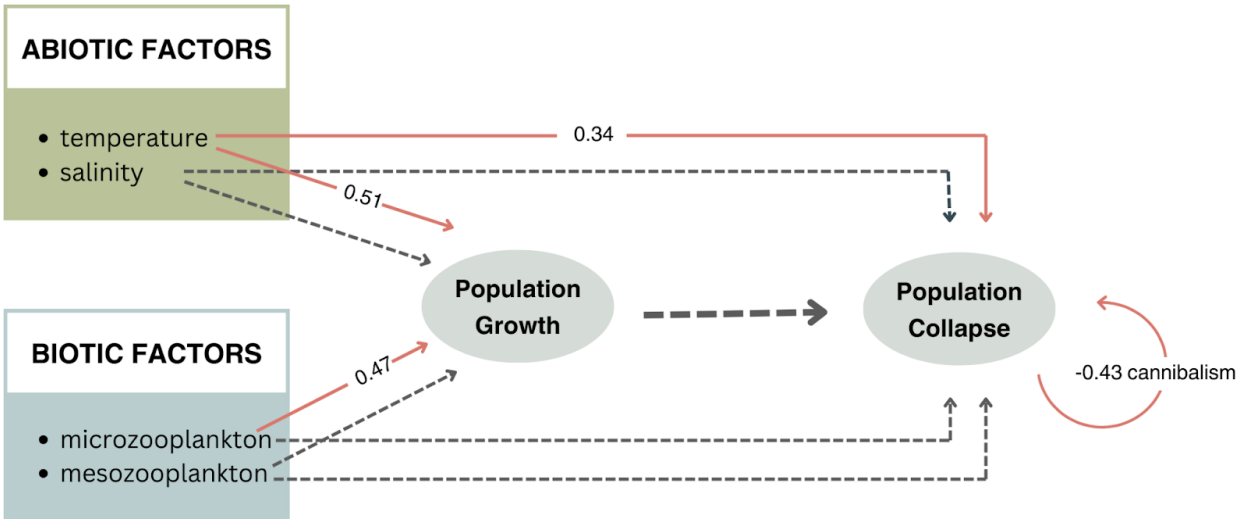
Javidpour et al. (2020) sought to provide answers to *M. leidyi's* puzzling late-season reproduction and the species' remarkable ability to sustain themselves throughout the winter. They hypothesised that cannibalism may be periodically utilized to obtain nutrients otherwise unavailable during the late seasons. To estimate abundance of larvae to adults relative to prey availability, researchers performed daily high-frequency field sampling of *M. leidyi* and their prey; observations occurred from pre-bloom to post-bloom periods within the Kiel Fjord (southwestern Baltic Sea). The abundance relationship between *M. leidyi* larvae and adults was linear during bloom growth periods. Bust phases (population collapse) were observed to have an increased abundance of adults. This is noteworthy as bust phases happen when juvenile *M. leidyi* and the zooplankton prey pool dramatically decline in number. Analysis of the abundance of larvae to adults with respect to prey availability suggests that the shift from interspecies to intra-species predation results in decreased daily rations of adults. However, rations during collapse periods contained an estimated 10-20% of body carbon, enough to sustain the adult population for 2-3 weeks.

Still, direct evidence of cannibalism needed to be collected. Adult *M. leidyi* were incubated alongside larvae radiolabelled with ^{15}N and monitored within a laboratory setting. Radiolabelling the larvae allowed researchers to calculate the difference in nutrient levels compared a treatment group of adults who had access to copepod prey (i.e. regular sources of nutrients). Concentrations of ^{15}N within adults incubated with the radiolabelled larvae were significantly higher than the treatment group that had access to copepod prey; an increased concentration of ^{15}N indicates that intra-species predation took place as the adults would have had to have eaten the larvae to accumulate a significantly higher concentration of ^{15}N . A control group consisting solely of radiolabelled larvae was monitored to ensure that radiolabelling did not factor into larvae mortality; the control group experienced zero larvae mortality over the 36-hour incubation.

Evidence of interspecies predation within the natural environment was collected by photographing a field of *M. leidyi* within 30 minutes after collecting samples from the population. Photographs from an *M. leidyi* bloom collapse showed an adult with two larvae within its cilia-lined feeding projections (auricles). The mesh netting used to capture adult specimens was too large for the larvae to be captured; therefore, *M. leidyi* adults did not consume larvae post-capture.

To determine the direct and indirect drivers of *M. leidyi* seasonal population growth, Javidpour et al. (2020) utilized structural equation modeling (SEM). Results from SEM indicated that food availability (e.g. abundance of microzooplankton) and increased temperatures significantly contributed to *M. leidyi* population growth (Focus Figure 1). Conversely, decreased temperature and cannibalism were associated primarily with a population nearly entering bust periods (Focus Figure 1). Observational data indicated that *M. leidyi* adults shift to cannibalism after depleting the copepod (a type of zooplankton) population.

These results provide unequivocal evidence of cannibalism amongst *M. leidyi* adults as an adaptation to survive low-feeding periods. Cannibalism is especially important to invasive *M. leidyi* living at northern range limits as the late season period is far longer than within their native habitats. Switching from zooplankton prey pools to intra-species predation allows for adults to continue growing, thereby providing potential opportunities to outcompete intraguild species and build up nutrient reserves! Research into the mechanisms responsible for *M. leidyi's* widespread success provides insight into managing their invasiveness. Due to its profound ecological and economic effects, *M. leidyi* has become the most well-studied (and most infamous) ctenophore species. There remains much to learn about *M. leidyi;* the research done by Javidpour et al. (2020) has helped explain how *M. leidyi's* bizarre late-season reproductive strategies function as an adaptation against lengthy periods of food scarcity.



Focus Figure 1. Summary of the key drivers of *Mnemiopsis leidyi* population dynamics: environmental conditions and prey availability. Black dashed lines indicate paths that are not statistically significant, whereas red solid lines indicate statistical significance ($p < 0.05$) and include their respective standard coefficients. Bloom phases are concurrent with temperature increases and the abundance of microzooplankton. Decreased temperature and a shift to cannibalism are characteristics of the late-bloom phase. These results suggest that cannibalism prevents complete population collapse once the microzooplankton prey pool has been emptied. (Adapted from Javidpour et al., 2020)

Additional Reference

Sasson, D.A., J.F. Ryan. 2016. The sex lives of ctenophores: the influence of light, body size, and self-fertilization on the reproductive output of the sea walnut, *Mnemiopsis leidyi*. PeerJ 4:e1846. https://doi.org/10.7717/peerj.1846