Ontogeny of pursuit, handling, and ingestion of planktonic prey by early stage American lobster *Homarus americanus*

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Introduction

The American Lobster (*Homarus americanus*) plays an integral role in the coastal northwest Atlantic as both a benthic consumer, and the target of the most valuable single species fishery in North America. In recent years there has been a decrease in the number of juvenile lobsters settling in coastal nursery habitats in the Gulf of Maine despite increases in reproductive adults. These declines in settlement correlate strongly with the climate driven shifts in the zooplankton assemblage in the Gulf of Maine (Carloni et al. 2018). Zooplankton serve as the primary food source for young lobsters during their planktonic stages, but knowledge of the specific diet of larval lobsters is limited. Shifts in the available prey assemblage may have greater impacts on lobster larvae at different points in their development, as lobsters undergo major morphological and behavioral changes in their early life stages which impact their ability to capture and handle prey. I addressed the following questions using feeding and behavioral experiments in the lab:

1) How does lobsters' prey selection change as they progress through their early life stages?
2) What are the underlying mechanisms influencing these changes in prey selection?

Methods

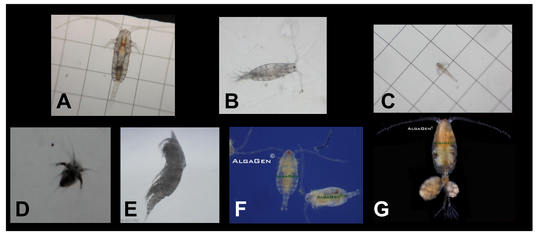

Figure 1. Images depicting the prey species used in feeding trials. A) *Calanus fimarchicus*. B) *Acartia*. C) *Artemia*. D) Barnacle nauplii. E) *Euterpina*, Photo courtesy of Scripps Institution of Oceanography. F) *Parvocalanus*, Photo courtesy of AlgaGen LLC. G) *Pseudodiaptomus*, Photo courtesy of AlganGen LLC.

- Feeding experiments (single lobster per trial)
  - 7 prey species of variable size and swimming ability:

Prey Species	Average Prey Size	Swimming Speed	Escape Response
Euterpina (copepodites and nauplii)	0.1 - 0.2 mm	Slow	Slow
Parvocalanus	0.2 - 0.4 m	Fast	Rapid
Artemia salina	0. 75 mm	Slow	Slow
Barnacle nauplii	1.0 mm	Slow	Slow
Acartia	1 mm	Fast	Rapid
Pseudodiaptomus	1.5 um	Fast	Rapid
Calanus finmarchicus	2 - 4 mm	Slow-Moderate	Rapid

  - Prey concentrations: 5/L, 10/L, 20/L, 50/L
  - Run for 6 hours at 16 °C in dark room
- Behavioral experiments
  - Tethered lobster (single lobster per trial)
    - Handling time and fine-scale feeding behavior
  - Free-swimming lobsters (multiple lobsters per trial)
    - Analysis in ImageJ
    - Pursuit time, swimming speed, net to gross displacement ratios

