

Final Report

Title of Project: Alterations of Lake Michigan benthic communities by the invasive colonial hydroid, *Cordylophora caspia*: effects on fish prey.

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Abstract – *Cordylophora caspia* is an invasive Ponto-Caspian colonial hydroid that appears to be expanding its range in southern Lake Michigan. Although little is known about the distribution and ecological effects of this benthic hydroid, their predatory feeding behavior on invertebrates raises concern as to their effect on food availability for benthivorous fishes. This project examined the distribution, feeding habits, and diets of *C. caspia* through a series of field surveys and laboratory experiments. The distribution of *C. caspia* is strongly associated with the presence of hard substrates in southern Lake Michigan harbors (piers and pilings) and offshore wrecks. Diets of field-collected *C. caspia* vary seasonally and consist primarily of dreissenid mussel veligers, small chironomids, and planktonic crustaceans, primarily cladocerans. Laboratory feeding experiments revealed that although *C. caspia* does not capture or ingest nematodes, they

are successful at capturing and ingesting chironomids and cladocerans. The ability for *C. caspia* to ingest these prey items is largely determined by prey body size and orientation of prey upon capture. In addition, *C. caspia* hydranths within a colony exhibit colony cooperation when more than one hydranth is successful in capturing a given prey item. Results from this study demonstrate that *C. caspia* has the potential to indirectly interact with benthic feeding fishes by sharing common food resources, however the presently restricted distribution of *C. caspia* likely minimizes these effects.

Introduction

The goals of this project were to determine the distribution of the invasive, Ponto-Caspian colonial hydroid, *Cordylophora caspia*, in southern Lake Michigan and to assess its potential impact on benthic macroinvertebrate communities. Because *C. caspia* is a benthic predator, results from our project will provide valuable insights as to how the presence of this invader will influence prey availability for benthivorous fishes. This project had three major objectives: (1) to document the locations and diets of *C. caspia* in southern Lake Michigan, (2) to assess the feeding habits of *C. caspia*, and (3) to determine whether the distribution of *C. caspia* is related to the presence of *Dreissena polymorpha* or *D. bugensis* as substrates.

Narrative Report

Objective 1 – Distribution and diets of *C. caspia* in southern Lake Michigan

Methods

Surveys for *C. caspia* were conducted by divers using SCUBA at six offshore sites to assess the distribution of the invasive hydroid in Lake Michigan. In addition, 2-4

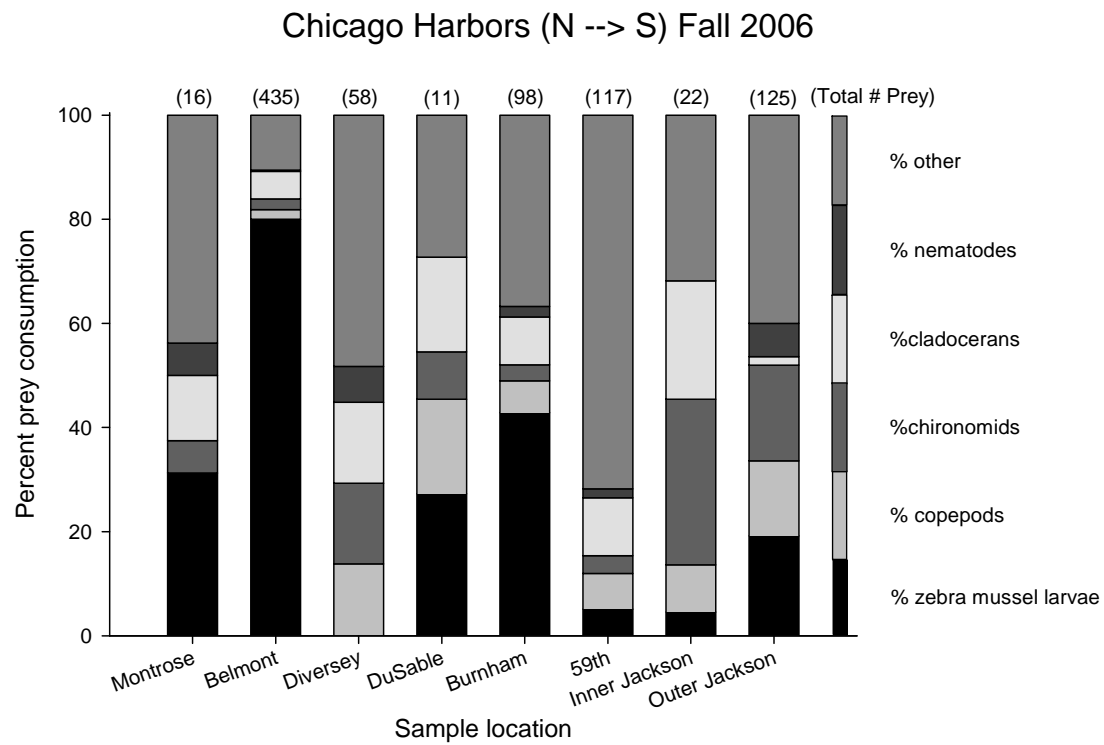
samples were collected from 8 of the 9 harbors in Chicago (Montrose, Belmont, Diversey, DuSable, Burnham, 59th Street, Inner Jackson, Outer Jackson) in 2006 and 2007.

