Invasive snails as potential and realized hosts for parasites in the Midwest

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Invasive species

- Over 120 billion dollars spent on invasive species each year
- Many species introductions are aquatic
- Over 50 species introduced in the Great Lakes

Hypophthalmichthys molitrix

Dreissena polymorpha

Invasive species and disease

- Invaders have been implicated in outbreaks of disease across a number of systems

- Mechanisms underlying the interaction
  - Complicated due to life cycles
  - Poorly understood
    - Distributions
    - Competency
    - Host and parasite life-history responses

- Enhance predictions of
  1) Disease persistence and spread
  2) Host responses (individuals and populations)

Invasive snails and disease

- Mollusks (including gastropods) are relatively common invaders
- Can generate issues due to interactions with free-living species

Invasive snails and disease

- Mollusks (including gastropods) are relatively common invaders
- Can generate issues due to interactions with free-living species
- Can cause problems through their transmission of macroparasitic organisms such as:
  - Nematodes
  - Trematodes

The Midwest's most wanted

Bithynia tentaculata

Cipangopaludina chinensis

Viviparus georgianus

Potamopyrgus antipodarum

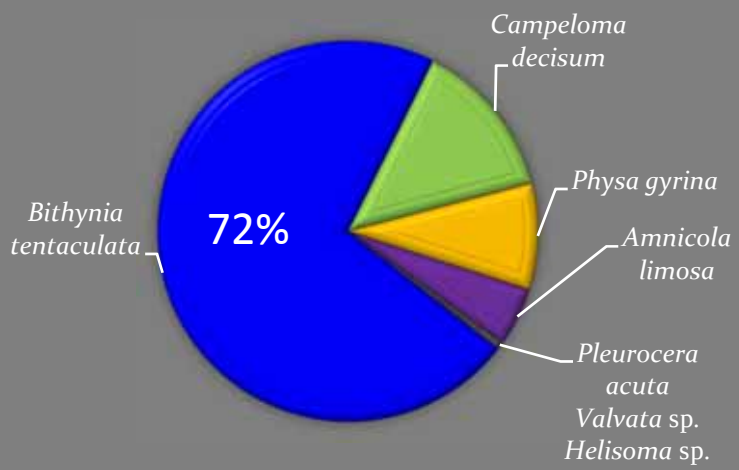
The Midwest's most wanted

Bithynia tentaculata

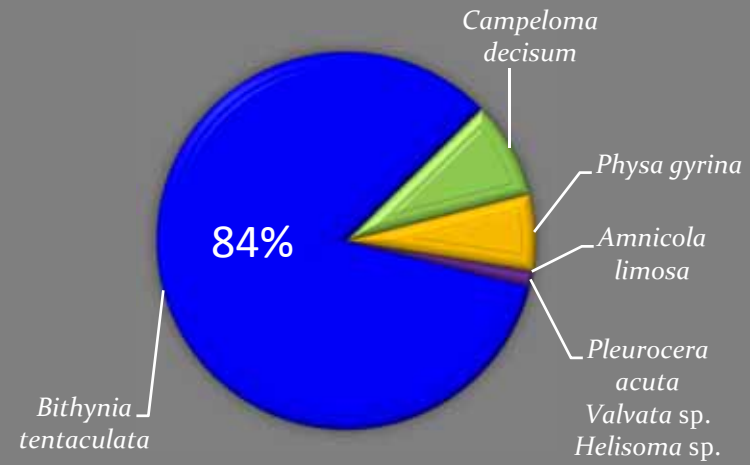
- Native of Europe
- Introduced into the Great Lakes in the 1880s
- Detected in the Mississippi in 2002
- Adults reach 12-15 mm in length
- ~3 year lifespan
- Disrupts the integrity of native aquatic communities

+

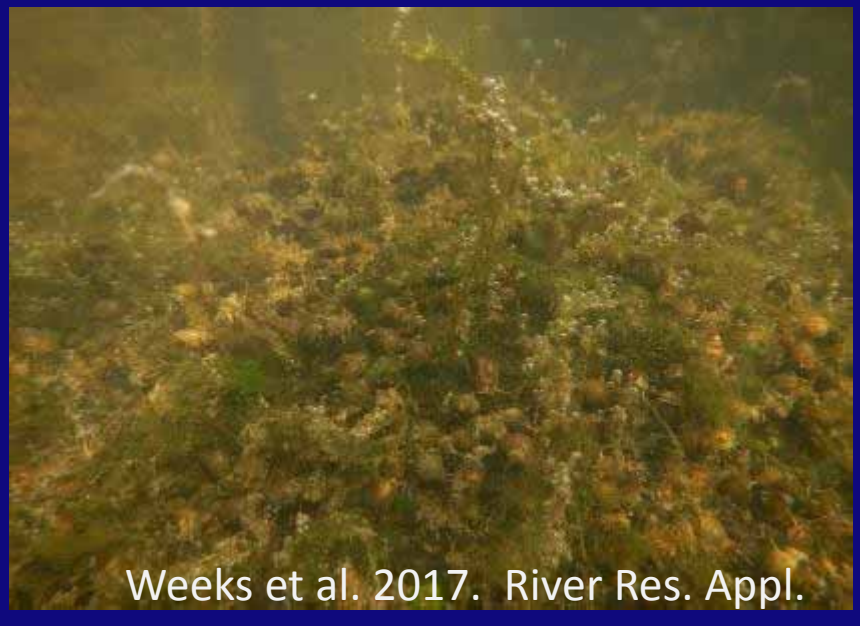
Results



Pool 7



Pool 8

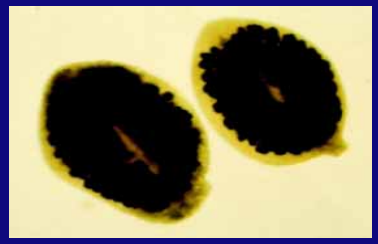


Weeks et al. 2017. River Res. Appl.

