Associations between hyperiid amphipods and gelatinous zooplankton

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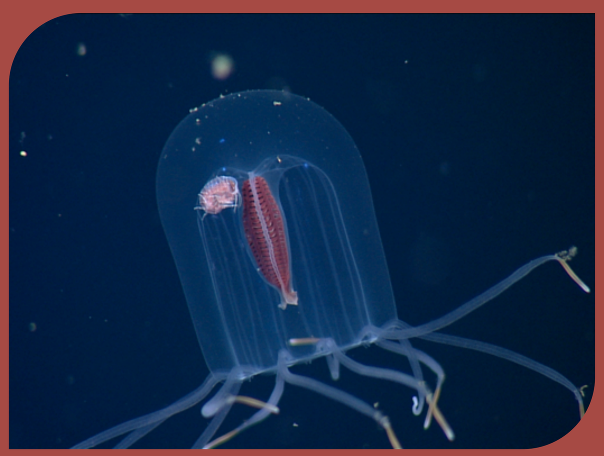


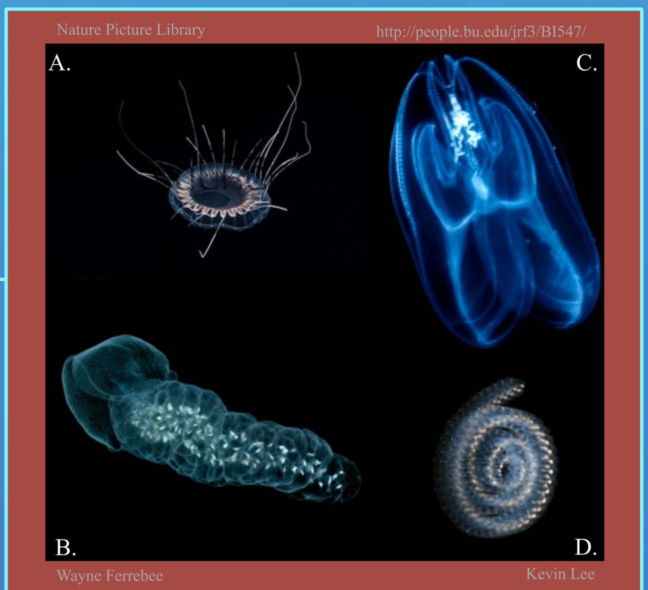
Hyperia sp. dorsally attached by fifth through seventh pereopods to the underside of a calycopsid medusa's bell

Introduction

Project Goal:
Identify associations between hyperiid amphipods and gelatinous zooplankton to examine specificity of host selection and interaction. Ultimately, this information will be used to better understand how hyperiid morphology relates to these associations.

Hyperiid amphipods are a diverse group of small pelagic marine crustaceans[1]. Suggested to have benthic ancestors, hyperiids have developed specializations to survive in the water column. These adaptations allow hyperiids to create a benthic-like existence by living on and within gelatinous zooplankton (salps, ctenophores, medusas, etc.)[3].

In many cases hyperiids do not merely live on the zooplankton, but use them for protection, feed on portions of their host, secure eggs in the host's tissues, and share food collected by the host[2]. Assessing the specificity of interactions between hyperiids and their hosts is necessary in understanding hyperiid evolution, reproduction, and behavior[4].



Common hosts of hyperiids
A. Medusa **C.** Ctenophore
B. Siphonophore **D.** Salp

Methods

I reviewed a target dataset of remotely operated vehicle *in situ* footage from Monterey Bay Aquarium Research Institute's (MBARI) video archives. MBARI's technicians searched the Video Annotation Reference System (VARS), a program created at MBARI, for amphipod associations and received 3586 video clips. We prioritized video observation data returned from the query of the VARS database for behavioral and taxonomic review based on the quality of the video clip (camera zoom, time spent). Orientation and location on host, number of hyperiids per host, damage to host, and any additional behaviors were noted for each reviewed video observation. In total, I reviewed 277 video clips of hyperiids and their gelatinous hosts. These videos were taken by the remotely operated vehicles (ROV) *Doc Ricketts, Tiburon , and Ventana,* (see below) from surface waters to depths of 3500m worldwide between 1989 and 2013.

Also, I sorted through 99 directly collected (blue-water SCUBA, submersibles, remotely operated vehicles) gelatinous specimen in the Smithsonian Institute's Invertebrate Zoology collection to locate and identify hyperiids associated with salps, pyrosomes, medusae, and siphonophores.