Hydroids were found at 2 of the 6 offshore sites and at all 8 harbors, though colonies were more prevalent at some harbors compared to others.

For each sample, 200 polyps were dissected and processed for gut analyses to determine the prey consumed by *C. caspia*. Prey were identified to the lowest possible taxonomic level. Although our initial intent was to identify prey to the genus level because of genus-specific differences in functional habit types (sprawling, climbing, burrowing, etc.) that would provide valuable information on prey acquisition and the feeding process of *C. caspia*, this was not always possible. Large chironomid larvae could be identified to the genus level, however because of their small size, early instar larvae could only be reliably identified to the subfamily level as could partial larvae.

Results

Our analyses found strong differences between harbors with respect to prey consumed (Figure 1). *Cordylophora caspia* from harbors with predominantly mud substrates, i.e., the two most southern harbors, Inner and Outer Jackson harbors, had a higher percentage of chironomids, however a general pattern was observed with zebra mussel larvae representing the majority of prey items (Figure 2).



Location	# of Samples	Total # Prey	# of Hydranths w/ Prey	Total Hydranths Dissected	Percentage of Hydranths with Prey
Montrose	1	16	13.0	100.0	13.0
Belmont	3	435	230.0	601.0	38.3
Diversey	3	58	51.0	602.0	8.5
DuSable	2	11	10.0	201.0	5.0
Burnham	3	98	92.0	611.0	15.1
59th	4	117	97.0	814.0	11.9
Inner Jack	2	22	19.0	95.0	20.0
Outer Jack	2	125	84.0	400.0	21.0

Figure 1. Percentage of prey types in the guts of *Cordylophora caspia* collected from Chicago harbors.

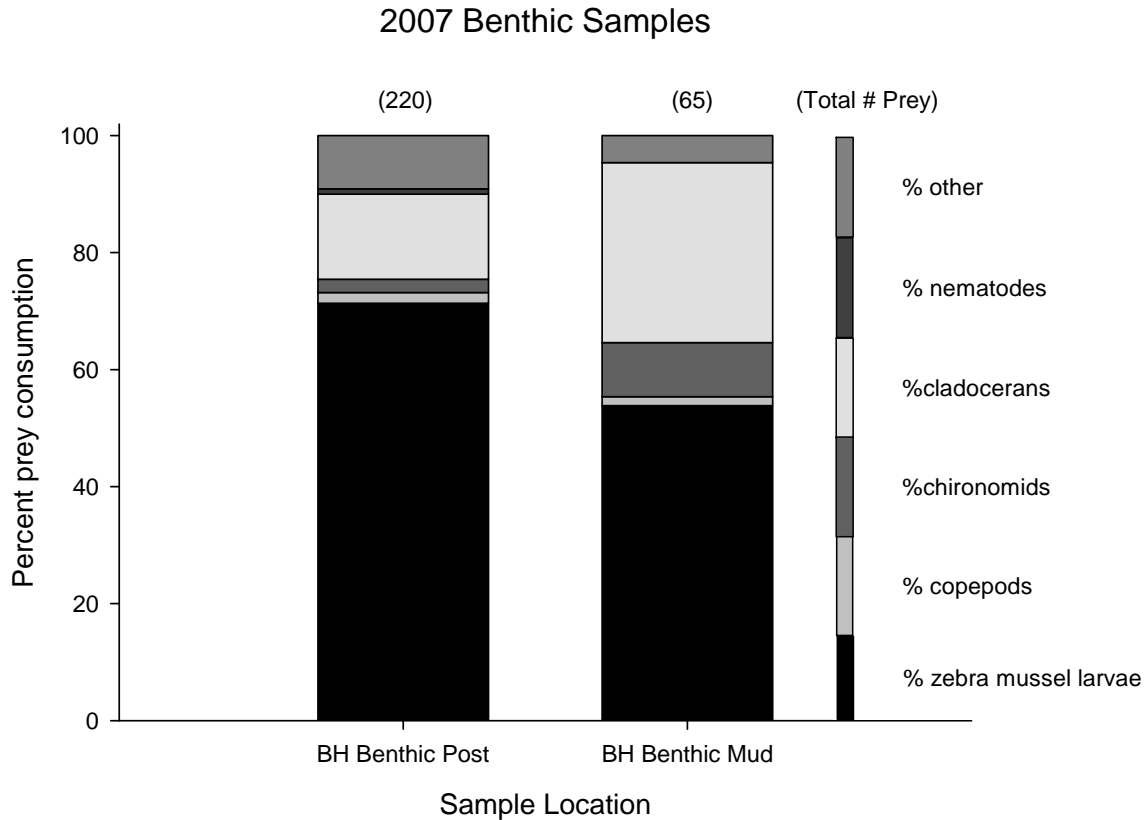


Figure 2. Diets of *Cordylophora caspia* from Burnham Harbor, July 2007.