- Pool 8
  - May 20, 2016

And if that wasn't bad enough……

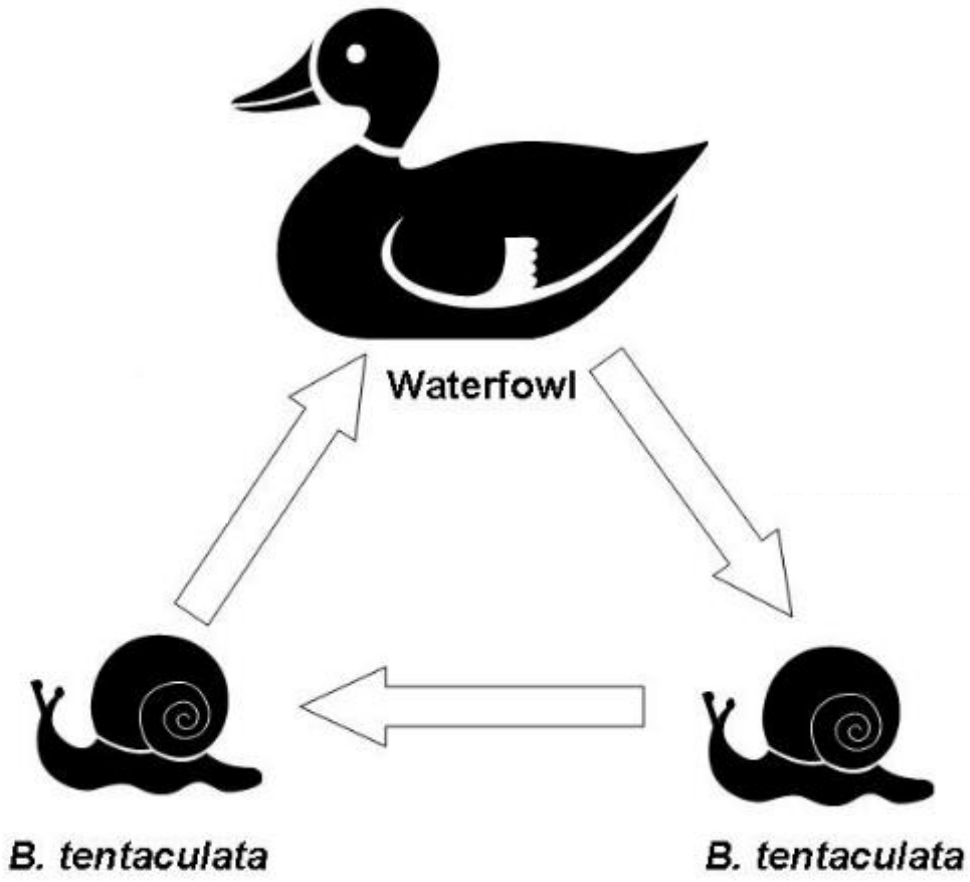
Cyathocotyle bushiensis



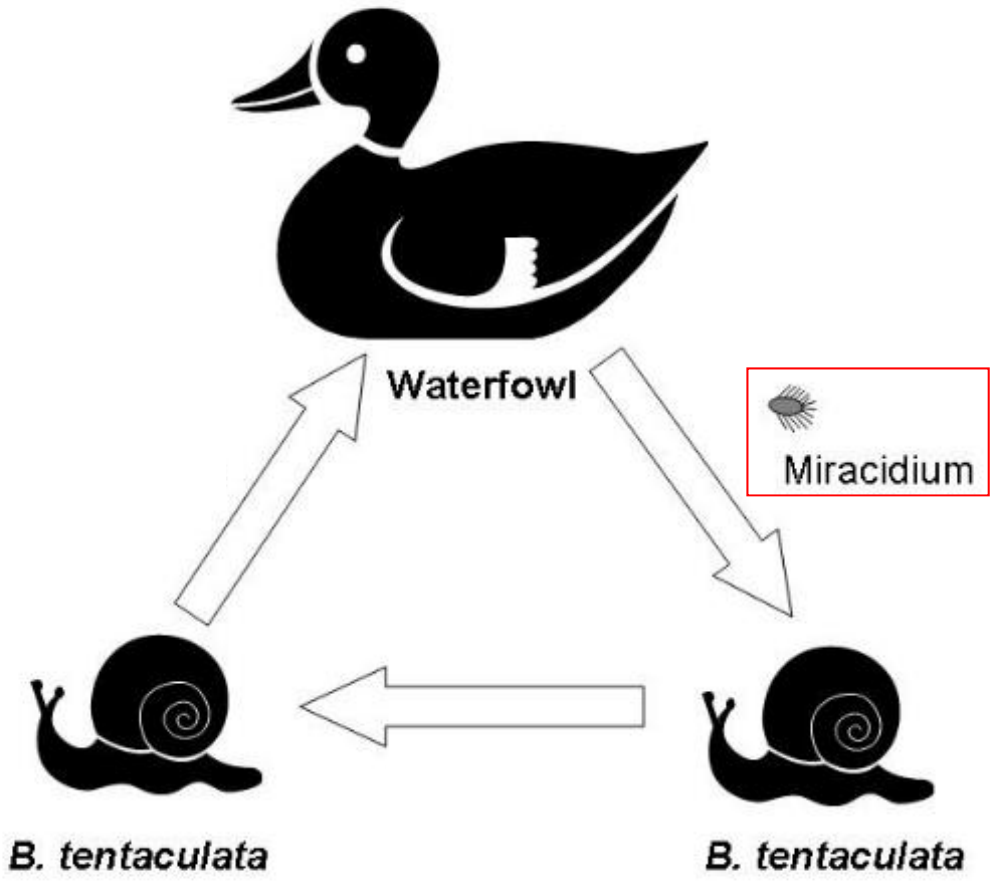
2 species of *Sphaeridiotrema*

Leyogonimus polyoon

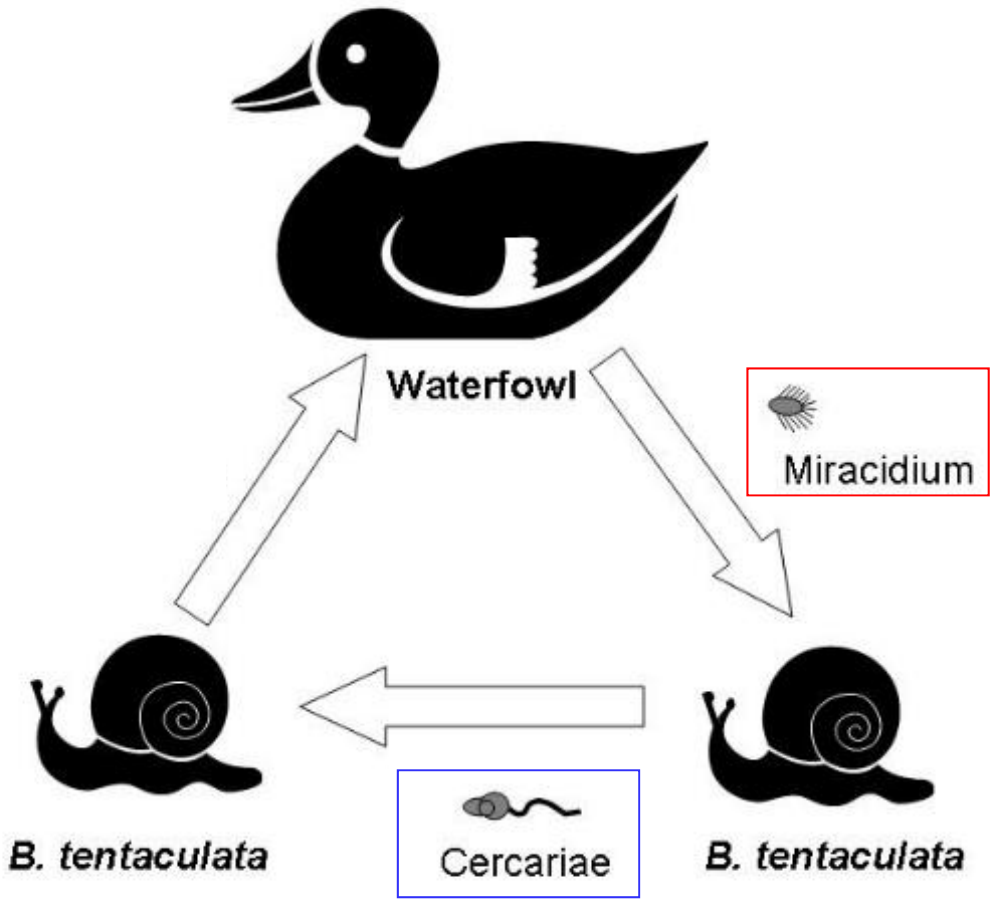
Life cycles



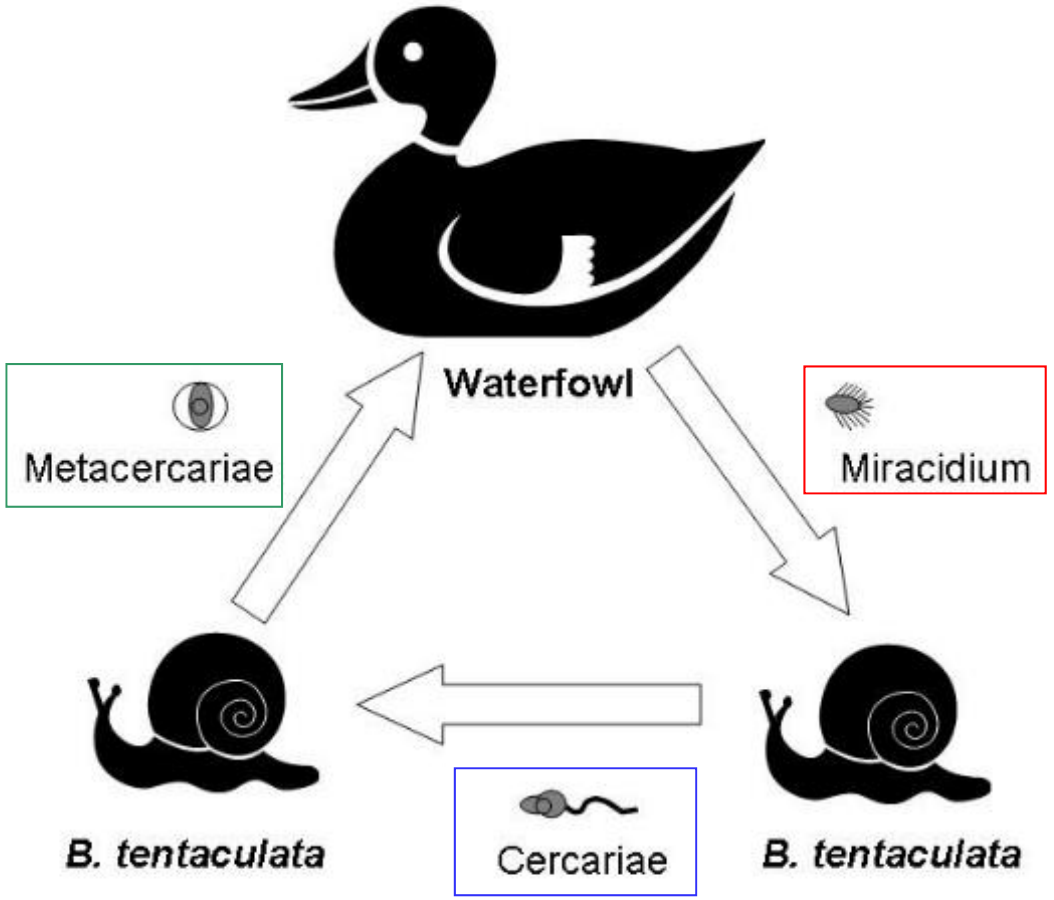
Life cycles



Life cycles


Waterfowl
Miracidium
B. tentaculata
Cercariae
B. tentaculata

Life cycles


Waterfowl
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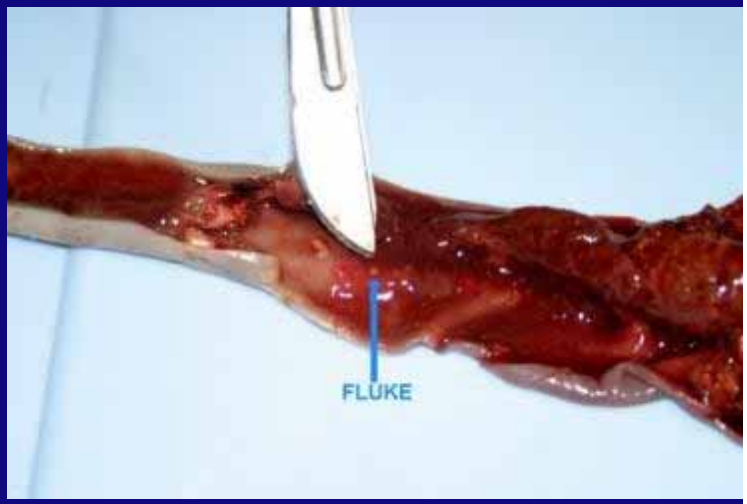
Pathology

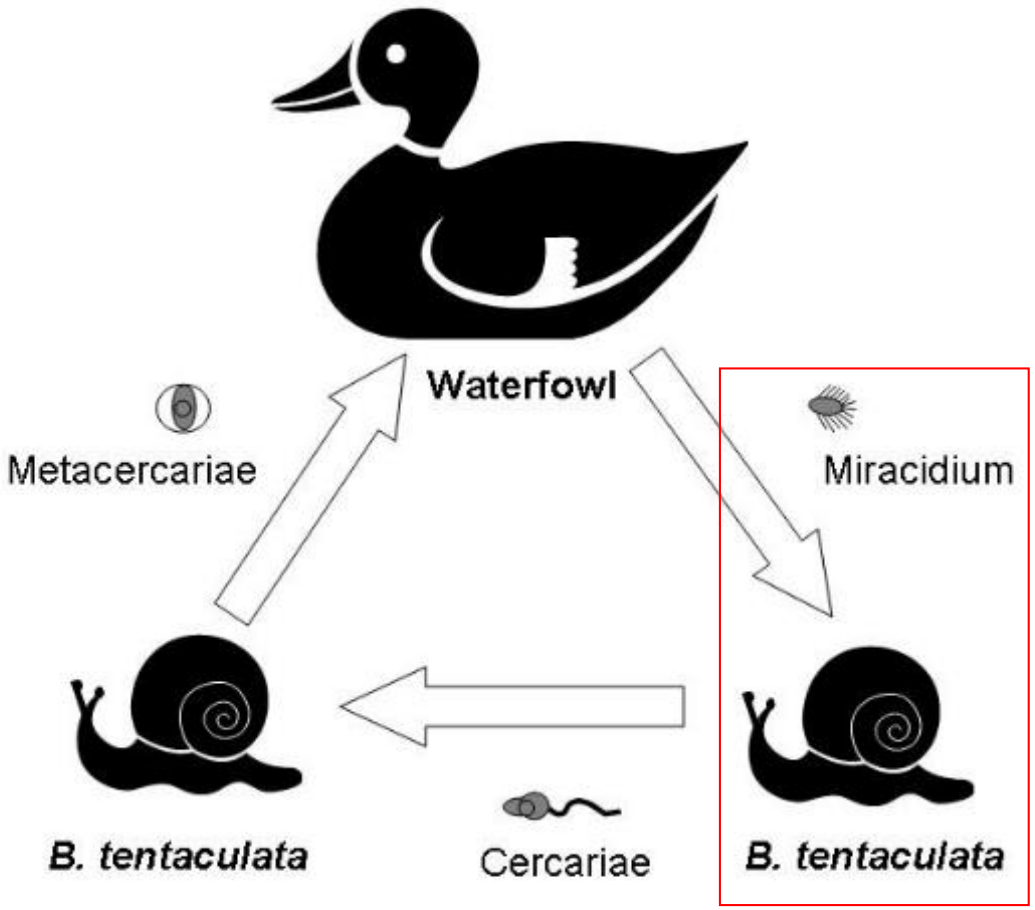
- Found in the lower intestines and cecae
- Fluke attachment and penetration causes severe tissue damage
- Extreme hemorrhaging and plaque formation 5-7 days post-infection
- Death in 5-9 days