Identifying collected hyperiids

Ventana, a remotely operated vehicle

Results

ROV footage:

- 90 of 600 observations of associations were hyperiids with the medusa *Solmissus*, making it the most common host in this data set. Hyperiids ate holes larger than their body size into their *Solmissus* hosts, insinuating that *Solmissus* is a substantial food source for hyperiids
- On average, the ctenophore *Hormiphora* had the highest infestation rate (4 per individual, maximum = 17). Hyperiids were exclusively found attaching to the *Hormiphora*'s comb rows with visible damage to comb rows in all 11 observations.
- 175 of 425 identifiable hyperiids (41%) were attached to internal structures of the host opposed to the more common attachment to external structures.
- Only 1 (Hyperiidae) of 11 taxonomically identifiable hyperiid families from the video footage is described in literature to attach with their dorsum toward the host by extending their pereopods behind their body[5]. However, 3 of the 11 families (Scinidae, Lanceolidae, and Hyperiidae) were seen exhibiting this behavior in the footage. 199 of 257 identifiable hyperiids (77%) were seen attached facing away from their host in this resting pose, opposed to facing the attachment site.
- *Phronima*, a well known obligate symbiont of salps[3], was the most identified free-swimming hyperiid (17 observations). However, 35 of 52 observed *Phronima sp.* were associated exclusively with *Salpida* and *Pyrosoma* (67%) opposed to freely swimming, confirming the ideology that hyperiids are primarily if not entirely parasitic in nature[3].

Laboratory:

- We found 3 *Vibilia sp.* and 1 pronoid in a single jar of *Salpa sp.* Since we sorted through 99 jars in the preserved gelatinous collection and found so few hyperiids, we speculate that the museum's sorting center removed amphipods from the gelata prior to inspection.

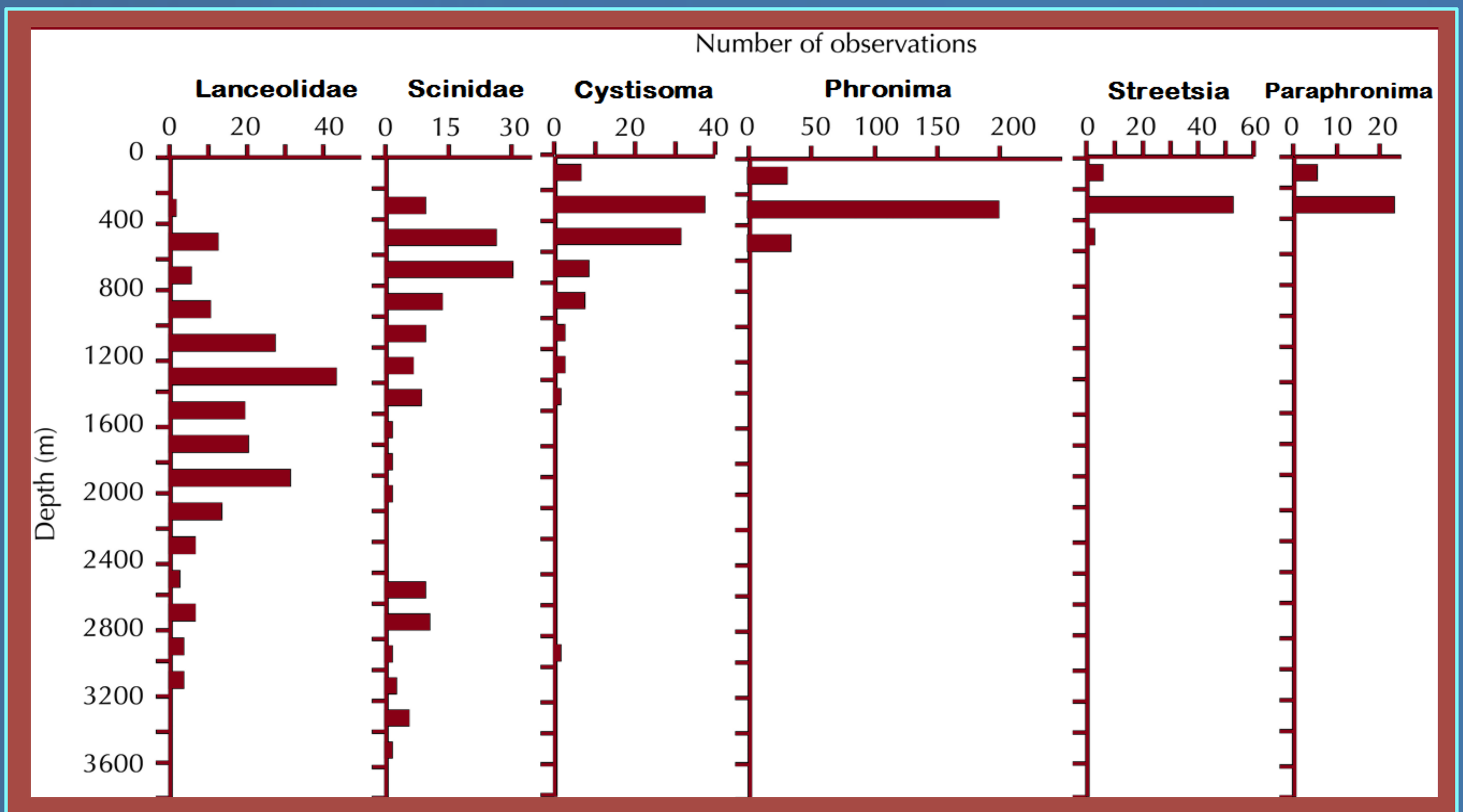
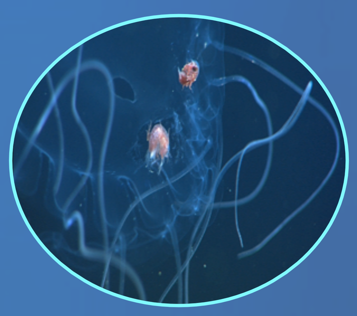
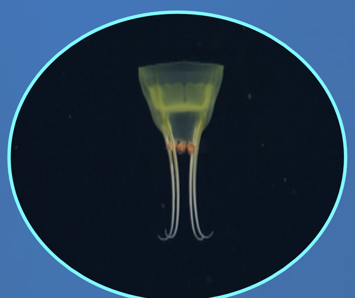