Objective 2 - Feeding Habits of *C. caspia*

The feeding habits of *C. caspia* were examined in a series of laboratory experiments using three taxa of invertebrate prey that represent potential prey types available to nearshore benthivorous fish.

Methods

All hydroid colonies were taken from lab cultures of *Cordylophora caspia* collected from Lake Michigan. *Cordylophora* uprights with 4-6 hydranths (unless otherwise noted) were strung on individual 2.5 x 2.5 cm glass slides. This slide size allowed for the placement of colonies in small mesh containers for feeding observations. Slides were placed with colonies positioned downward, in modified slide trays and

maintained in five-gallon aquaria. Unless otherwise noted, the colonies were starved for 3 days prior to each experiment. Each colony was used once in a feeding trial.

Laboratory cultured *Artemia* were used both for maintaining the *Cordylophora* cultures and for the preliminary observations of feeding behavior.

The experiments were run using *Daphnia magna*, nematodes, and chironomid larvae as prey. Because *Bosmina* specimens, the most common cladoceran prey item of *Cordylophora* (field gut analysis, personal observation), were not readily available for purchase, *D. magna* were chosen as a substitute. *Daphnia magna*, which is similar to *Bosmina* in both size and morphology, was purchased from Carolina Biological Supply (Burlington, NC). A culture of soil nematodes containing a mixture of several different species was obtained from Ward's Natural Science (Rochester, NY). *Chironomus tentans*, a representative species of chironomid larvae, was obtained from Aquatic Bio Systems (Fort Collins, CO) in the form of egg cases and second instar larvae.

Toby Teaboys[®] were used as experimental containers to ensure contact between prey and hydroid colonies in each experiment. Toby Teaboys[®] are small plastic baskets lined with 224- μ m polyester mesh. The teaboys were purchased from the Plymouth Tea Company in Maine. All water used to culture organisms and conduct experiments was obtained from Lake Michigan and filtered through 53 μ m mesh netting.

Results

Preliminary Observations of Feeding Behavior

Preliminary observations of non-feeding hydranths and feeding behavior were made so that feeding responses could be quantified in subsequent feeding trials. The range and frequency of hydranth and tentacle movement of 28 *C. caspia* were observed.

Colonies were starved for 1-5 days before each observational period to determine the ideal starvation period for use in later experiments. Colonies were observed immediately after being removed from culture tanks and after a 15 min acclimation period to ensure that hydranths were in a resting state. Colonies were observed for 15 min and all hydranth movements were recorded. After the initial 15 min period, *Artemia* were introduced to the colonies to confirm feeding capabilities and any resulting hydranth responses were recorded.

Observations from these preliminary experiments indicated that a starvation period of 3 d was optimal and that a period of acclimation after being removed from the culture tanks was sufficient for colonies to be in a state of rest for subsequent feeding experiments.

Nematode Experiments

Ten colonies of *C. caspia* were acclimated for 15 min in separate containers of standing water after which they were placed in individual Toby Teaboy[®] in glass pudding bowls filled with a minimal amount of filtered Lake Michigan water. This experiment used colonies with 2-10 hydranths/colony. Thirty nematodes of varying sizes and genera were added to each of these Toby Teaboy[®] and colonies were observed continuously for 20 min. Each observed encounter, capture, and ingestion were noted. At the end of the trial, colonies that had captured or ingested nematodes were preserved in 75% alcohol for later dissection. Colonies that did not capture nematodes were fed *Artemia* to confirm that they were capable of capturing prey.

Daphnia Experiments

Cordylophora caspia colonies were acclimated for 15 min in separate containers

of standing water and were then placed in individual teaboyes as described for the nematode feeding experiments. Two trials that differed only in the length of the observational period were conducted using *Daphnia magna* as prey. Preliminary observations showed that only 5 *Daphnia* should be introduced to each colony. In the first trial, ten *C. caspia* colonies were observed for 30 min after introducing 5 *Daphnia* (mean length=1545.8 μm , n=10, SD=141.3) to each colony. Similarly, in a second trial, 10 colonies were exposed to 5 *Daphnia* each (mean length=1286.3 μm , n=20, SD=196.9) for 60 min. The observational period was extended for the second trial to ensure ample opportunity for the hydroid to capture *Daphnia* because few were captured in the first trial. During both trials, each colony was checked at 5 min intervals and all observed encounters, captures, and ingestions were noted. After the observational time had elapsed, colonies that had not captured or ingested *Daphnia* were discarded. Colonies that had one or more *Daphnia* attached to tentacles were kept alive until the *Daphnia* had been either ingested or dropped. These colonies, along with those that had ingested *Daphnia*, were then preserved in 75% alcohol for later dissection to determine exact prey size.