Mortality in the Upper Mississippi River

- Thousands of bird deaths each year
- > 80,000 deaths have been reported since 2002
- Primarily lesser scaup and coot
- 13 species reported
- Thought to be further stressing avian populations already in decline

Life cycles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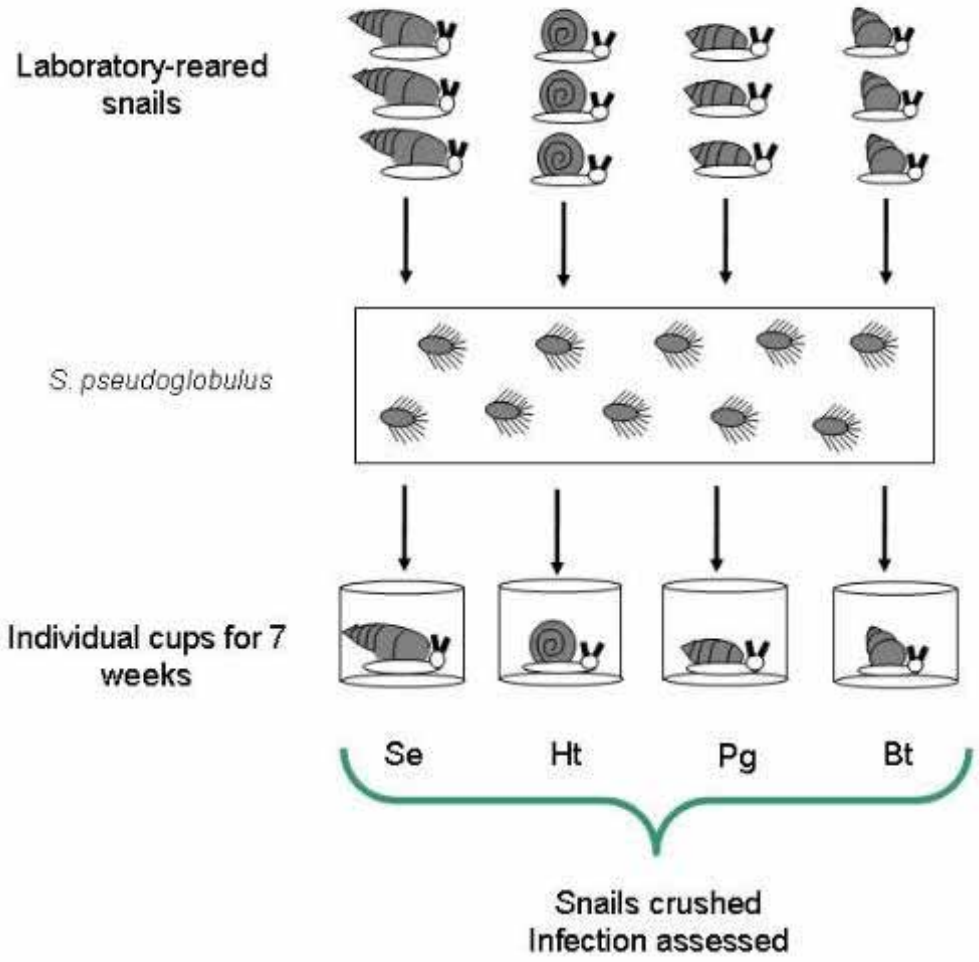
Host competency experiment - miracidia



Miracidial exposures

Snail species	Snail status	Sample size (n)	Mean size (±SE)	Prevalence (% infected)
Helisoma trivolvis	Native	23	3.45 (± 0.82)	0
Physa gyrina	Native	16	4.01 (± 0.50)	0
Stagnicola elodes	Native	11	5.23 (± 1.03)	0



Sandland et al. 2013. Hydrobiologia

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B. tentaculata	Invasive	19	3.93 (± 0.68)	84



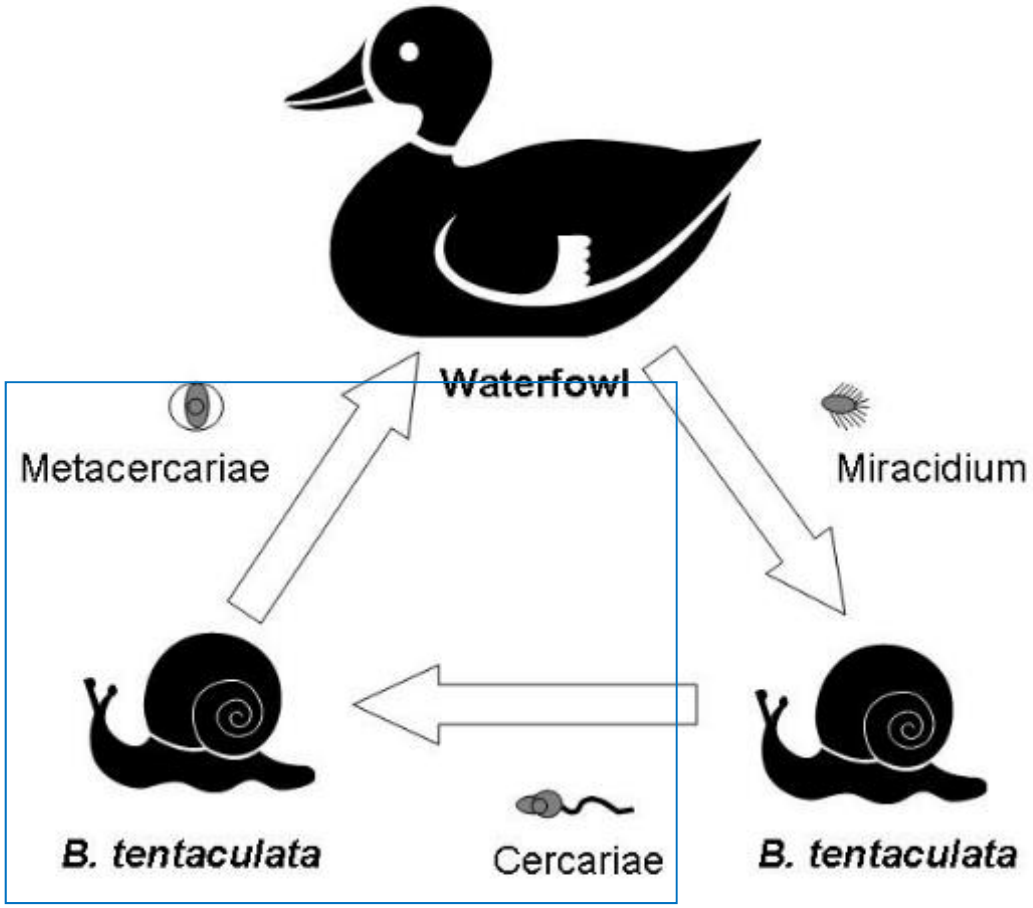

Sandland et al. 2013. Hydrobiologia

Conclusions – first stage

1) *Sphaeridiotrema pseudoglobulus* appears to have narrow specificity for snails at the first life-cycle stage

2) Native snails may be infected but parasites fail to develop – life-history consequences?

Life cycles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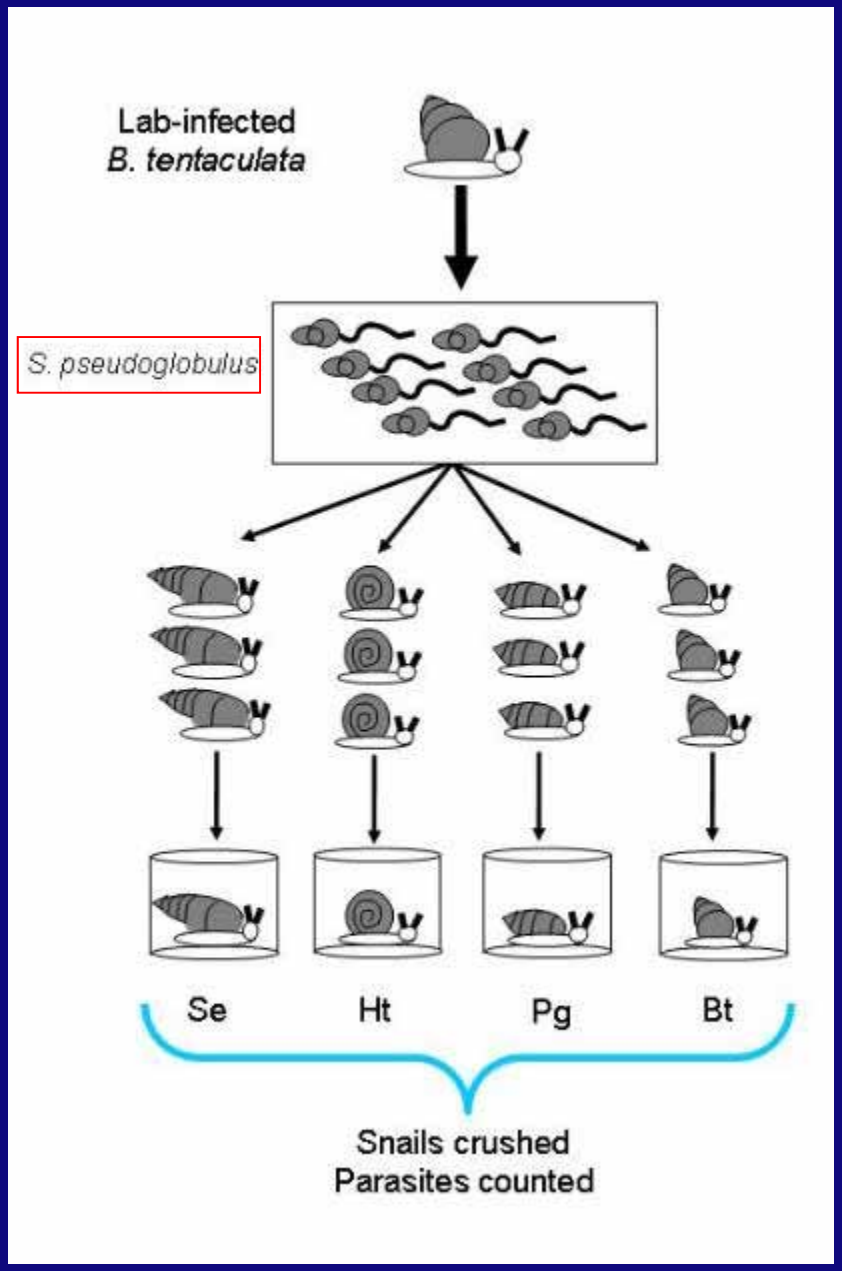
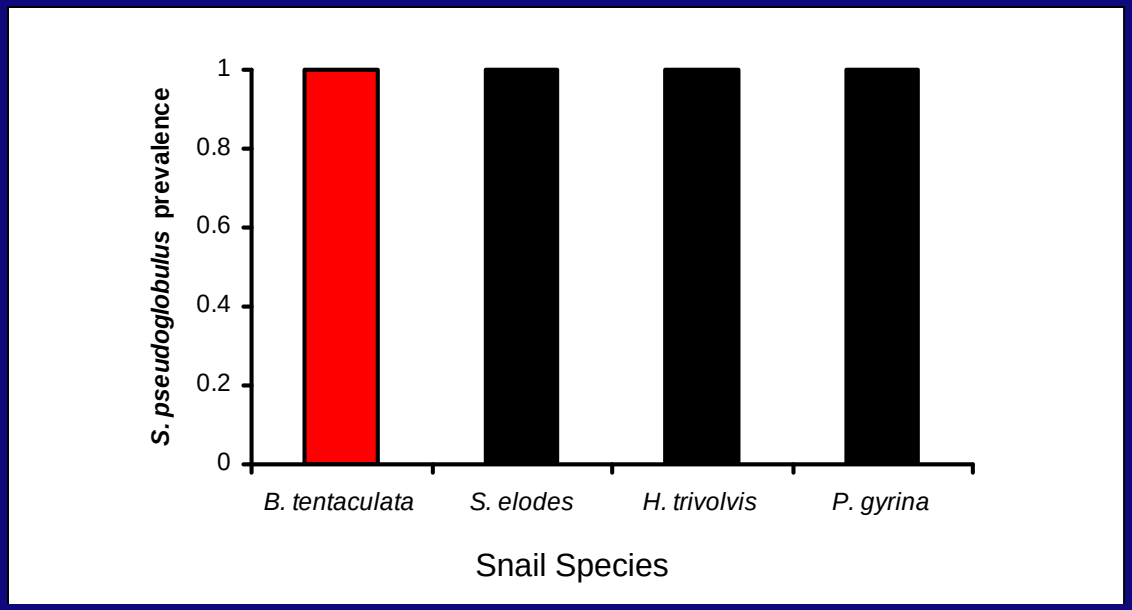
Host competency experiment - cercariae