Results

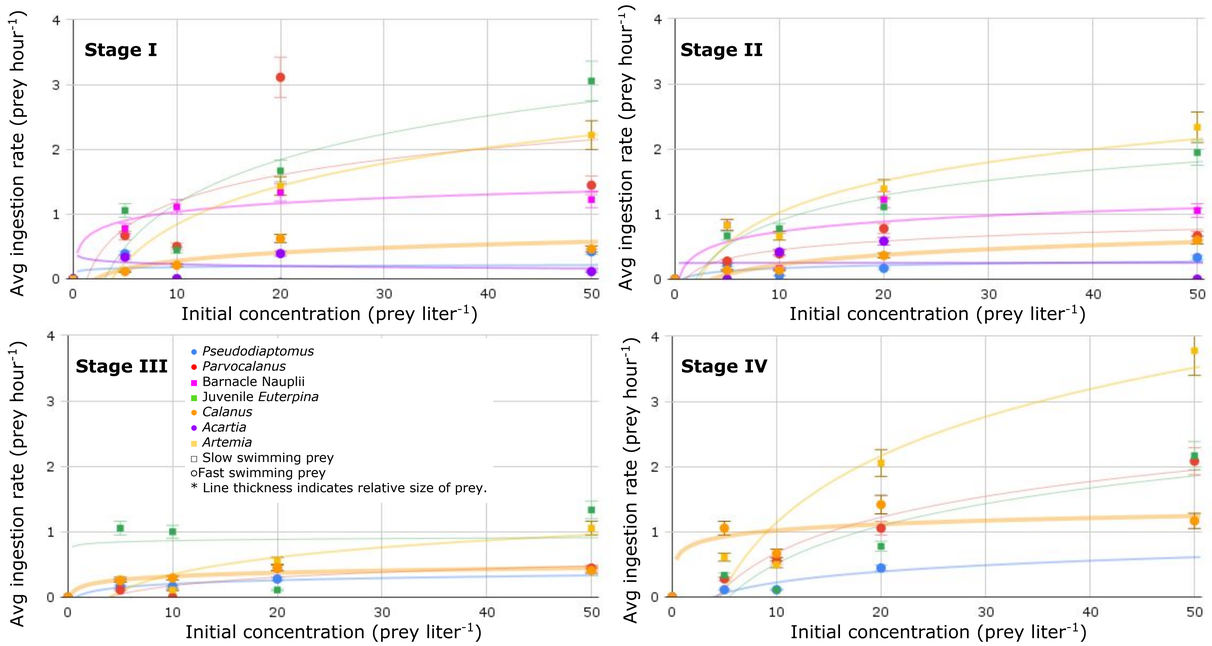

Figure 2. Average ingestion rates of early stage lobsters on prey items of different sizes and swimming speeds. Error bars indicate a margin of error of +/-10 percent. Higher ingestion of slow swimming prey (indicated by squares) in stages one through three. Similar ingestion rates by stages one and two larvae, with a drop in ingestion during stage three. Increased ingestion by stage four postlarvae on *Calanus finmarchicus* compared to earlier stages.

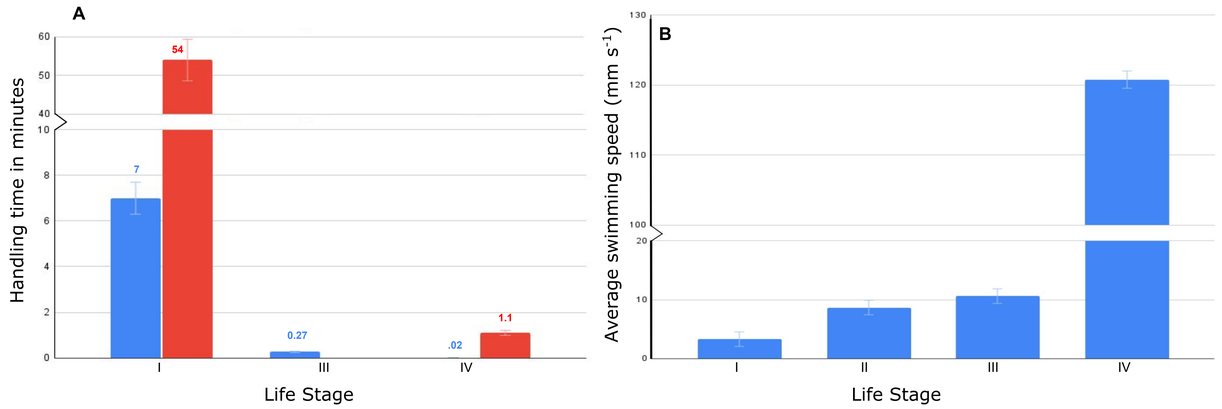

Figure 3. A) Handling time in minutes for two prey species, *Artemia* and *Calanus finmarchicus*. B) Average swimming speed of early stage lobsters gathered from behavioral experiments. Error bars indicate a margin of error of +/-10 percent. Significant decrease in handling time from stage I to stage IV for both *Artemia* and *Calanus*. Steady increase in swimming speeds between stages I and III (3.3 mm/s to 10.6 mm/s), with rapid increase in stage IV (120.8 mm/s or 12.08 cm/s).