Chironomid Experiments

Feeding trials using chironomids were conducted in a similar fashion to the experiments using nematodes and *Daphnia* as prey. For each trial 1-5 chironomids were introduced to each *Cordylophora* colony. Chironomids were separated into small, medium and large size classes to test the upper limits of *Cordylophora*'s ability to capture and ingest prey (Table 1). Small chironomids (mean length=1186.5 μm , n=116, SD=150.5) were first instar larvae, whereas medium (mean length=5409.8 μm , n=29,

SD=1185.6) and large (mean length=8096.8 μm , n=14, SD=1509.0) were a combination of second and third instar larvae.

Because chironomids are benthic and rarely swim, 3 types of trials were performed to ensure that contact occurred (Table 1). Three different preliminary trials were performed to determine the ideal prey density to use for the medium and large chironomid class trials (2-4 chironomids). For the actual feeding experiments, indirect trials consisted of introducing chironomids to the Teaboy without directing prey to the *Cordylophora* colony. In the direct trials chironomids were introduced directly into the tentacles of at least one hydranth using a pipette. In the indirect-direct trials chironomids were initially introduced to the Teaboy without being directed to the *Cordylophora* colony. After a period of time (medium: 35-45 min, large: 20 min), due to a lack of interaction, the chironomids were directly placed in the tentacles of a hydranth and observed periodically for 5-6 hours.

Table 1. Summary of experimental protocol used for chironomid experiments.

	Colonies used	Chironomids / Teaboy	Observation Period
Small			
Indirect	20	5	60 mins
Direct	20	1	until ingestion
Medium			
1 st indirect preliminary	2	2	60 mins
2 nd indirect preliminary	2	4	60 mins
Indirect	12	2	60 mins
Indirect-direct	5	1	35-45 mins (indirect); 5hr (direct)
Large			
Indirect-direct	8	2	20 mins (indirect); 6 hr (direct)

Results

Preliminary Observations of Feeding Behavior

Hydranths exhibited extensive tentacle movement after removal from the culture tank. However, the tentacles were much less active when they had been acclimated in a separate container with no water movement for 15 min prior to observation. The amount of movement that any given colony exhibited also appeared to be dependent on the length of time the colony had been starved. Colonies starved for 1 d moved relatively little, as did colonies starved for 5 d. Based on these preliminary observations, we chose to conduct the feeding experiments with colonies that had been starved for 3 d and acclimated for fifteen minutes before experimentation.

Nematode Experiments

All hydranths of the 10 colonies used were dissected and found to contain no nematodes in the guts. Of the 10 colonies, 3 colonies had a single hydranth capture a single nematode. However, no ingestion occurred. Observations made during feeding trials indicated that the nematodes were able to swim freely through the tentacles of the hydroids without being captured. All colonies were able to successfully capture and ingest *Artemia* after the nematode experiments, indicating that they were capable of feeding. No further feeding experiments using nematodes were conducted due to the lack of ingestion.

Daphnia Experiments

Cordylophora colonies captured and ingested *Daphnia* in both trials (Table 2); however, many of the captured *Daphnia* were not ingested. This appeared to be a

consequence of the hydranths' inability to fully envelop the prominent posterior spine of *Daphnia*. The hydranths experienced difficulty when attempting to ingest a *Daphnia* sideways because of the added length of the spine. In these cases, the hydranths released the prey. All of the ingested *Daphnia* were ingested anterior end first, supporting the suggestion that the posterior spine interfered with ingestion.

Table 2. The results for *Daphnia* captured and ingested by *Cordylophora* hydranths.

	Trial 1	Trial 2
Number of colonies used	N=10	N=10
Number of hydranths	N=49	N=43
Number of <i>Daphnia</i> used/colony	N=5	N=5
Number of <i>Daphnia</i> captured	N=8	N=6
Number of <i>Daphnia</i> ingested	N=3	N=2
Percentage of hydranths that captured a <i>Daphnia</i>	16 %	14 %
Percentage of hydranths that ingested a <i>Daphnia</i>	6 %	4.5 %

Chironomid Experiments

Small Chironomid Trials

All colonies in the direct feeding experiment using small chironomids ingested larvae within 10 mins. All captured chironomids were quickly ingested in the indirect trials as well. However, results from the indirect trials suggested that chironomid

behavior inhibited capture by hydranths. Only 6 of the 100 small chironomids indirectly introduced to colonies were captured. Observations from the indirect trials indicated that chironomids spent most of their time at the base of the colonies and rarely swam. This position kept them well away from the hydranths and thus they were not often captured.