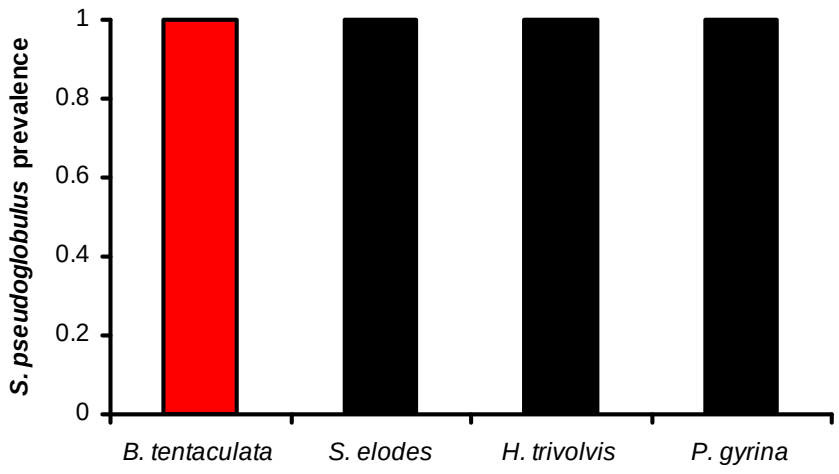


Cercarial exposures



Sandland et al. 2014.
J. Wildlife Disease

Cercarial exposures

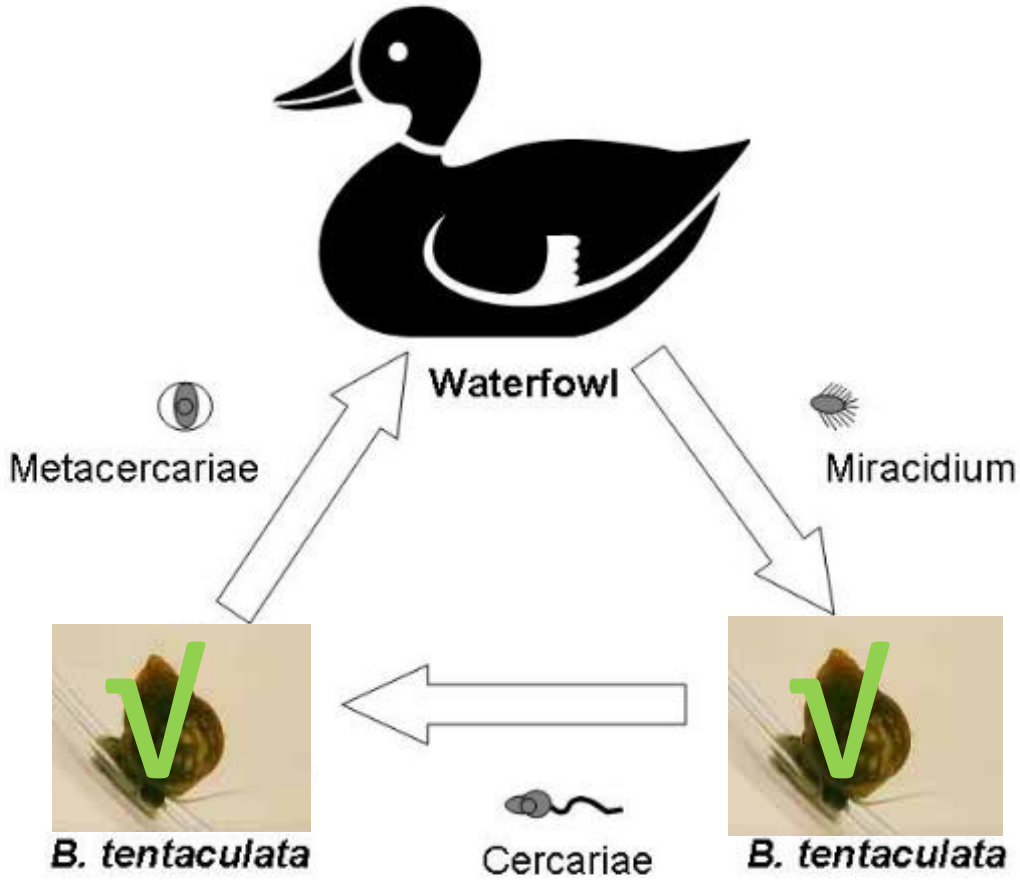


Sandland et al. 2014.
J. Wildlife Disease

Conclusions – second stage

1) *Sphaeridiotrema pseudoglobulus* - broad host competency in 2nd intermediate hosts
   - Enhanced transmission to waterfowl?

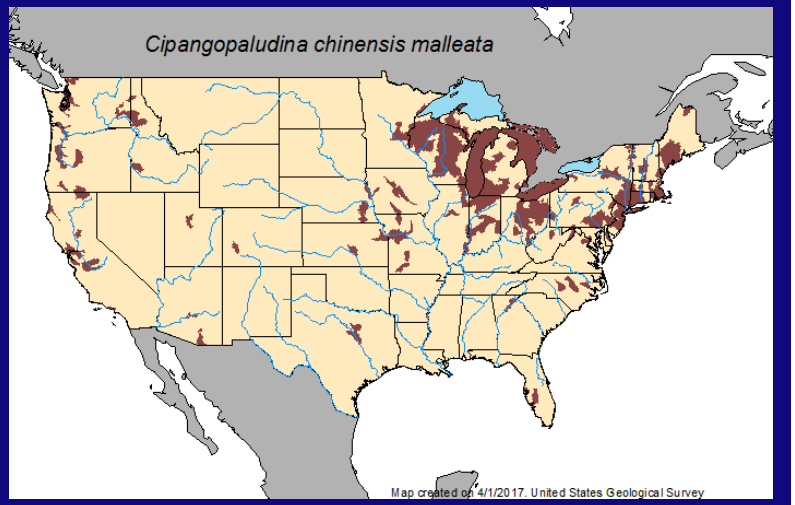
Bithynia as hosts for digeneans in the Midwest?



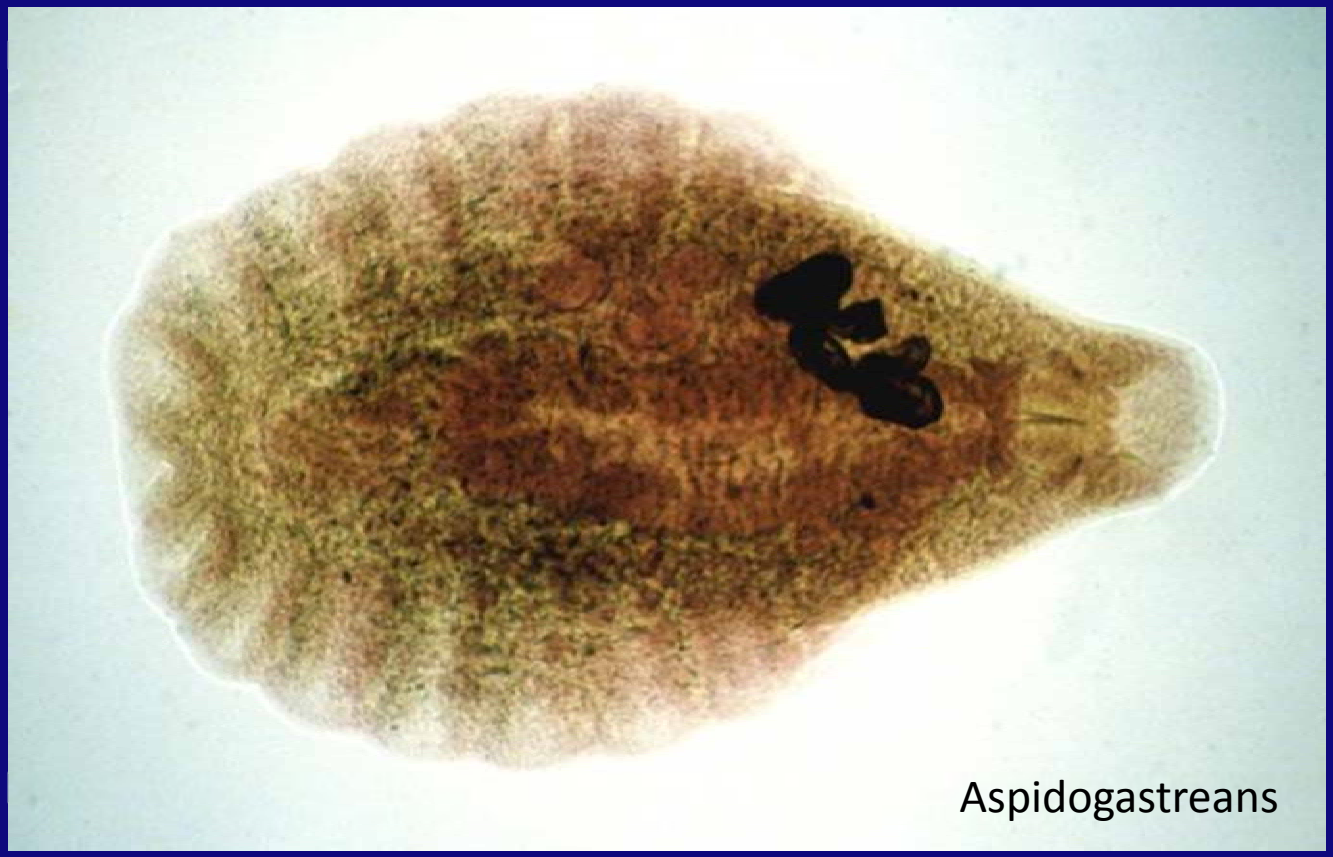
The Midwest's most wanted

Chinese Mystery Snails (CMS)