Figure 1. The depth distribution of hyperiids from ROV footage
Since hyperiids are believed to be symbionts with gelata at least once in their life (secured to host at birth)[3], defining their depth distribution is vital for understanding host selection



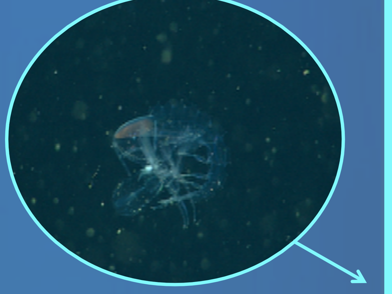
2 hyperiids eating the stomach pouches of a *Solmissus*



3 hyperiids on the bell of an *Aegina citrea*

A highly parasitized *Hormiphora* by hyperiids of similar life stages

A large hyperiid attached to the underside of an *Aegina*'s bell



Cystisoma parasitizing a *Hormiphora* smaller than itself

Hyperiid attached to the bell margin of a *Cunina*

Glossocephalus parasitizing the comb rows of a *Beroe gracilis*

Phronima living in a salp barrel while feeding on a *Pyrosoma*

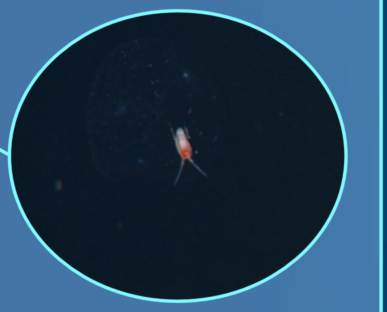
Scina facing away from its *Frillagalma vityazi* host

Table 1. Hyperiid and gelata associations discovered in MBARI's ROV footage that have not been previously identified in scientific literature
(M) = Medusa (C)= Ctenophore
(Sa)=Salp (Si)=Siphonophore