Medium and Large Chironomid Trials

Experiments with second and third instar chironomids demonstrated that *Cordylophora* is capable of capturing and ingesting prey many times larger than the hydranths themselves (Table 3). This was often accomplished with colonial cooperation because capture by a single hydranth was usually insufficient to subdue and ingest large chironomids. Once chironomid contact was made with the hydranth, the chironomid would continue to thrash around and this often led to their subsequent capture by other hydranths in the colony. At this point, chironomid movement was limited, facilitating ingestion by two separate hydranths. The hydranths continued to engulf the chironomid and met in the middle of the chironomid. In some instances, the two hydranths absorbed haemolymph from the constricted chironomid.

Table 3. Chironomids captured and consumed by *Cordylophora* relative to size.

Chironomids were either directly introduced to make contact with hydranth tentacles or simply placed in Toby Teaboys[®] to see if contact between the tentacles and prey would occur.

Indirect Experiments		
	Small	Medium
Number of colonies used	20	12
Number of hydranths	95	51
Number of chironomids used/colony	5	2
Number chironomids captured	6	7
Number chironomids ingested	6	6
% hydranths partially ingesting chironomids	0	11.7
% hydranths entirely ingesting chironomids	6.3	0
% hydranths that captured a chironomid	6.3	17.6

Direct Experiments			
	Small	Medium	Large
Number of colonies used	20	5	8
Number of hydranths	95	23	34
Number of chironomids used/colony	1	1	2
Number chironomids captured	20	5	8
Number chironomids ingested	20	5	6
% hydranths partially ingesting chironomids	0	26.0	17.6
% hydranths entirely ingesting chironomids	21.0	4.3	0
% hydranths that captured a chironomid	21.0	52.1	64.7

Objective 3 – Relationship between *C. caspia* and dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*)

The progressive displacement of zebra mussels (*Dreissena polymorpha*) by congeneric quagga mussels (*D. bugensis*) in southern Lake Michigan has implications for the distribution of *C. caspia* because of the hydroids use of dreissenids as an attachment substrate. Zebra mussels require a hard substrate for attachment thereby limiting the distribution of zebra mussel-associated *C. caspia*. In contrast, quagga mussels can attach

to hard or soft substrates thus facilitating *C. caspia*'s ability for establishment in areas where they would otherwise be absent.

Results

Field surveys by divers using SCUBA confirmed that *D. bugensis* was the numerically dominant dreissenid taxon in most harbors (Figure 3). *Cordylophora caspia* was present on 55% of quagga mussels (Figure 4) and 46% of zebra mussels (Figure 5) in southern Lake Michigan harbors. The presence of *C. caspia* on quagga mussels was more uniform across all harbors than on zebra mussels, suggesting that the incidence of *C. caspia* likely will increase in southern Lake Michigan as quagga mussels continue to displace zebra mussels.