- Native to Asia
- First reported in San Francisco (1892)
- Currently reported from 834 sites just in Wisconsin (includes lakes and rivers)
- Suggested negative correlations between CMS densities and those of native snails
- Another concern: in its native range it hosts a number of digeneans, including human echinostomes



Reported infections in CMS from North America



Aspidogastreans

Penner 1942. J. Parasitol.
Michelson 1970. J. Parasitol
Jokinen 1982. The Nautilus
Karatayev et al. 2012. J. Shellfish Res.

Wisconsin CMS assessment

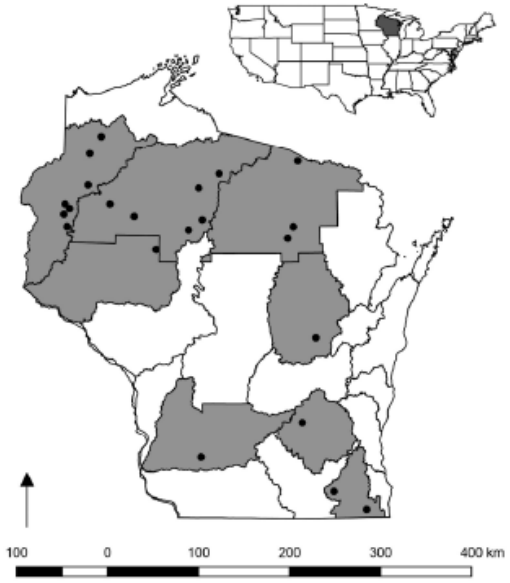


Figure 1. Inset: Map of the United States with study area, Wisconsin, indicated by filled polygon. Larger map: State of Wisconsin with major drainage basins outlined. Drainages sampled are shown in gray; the location of each lake with populations of CMS examined in this study indicated by filled black circle.

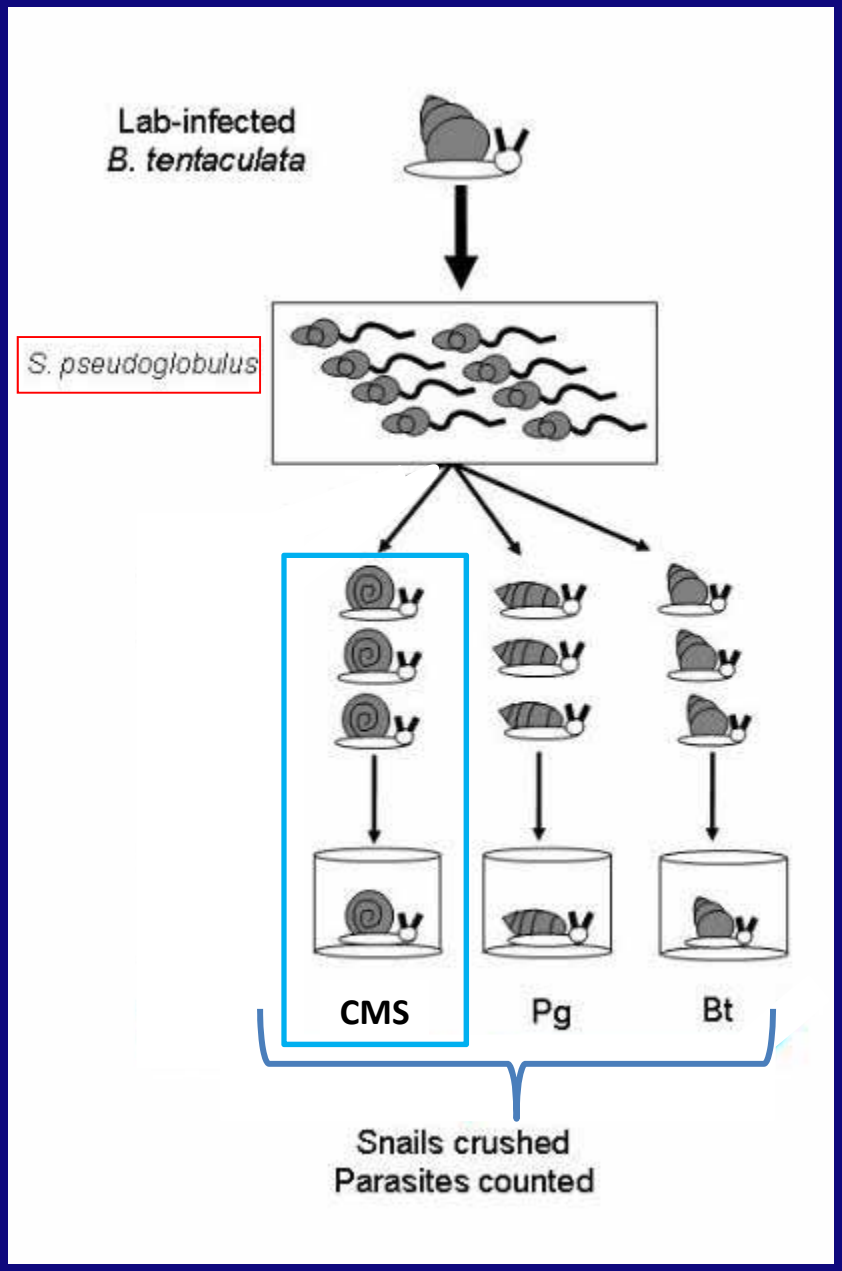
Table 1. Wisconsin drainage basins with number of lakes surveyed and number (*n*) of Chinese mystery snails (CMS) necropsied per basin. Number of infected CMS is also indicated. (* Indicates the watershed where one individual was infected with *Aspidogaster conchicola* and a second individual was infected with *Cyathocotyle bushiensis*).

Lake	*n* snails necropsied	*n* infections	Parasite species
Lake Poygan	1	0	
Sauntry's Pocket	1	0	
Ward Lake	14	0	
Antler Lake	15	0	
Big Blake Lake	1	0	
Camelia Lake	9	0	
Amacoy Lake	3	0	
Round Lake	15	0	
Sailor Lake	10	0	
Little Chelsea Lake*	4	2	*A. conchicola, C. bushiensis*
Mondeaux Flowage	16	0	
Hulls Lake	17	0	
Big Sand Lake	1	0	
Red Cedar	13	0	
Blackhawk Lake	1	0	
Lazy Lake	2	0	
Paddock Lake	3	0	
Powers Lake	4	0	
Kimbal Lake	1	0	
South Neva Lake	1	0	
Big Bass Lake	3	0	
Lincoln Lake	12	0	
	n = 147	*n* = 2	

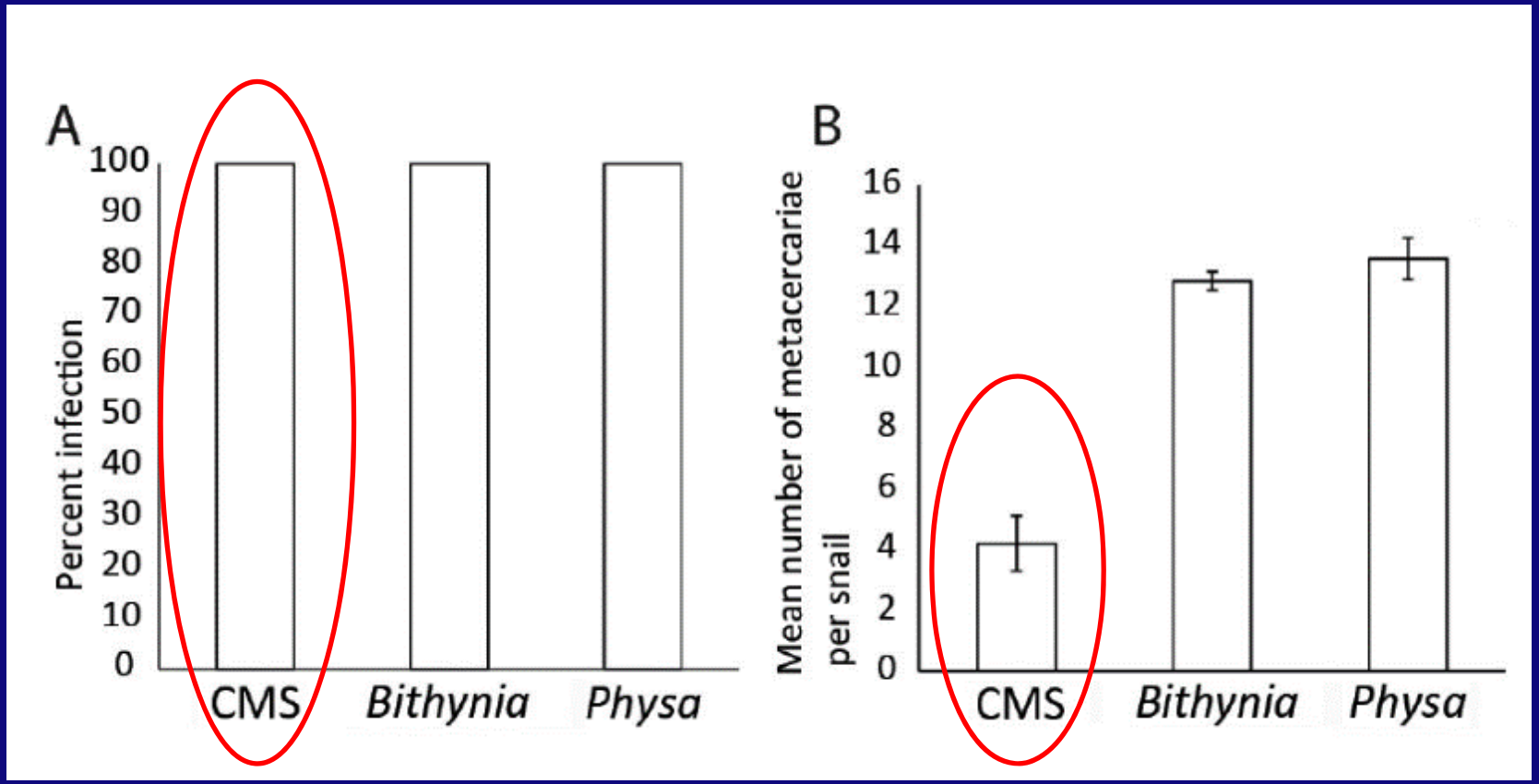
Harried et al. 2015. Aquatic Invasions

How about experimental exposures of CMS to cercariae?