Hyperiid	Host Gelata
Cystisoma sp.	*Aegina citrea* (M)
--	*Hormiphora* (C)
Glossocephalus sp.	*Bathocyroe* (C)
--	*Beroe gracilis* (C)
Hyperia sp.	*Hormiphora californiensis* (C)
Hyperia medusarum	*Solmissus* (M)
Iulopis sp.	*Aegina citrea* (M)
Scina sp.	*Bathocyroe* (C)
--	*Demophyes haematogaster* (Si)
--	*Frillagalma vityazi* (Sa)
--	*Eutonina indicans* (M)
--	Indescribed siphonophore sp. 1 (Si)
--	*Haliscera conica* (C)
--	*Kiyohimea usagi* (C)
--	*Lampocteis* (C)
--	*Prayinae* (S)
--	*Solmissus* (M)
--	*Thalassocalyce inconstans* (C)
Streetsia sp.	*Thalassocalyce inconstans* (C)
Lanceolidae	*Chromatonema* (C)
--	*Periphyllopsis* (M)
Scinidae	Halicreatidae (M)

Glossocephalus utilizing its pereopods to hold onto the lobe of a *Bathocyroe*

Scina holding onto the bell margin of a *Haliscera conica*



Scina externally attached to a *Prayinae*

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Literature Cited

[1] Bowman, T. E. & H.-E. Gruner, 1973. The families and genera of Hyperiidea (Crustacea: Amphipoda). Smithsonian Contributions to Zoology 146: 1–64.
[2] Gasca, R., & S. Haddock, 2004. Associations between gelatinous zooplankton and hyperiid amphipods(Crustacea: Peracarida) in the Gulf of California. Hydrobiologia 530/531: 529–535.
[3] Laval, P., 1980. Hyperiid amphipods as crustacean parasitoids associated with gelatinous zooplankton. Oceanography and Marine Biology Annual Review 18: 11–56.
[4] Harbison, G. R., D. C. Biggs, & L. P. Madin, L. P., 1977. The associations of Amphipoda Hyperiidea with gelatinous zooplankton – II. Associations with Cnidaria, Ctenophora, and Radiolaria. Deep-Sea Research 24: 465-488.
[5] Vinogradov ME, AF Volkov, TN Semenova. 1996. Hyperiid amphipods (Amphipoda, Hyperiidea) of the world oceans. Lebanon, USA: Science Publishers, Inc., pp. 1-632.

Conclusions

- Knowledge of hyperiid and gelatinous zooplankton associations progressed immensely with the invention of ways to directly observe these interactions (blue-water SCUBA, submersibles, ROVs) because collection in nets disrupts the associations[2]. Identification beyond genus or family level is generally not possible from video footage alone. Video observations are still useful additions to our understanding of hyperiid associations because they allow us to observe methods of attachment, number of parasites per host, and depth of the associations.
- Knowing hyperiid depth distribution can help us infer potential host species due to zooplankton's tendency to occupy a specific depth range (Fig. 2).
- Overall, we were able to identify 22 new hyperiid/gelata symbioses, define the depth distribution of 6 hyperiid groups, and describe specific behaviors such as method of attachment which helps us understand the nature of these relationships.

Future Endeavors:

- Further describe the specificity of hyperiid and gelata associations, noting the depths at which they occur
- Analyze hyperiid morphology to determine the factors that play a role in host selection

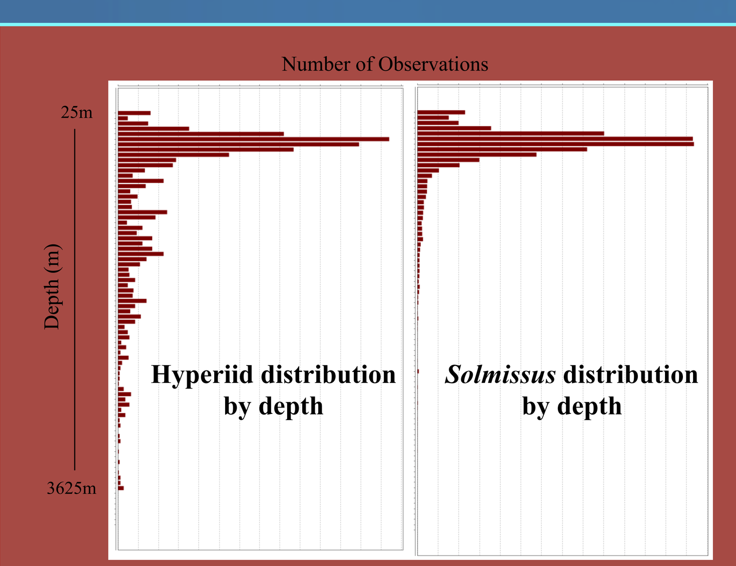

Figure 2. The comparison of depth distributions of the most common association (*Solmissus*) found in results portrays that hyperiids can be found where their hosts reside