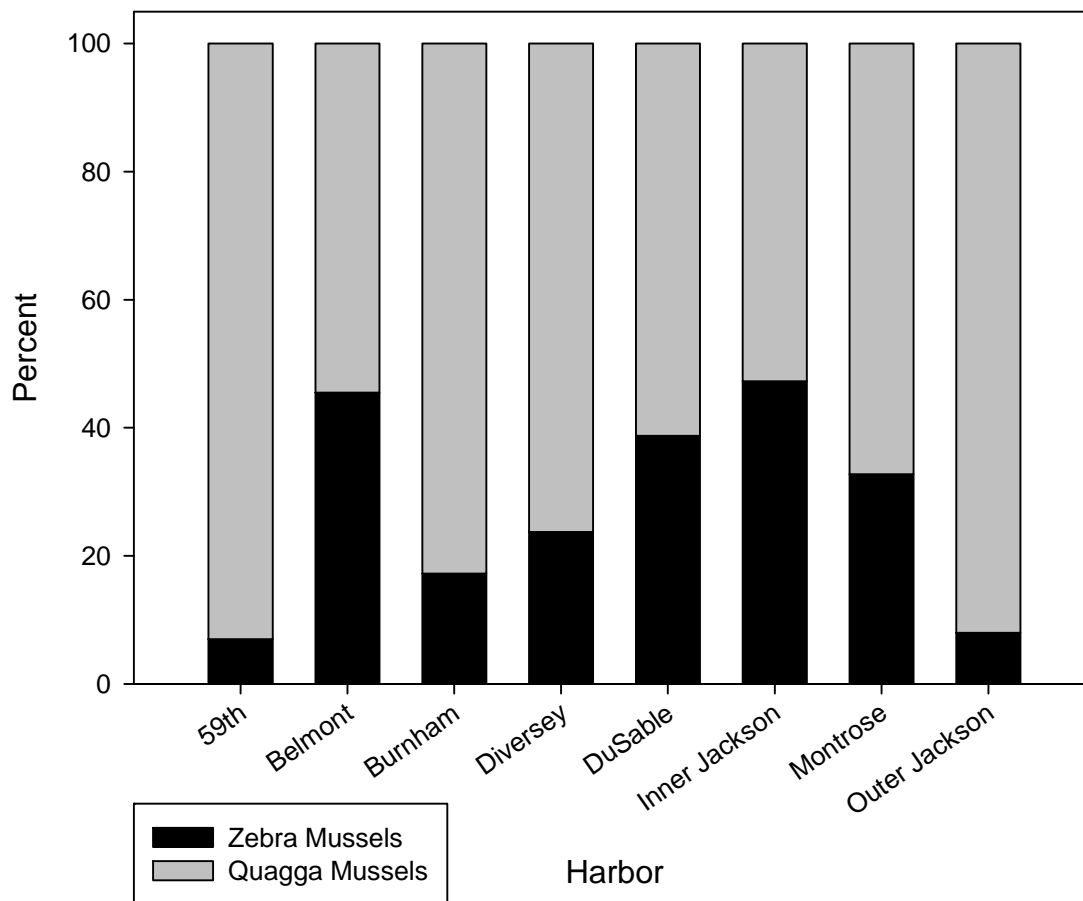


Figure 3. Relative abundance of zebra mussels (*Dreissena polymorpha*) and quagga mussels (*D. bugensis*) in southern Lake Michigan harbors.

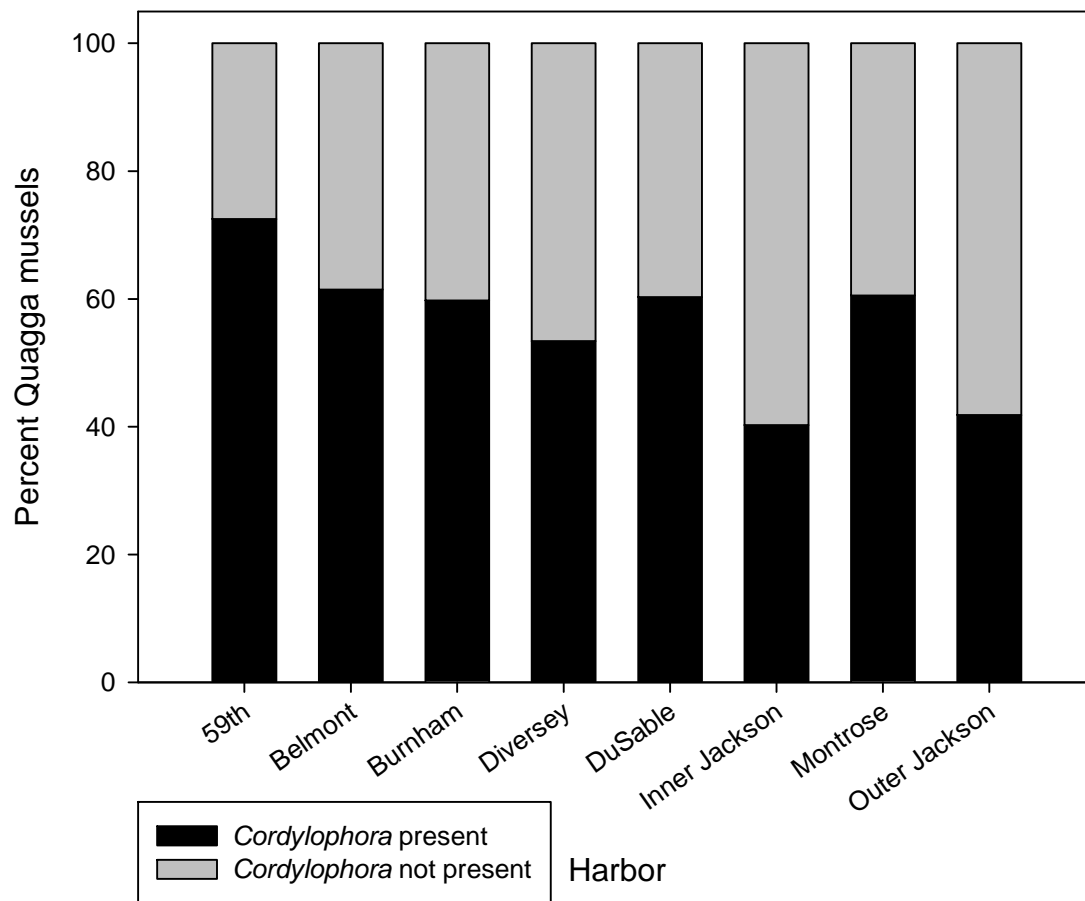


Figure 4. Relationship between *C. caspia* and quagga mussels (*D. bugensis*) in southern Lake Michigan harbors.