Host competency experiment - cercariae



Experimental exposures to parasite larvae (*S. pseudoglobulus*)



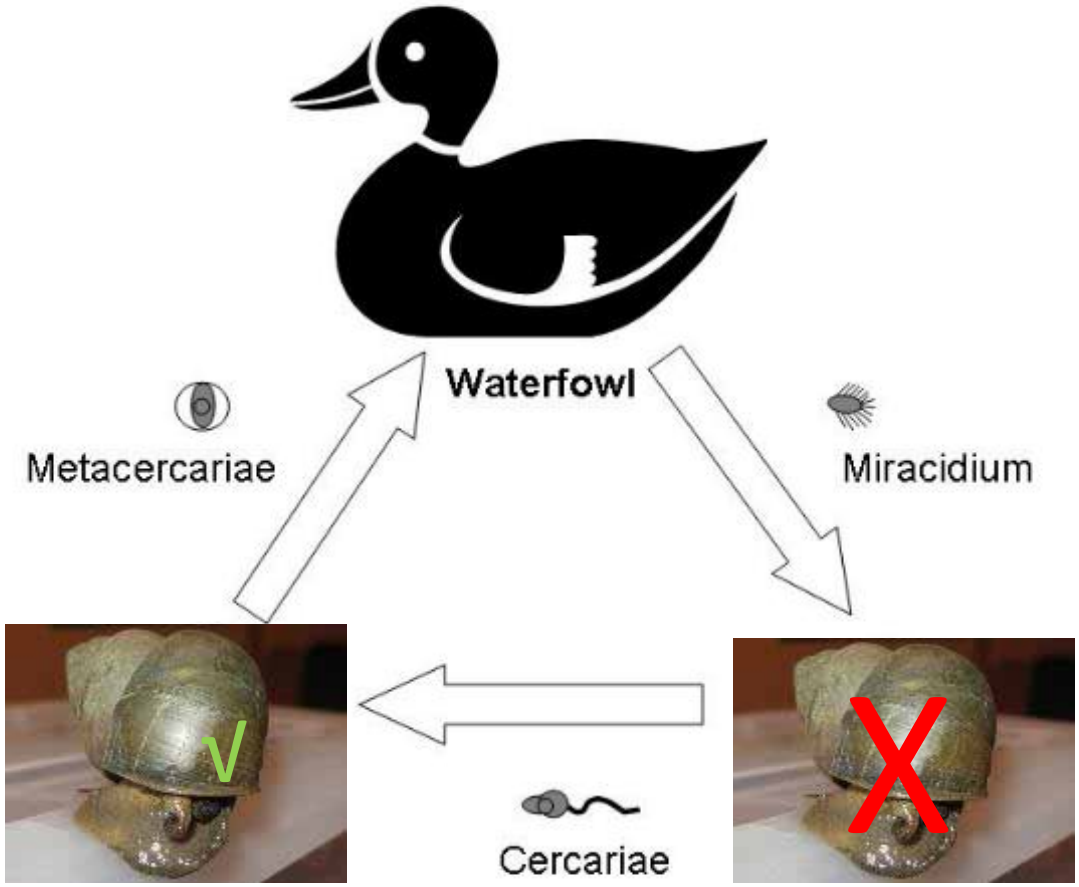
Harried et al. 2015. Aquatic Invasions

Conclusions

1) Based on field collection, CMS do not frequently serve as first hosts for digenean species
   - Aspidogastreans tend to be the most common infection in these snails

2) Based on field and experimental studies, CMS can serve as second hosts for digenean parasites, but compatibility appears to differ relative to other snail species

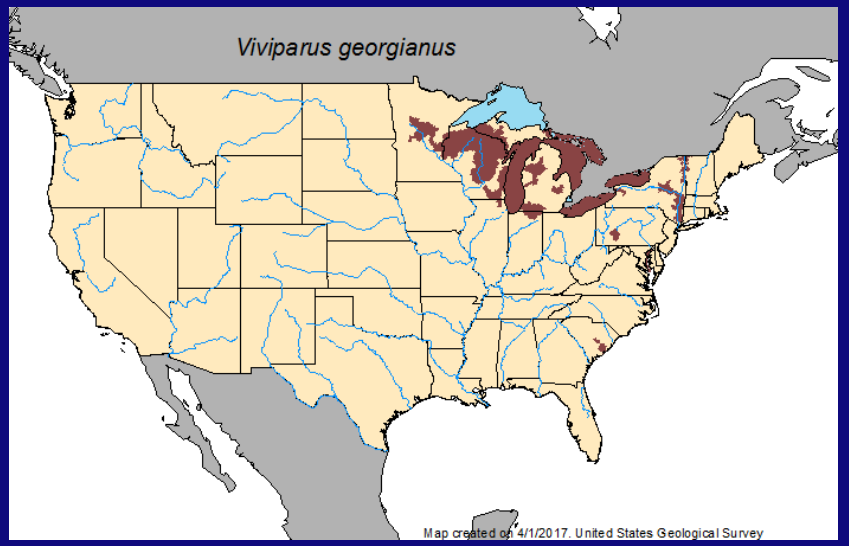
CMS as hosts for digeneans in the Midwest?



The Midwest's most wanted

Banded Mystery Snails

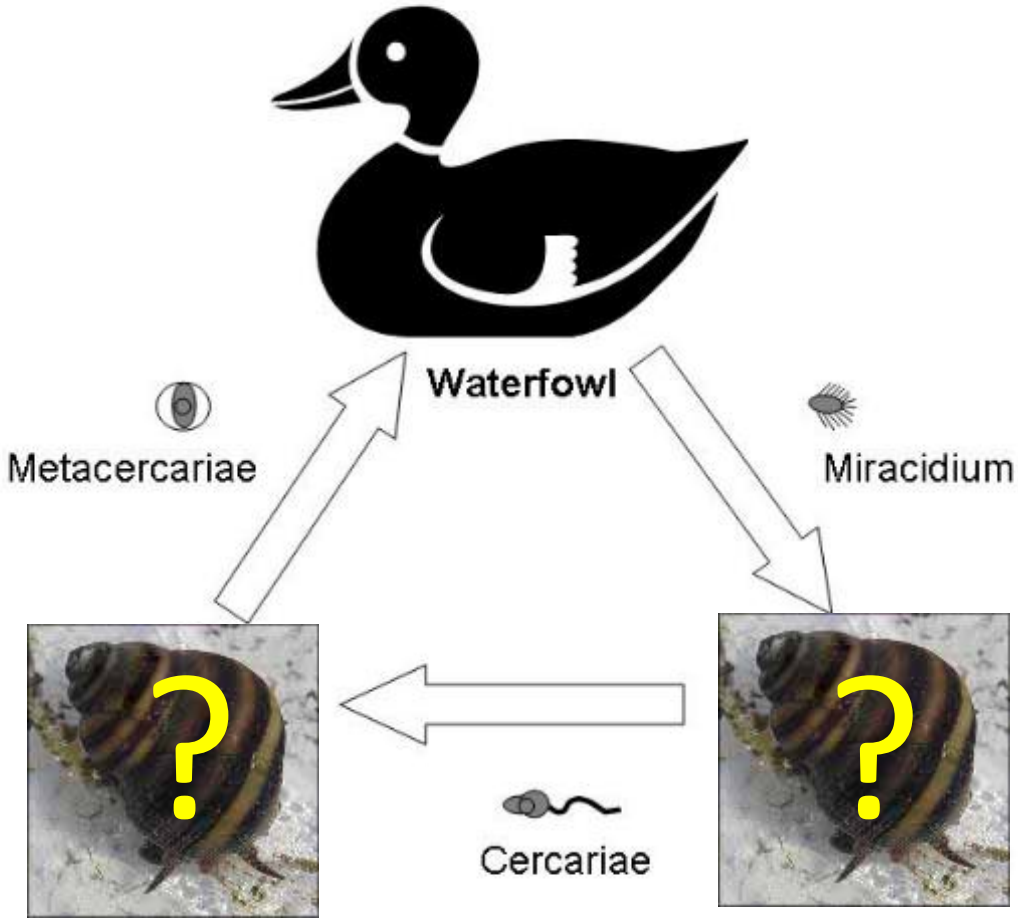
- Introduced from the south eastern region of the US
- First introduced into the Hudson River Drainage in 1867
- 3-4 year life span
- Reported from > 300 waterbodies in Wisconsin
- BMS can consume largemouth bass embryos when they invade nests



Banded Mystery Snails - infections

- Not well studied
- One report (Wade, 1985), suggested that BMS are “infected” by a number of organisms including:
  - Cercaria, metacercaria (digeneans)
- Our necropsies have not revealed flatworm infections in this species

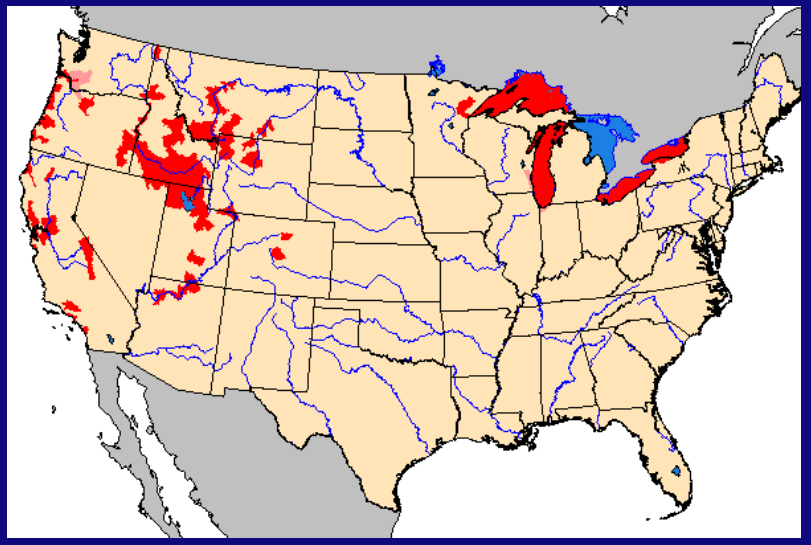
BMS as hosts for digeneans in the Midwest?