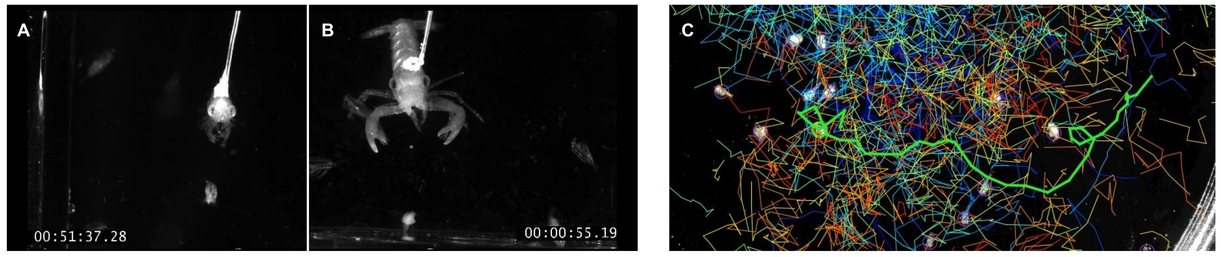

Figure 4. A) Stage I larva feeding on *Calanus* in tethered trial. B) Stage IV postlarva feeding on *Calanus* in tethered trial . C) Tracked path of free swimming stage I lobster larvae in ImageJ analysis software.

Discussion

- Early larval stages exhibit a preference for smaller and slower swimming prey items, which are captured and consumed more quickly.
- Stage IV postlarvae are significantly faster swimmers and are able to handle the same prey 40 to 50 times more efficiently than stage I larvae.
- Ecological benefits of reduced handling times:
  - Increase the amount of time a lobster is able to search for additional prey
  - Increase the amount a lobster can consume in a given amount of time
  - Decrease the amount of time it spends in a more vulnerable feeding state, potentially reducing predation risk
- Ecological benefits of increased swimming speeds:
  - Enable a lobster to capture faster prey items
  - Increase encounter rates by allowing the lobster to search greater volumes of water in a given amount of time

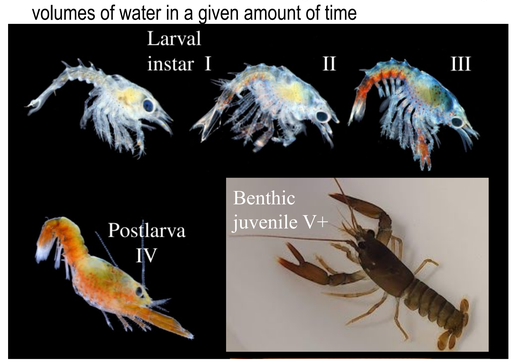

Figure 5. Photos of early stage lobsters (I - IV) taken by Jes Waller. Photo of benthic juvenile taken by Evie Layland.

Next Steps and Broader Impacts

- Continue video analyses of larval swimming behaviors
- Begin analysis of prey swimming behaviors
- Compare selected prey species with other common species in the Gulf of Maine on the basis of size and swimming ability

- Greater understanding of how lobster larvae interact with their environment during their early planktonic stages
  - increased knowledge of larval lobster feeding habits and prey handling ability
  - Better understanding of how lobsters may be impacted by climate driven changes in prey availability

References and Acknowledgements

Carloni, J.T., Wahle, R.A., Geoghegan, P., & Bjorkstedt, E. (2018). Bridging the spawner-recruit disconnect: trends in American lobster recruitment linked to the pelagic food web. Bulletin of Marine Science. 94(3), 719-735. https://doi.org/10.1002/edn3.41

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