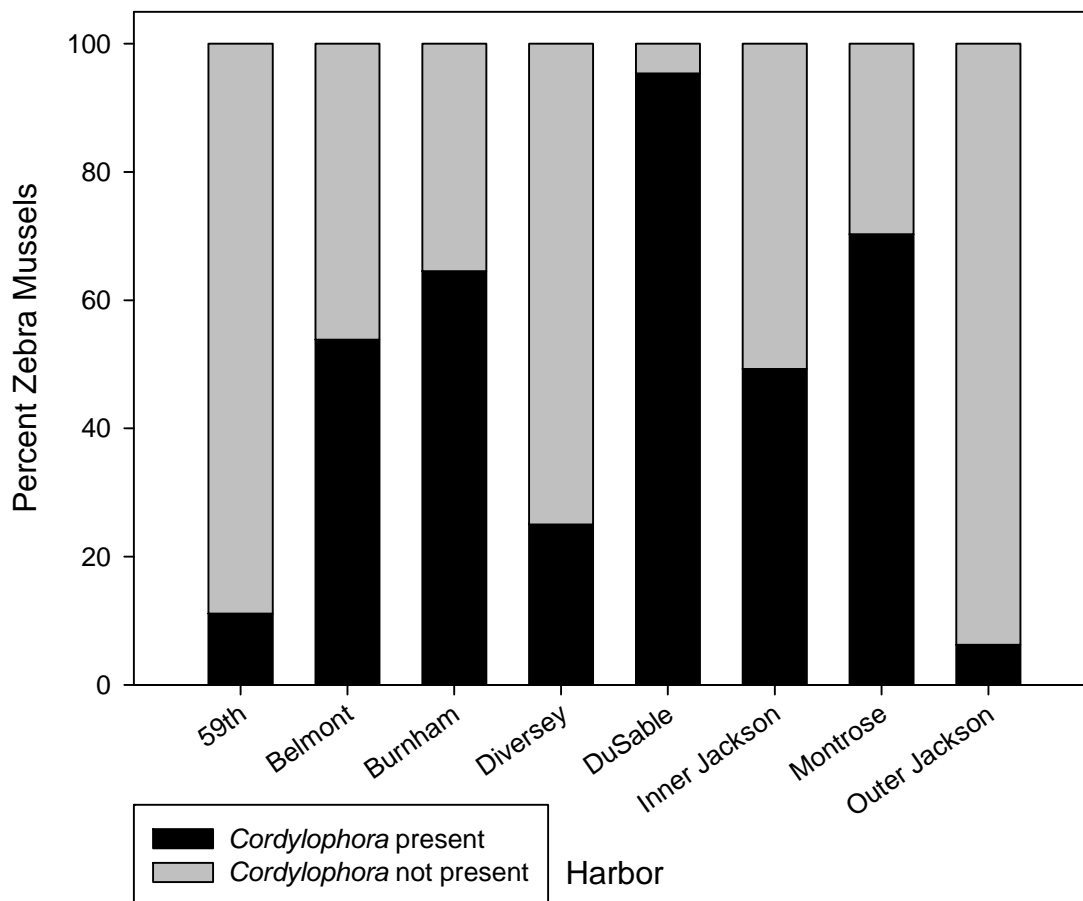


Figure 5. Relationship between *C. caspia* and zebra mussels (*D. polymorpha*) in southern Lake Michigan harbors.

Potential Applications or Benefits

Although the potential for *C. caspia* to impact fish food availability in southern Lake Michigan is low due to its presence in primarily harbor areas or on areas with hard substrates, the ability for *D. bugensis* to colonize soft substrates suggests that the impact on fish prey may increase as *D. bugensis* expands its range on a greater variety of substrates. These results have strong implications not just for southern Lake Michigan, but for other areas of the Great Lakes as well.

Keywords – Lake Michigan, invasive species, benthic invertebrates, predation, fish food availability

Lay Summary

The goal of this project was to assess the distribution and potential effects on fish prey of an invasive Ponto-Caspian colonial hydroid, *Cordylophora caspia*, in southern Lake Michigan. Although *C. caspia* has been present in low densities in Lake Michigan for many years, recent range expansion has raised concerns as to how their presence and predatory feeding on invertebrates may impact fish prey availability.

Field surveys indicate that *C. caspia* is restricted to hard substrates such as piers, docks, and submerged wrecks. Because *C. caspia* requires a hard substrate for attachment, we also addressed whether this invasive hydroid was more commonly found associated with quagga (*D. bugensis*) or zebra mussels (*D. polymorpha*), which represent an additional source of hard substrates in southern Lake Michigan. Our results suggest that *C. caspia* was more commonly associated with *D. bugensis* than *D. polymorpha*. In addition, the occurrence of *C. caspia* on *D. bugensis* was less variable among harbors compared to *D. polymorpha*.

Diets of field-collected *C. caspia* are comprised primarily of larval zebra and quagga mussels, however when those prey sources are not readily available, *C. caspia* can effectively feed on other invertebrates such as chironomid larvae and crustacean zooplankton, two important food resources for young-of-the-year and benthic fish. Laboratory feeding experiments confirmed the successful capture and consumption of these non-mussel food items. Overall results from this project demonstrate that *C. caspia* has the potential to influence prey availability for fish, however the extent of their impact

is strongly influenced by the availability of hard substrates, e.g., docks, pilings, wrecks, and dreissenid mussels, for attachment.

International Implications

Because zebra and quagga mussels are present in all the Great Lakes, the consequences of quagga mussel range expansion on fish food availability has implications for both U.S. and Canadian waters.