The Midwest's most wanted

New Zealand Mudsnail

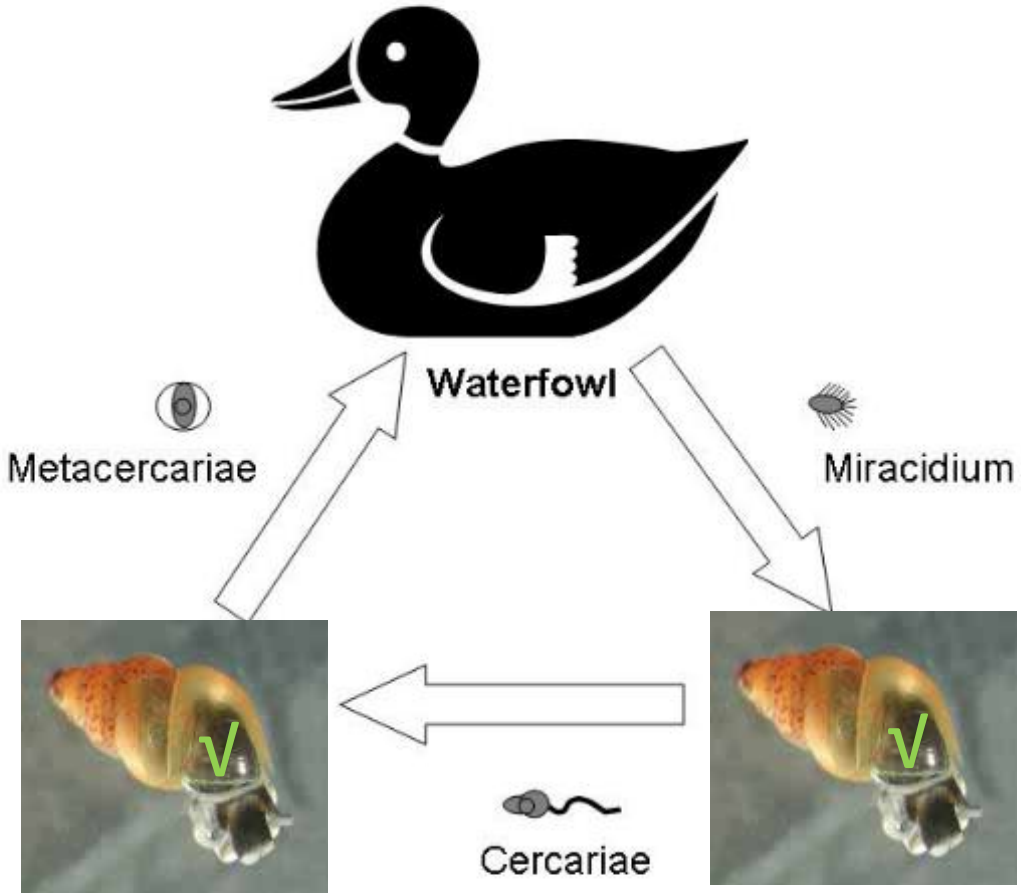
- Introduced from New Zealand
- Very small
- Half a million snails/m^2
- Asexual populations
- Impacts on entire freshwater systems by impacting invertebrates and fish



New Zealand Mudsnail infections

- 270 snails dissected (Lake Ontario tributary), none of the snails were infected (Karatayev et al. 2012. J. Shellfish Res.)
- 960 snails shed for parasites (Wyoming), 1 snails was infected with cercariae (Cohen et al. 2009. J. Parasitol.)
- 150 dissected snails (Wyoming), 5 snails had metacercariae of 2 species (Cohen et al. 2009. J. Parasitol.)

Mudsnails as hosts for digeneans in the Midwest?

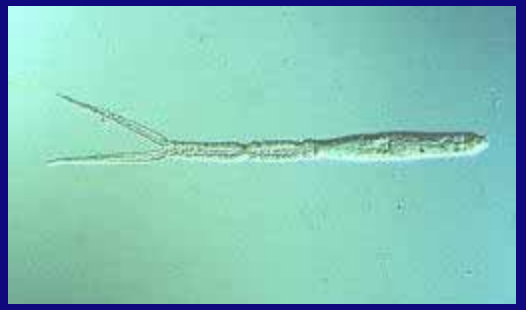


Swimmer Itch: an emerging issue locally and globally

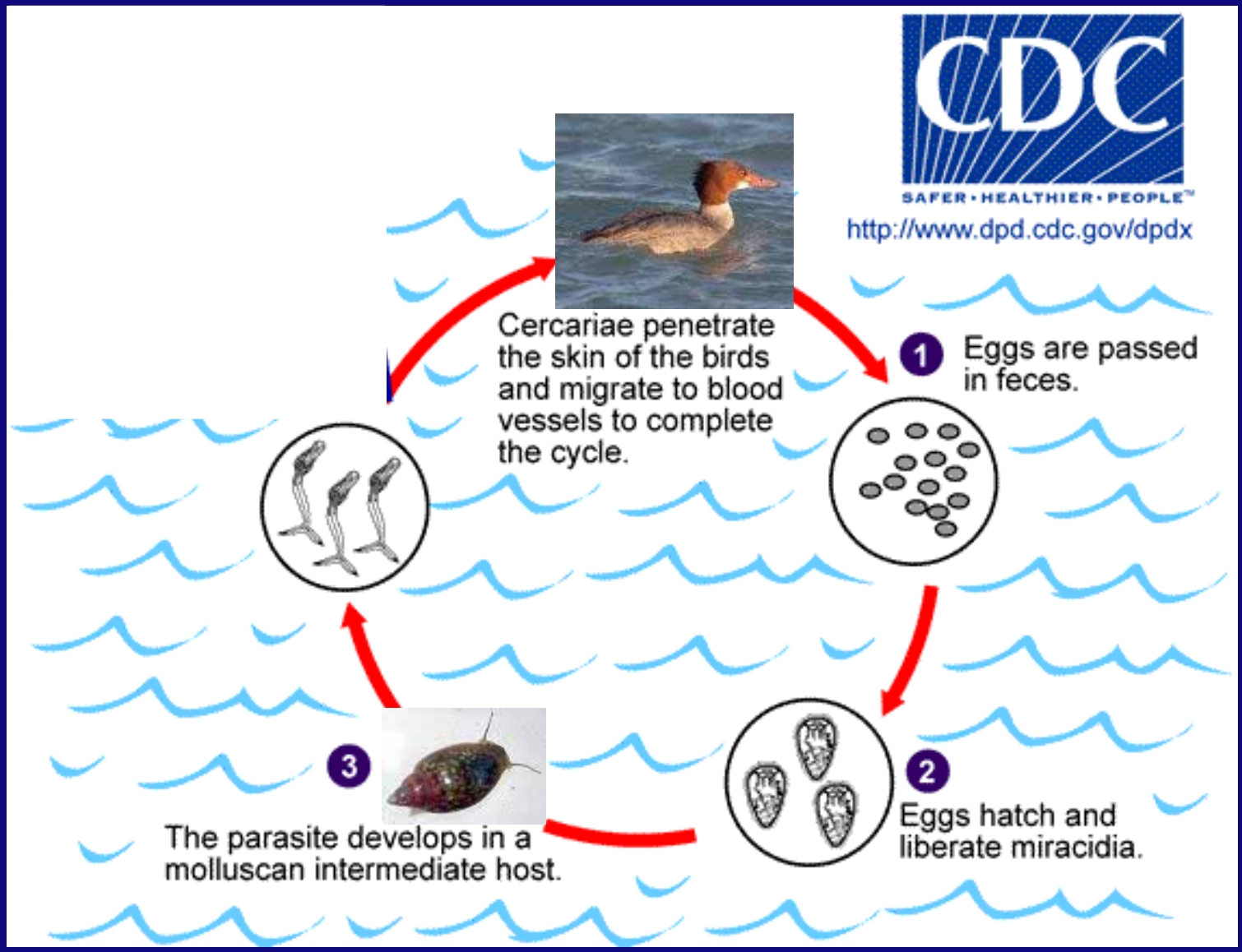
Do invasive snail species play a role?

Swimmer Itch: an emerging issue

- Worldwide problem caused by digenean parasites (again!)
- Costs associated with outbreaks
  - Lost tourism
  - Healthcare
  - Mitigation
- Prevalent in the Midwest
  - Devil's Lake, WI
- Recently recognized as an emerging disease



Parasite life cycle



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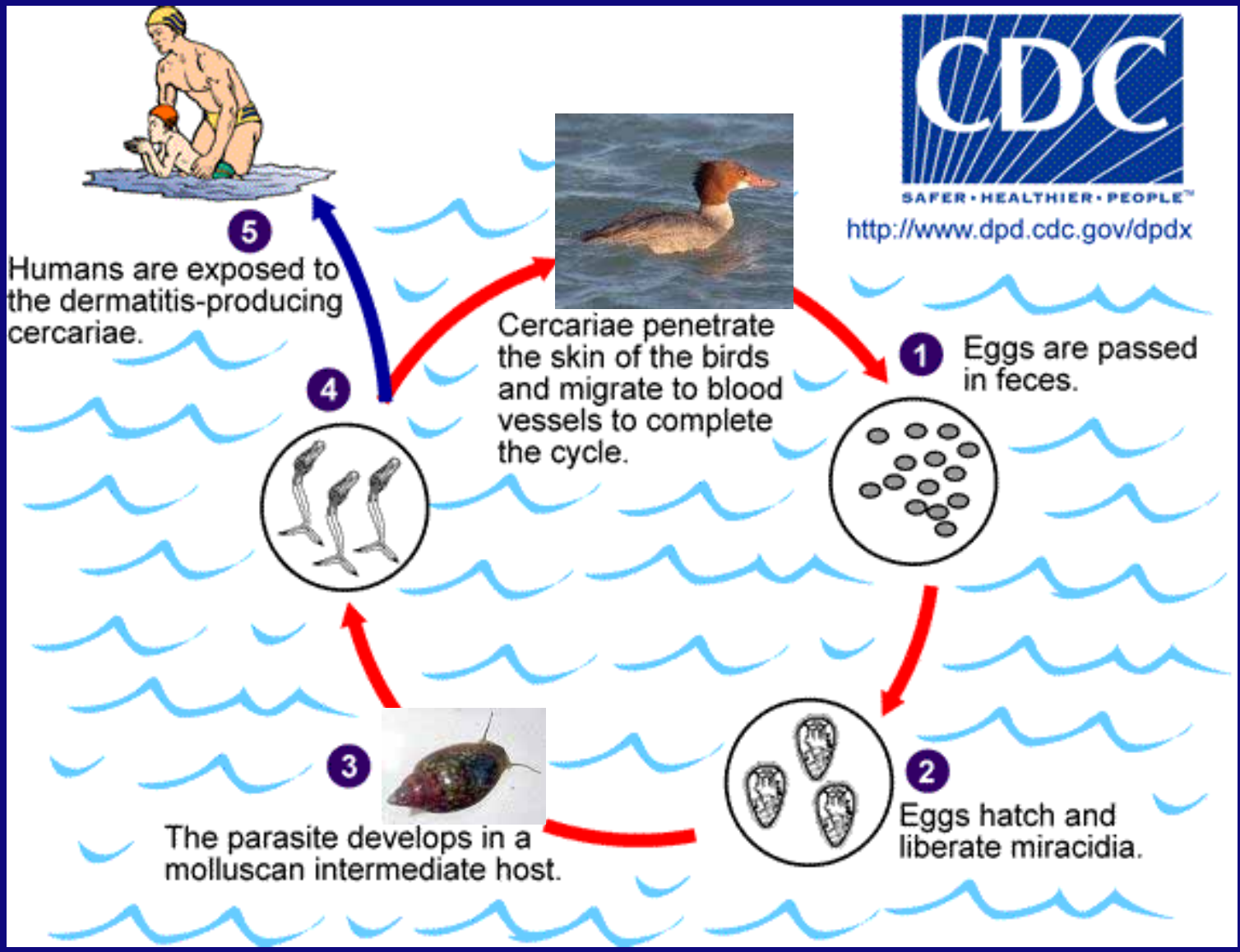

Consequences of infection

- Humans
  - Dead-end hosts
- Skin penetration
  - Inflammatory responses
  - Itching and irritation lasting weeks
  - In some cases: fever, swollen lymph nodes, diarrhea, anaphylaxis

Reported trematodes responsible for swimmer's itch (Horak et al. 2015)

TABLE 1 Summary of general host use of known genera of schistosomes, reflecting current knowledge, habitat in the definitive host, and broad geographic locality

Genus	Snail host	Mammalian/avian host	Definitive host habitat	Locality	Aquatic habitat	Major areas for outbreaks
Austrobilharzia	Nassariidae, Batillaridae, Littoriniidae, Potamidiidae	Charadriiformes	Visceral	Global	Marine	Shallow marine areas, tidal pools
Ornithobilharzia	Batillaridae	Charadriiformes	Visceral	Global	Marine	Shallow marine areas, tidal pools
Macrobilharzia	Unknown	Suliformes (*Anhinga*)	Visceral	North America, Africa	Unknown	Unknown if causes dermatitis
Bivitellobilharzia	Unknown	Elephantidae, Rhinocerotidae	Visceral	Africa, Asia	Freshwater	Probably freshwater rivers
Schistosoma	Planorbidae, Lymnaeidae, Pomatiopsidae	Mammalia	Visceral, Nasal	Eurasia, Africa, South America	Freshwater	Mostly eutrophic ponds
Heterobilharzia	Lymnaeidae	Mammalia	Visceral	North America	Freshwater	Marshy areas
Schistosomatium	Lymnaeidae	Rodentia	Visceral	North America	Freshwater	Marshy areas
Bilharziella	Planorbidae	Anseriformes, Gruiformes, Ciconiiformes, Podicipediformes	Visceral	Europe	Freshwater	Eutrophic ponds
Species isolated from *Haminoea*	Haminoeidae	Charadriiformes, Pelicaniformes	Visceral	North America	Marine	Shallow marine areas, tidal pools
Gigantobilharzia[a]	Physidae	Passeriformes	Visceral	North America	Freshwater	Marshy areas, usually with cattails
Dendritobilharzia	Planorbidae	Anseriformes, Gruiformes, Pelicaniformes, Gaviiformes	Visceral	Global	Freshwater	Unknown if reports of dermatitis
Jilinobilharzia	Unknown	Anseriformes (Anatidae)	Visceral	China	Unknown	Unknown if reports of dermatitis
Allobilharzia	Unknown	Anseriformes (swans)	Visceral	Northern Hemisphere	Unknown	Unknown if causes dermatitis
Anserobilharzia	Planorbidae	Anseriformes (geese)	Visceral	Northern Hemisphere	Freshwater	Eutrophic ponds, reservoirs
Trichobilharzia	Lymnaeidae, Physidae	Anseriformes (Anatidae)	Visceral, nasal	Global	Freshwater	Eutrophic ponds, glacial lakes, reservoirs

[a] Since *Gigantobilharzia* is not a monophyletic genus, the information listed here is for *G. huronensis* only.

Clinical Microbiology Reviews

Swimmer Itch and invasive snails

- Growing concern as invasive snails increase in frequency and densities across the U.S.
- Are there any examples that we know of?

FIG 2 Furcocercaria of Trichobilharzia regenti with protruded acetabulum (arrow), lateral view. Bar, 200 μm. (Courtesy of I. Bulantová, reproduced with permission.)

Cercarial Dermatitis Transmitted by Exotic Marine Snail

Sara V. Brant, Andrew N. Cohen, David James, Lucia Hui, Albert Hom, and Eric S. Loker

2010. Emerging Inf. Dis.

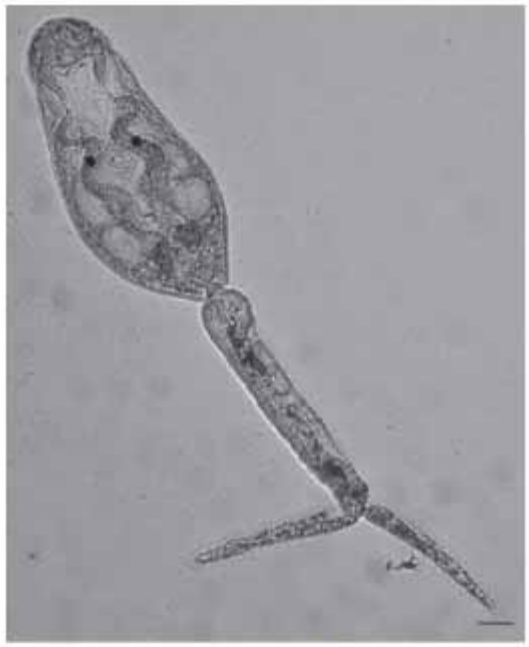

Figure 3. Live schistosome cercaria from a *Haminoea japonica* snail. Scale bar = 30 µm. Measurements are shown in Table 2.

Evidence for swimmer's itch in invasive snails

Reported hosts for swimmer's itch parasites (Horak et al. 2015)

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Clinical Microbiology Reviews

Reported hosts for swimmer's itch parasites in freshwater systems

TABLE 1 Summary of general host use of known genera of schistosomes, reflecting current knowledge, habitat in the definitive host, and broad geographic locality

Genus	Snail host	Mammalian/avian host	Definitive host habitat	Locality	Aquatic habitat	Major areas for outbreaks
Austrobilharzia	Nassariidae, Batillaridae, Littoriniidae, Potamididae	Charadriiformes	Visceral	Global	Marine	Shallow marine areas, tidal pools
Ornithobilharzia	Batillaridae	Charadriiformes	Visceral	Global	Marine	Shallow marine areas, tidal pools
Macrobilharzia	Unknown	Suliformes (*Anhinga*)	Visceral	North America, Africa	Unknown	Unknown if causes dermatitis
Bivitellobilharzia	Unknown	Elephantidae, Rhinocerotidae	Visceral	Africa, Asia	Freshwater	Probably freshwater rivers
Schistosoma	Planorbidae, Lymnaeidae, Pomatiopsidae	Mammalia	Visceral, Nasal	Eurasia, Africa, South America	Freshwater	Mostly eutrophic ponds
Heterobilharzia	Lymnaeidae	Mammalia	Visceral	North America	Freshwater	Marshy areas
Schistosomatium	Lymnaeidae	Rodentia	Visceral	North America	Freshwater	Marshy areas
Bilharziella	Planorbidae	Anseriformes, Gruiformes, Ciconiiformes, Podicipediformes	Visceral	Europe	Freshwater	Eutrophic ponds
Species isolated from *Haminoea*	Haminoeidae	Charadriiformes, Pelicaniformes	Visceral	North America	Marine	Shallow marine areas, tidal pools
Gigantobilharzia[a]	Physidae	Passeriformes	Visceral	North America	Freshwater	Marshy areas, usually with cattails
Dendritobilharzia	Planorbidae	Anseriformes, Gruiformes, Pelicaniformes, Gaviiformes	Visceral	Global	Freshwater	Unknown if reports of dermatitis
Jilinobilharzia	Unknown	Anseriformes (Anatidae)	Visceral	China	Unknown	Unknown if reports of dermatitis
Allobilharzia	Unknown	Anseriformes (swans)	Visceral	Northern Hemisphere	Unknown	Unknown if causes dermatitis
Anserobilharzia	Planorbidae	Anseriformes (geese)	Visceral	Northern Hemisphere	Freshwater	Eutrophic ponds, reservoirs
Trichobilharzia	Lymnaeidae, Physidae	Anseriformes (Anatidae)	Visceral, nasal	Global	Freshwater	Eutrophic ponds, glacial lakes, reservoirs

[a] Since *Gigantobilharzia* is not a monophyletic genus, the information listed here is for *G. huronensis* only.

Clinical Microbiology Reviews

Reported hosts for swimmer's itch parasites in freshwater systems

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Bivitellobilharzia	Unknown	Elephantidae, Rhinocerotidae	Visceral	Africa, Asia	Freshwater	Probably freshwater rivers
Schistosoma	Planorbidae, Lymnaeidae, Pomatiopsidae	Mammalia	Visceral, Nasal	Eurasia, Africa, South America	Freshwater	Mostly eutrophic ponds
Heterobilharzia	Lymnaeidae	Mammalia	Visceral	North America	Freshwater	Marshy areas
Schistosomatium	Lymnaeidae	Rodentia	Visceral	North America	Freshwater	Marshy areas
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[a] Since *Gigantobilharzia* is not a monophyletic genus, the information listed here is for *G. huronensis* only.

Conclusions

1) Based on field collections, some invasive species (e.g. *Bithynia*) can serve as hosts for digenean parasites, BUT not those responsible for swimmer's itch

2) On the other hand, digenean infections in other invasive snail species (e.g. CMS) are generally uncommon (based on past research)

3) This, along with information about the snail species that harbor swimmer's itch parasites suggest a limited role for invasives in the persistence and/or exacerbation of this issue

Acknowledgements

Laura Herman,
Scott Van Eggeren
Maureen Ferry

Jim Nissen
Kendra Niemec
Calvin Gehri
Stephen Winter

Rebecca Cole
Jennifer Sauer

Roger Haro
Kathryn Perez
Brittany Harried
Chris Glodosky
Ben Walker
Rick Gillis