Media Coverage – n.a.

Partnerships – see Related Projects below

Publications and Presentations

- Folino-Rorem, N.C., M.J. Duggan, A. Parry Macdonald, E.K. Mindrebo, and M.B. Berg. 2009. Distribution and diet of the invasive Ponto-Caspian hydroid, *Cordylophora caspia*, in southern Lake Michigan: potential effects on fish prey availability. Accepted for presentation at the 57th Annual Meeting of the North American Benthological Society, 17-22 May, Grand Rapids, MI. (Poster).
- Folino-Rorem, N.C. 2008. Alterations of Lake Michigan benthic communities by the invasive colonial hydroid *Cordylophora caspia*: effects on fish prey. COSEE Great Lakes, Lake Michigan Exploration Workshop (for Teachers). Shedd Aquarium, Chicago, IL.
- Folino-Rorem, N.C. 2008. Ecological impacts of the invasive Ponto-Caspian hydroid *Cordylophora* in aquatic habitats. Wheaton College, Wheaton, IL.
- Berg, M.B. 2008. Impacts and control of aquatic invasive species: Great Lakes to Hawaii. Associated Colleges of the Chicago Area, Benedictine University, Lisle, Illinois.
- Folino-Rorem, N.C. and M.B. Berg. 2007. Impact of the invasive Ponto-Caspian hydroid, *Cordylophora caspia* on benthic macroinvertebrate communities in southern Lake Michigan: effects on fish prey availability. 15th International Conference on Aquatic Invasive Species, Nijmegen, The Netherlands.
- Folino-Rorem, N.C. 2007. Ecological impacts of the invasive Ponto-Caspian hydroid *Cordylophora* in aquatic habitats. University of New Hampshire, Durham, NH.
- Folino-Rorem, N. 2007. The impact of the invasive Ponto-Caspian hydroid *Cordylophora caspia* on macroinvertebrate communities. Hobart and William Smith College:

Finger Lakes Institute, Geneva, NY

- Folino-Rorem, N. 2007. Alterations of Lake Michigan benthic communities by the invasive colonial hydroid, *Cordylophora caspia*: effects on fish prey. Wheaton College Science Division Research Program. (Presentation and Poster).
- Duggan, M., E. Mindrebo, and N.C. Folino-Rorem. 2007. Alterations of Lake Michigan benthic communities by the invasive colonial hydroid, *Cordylophora caspia*: effects on fish prey Homecoming Weekend for Alumni, Administration and Peers. (Poster)
- Folino-Rorem, N. and M.B. Berg. 2007. The impact of the invasive Ponto-Caspian hydroid, *Cordylophora caspia*, on benthic macroinvertebrate communities in southern Lake Michigan: effects on fish prey availability. Fifteenth International Conference on Aquatic Invasive Species, Nijmegen, The Netherlands. (Poster)
- Folino-Rorem, N. 2006. Alterations of Lake Michigan benthic communities by the invasive colonial hydroid, *Cordylophora caspia*: effects on fish prey. Wheaton College Science Division Research Program. (Presentation and Poster).
- Papp, E., S. Wood, and N.C. Folino-Rorem. 2006. Alterations of Lake Michigan benthic communities by the invasive colonial hydroid, *Cordylophora caspia*: effects on fish prey Homecoming Weekend for Alumni, Administration and Peers. (Poster)

Undergraduate/Graduate Names and degree supported by grant

1. Nicole Furlan – senior – B.S., Loyola University Chicago – grant and matching funds support
2. Esther Papp – junior and senior – B.S., Wheaton College – grant and matching funds support
3. Stephen Wood – senior – B.S., Wheaton College – matching funds support
4. Tracey Harris – senior – B.S., Wheaton College – matching funds support
5. Matt Dugan – freshman, sophomore, junior – B.S., Wheaton College – grant support
6. Parry Macdonald – freshman, sophomore, junior – B.S., Wheaton College – grant support
7. Emily Mindrebo – sophomore, junior – B.S., Wheaton College – grant support

Related Projects

- 1) Distribution and population structure of the invasive hydrozoan *Cordylophora* in the Great Lakes
 - Collaborator: Dr. John A. Darling, US Environmental Protection Agency, Cincinnati, OH
 - Funds provided by EPA and Wheaton College

2) The Occurrence and Feeding Biology of the invasive hydroid *Cordylophora* in The Finger Lake, NY

- Collaborator: Dr. Meghan Brown, Hobart and William Smith Colleges; specialty in zooplankton ecology
- Funds for travel and meeting with collaborator provided by Wheaton College
- Folino-Rorem and Brown are planning a future collaboration that will parallel the currently funded IISG project by comparing the distribution and feeding biology of *Cordylophora* in the Finger Lakes of NY to that in Lake Michigan.
- Possible funding source for collaborative work: NY Sea Grant

Awards and Honors – n.a.

Patents/Licenses – n.a.