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Boom and bust of an aquatic invasive species? Population monitoring of the New Zealand mudsnail (*Potamopyrgus antipodarum*) and interactions with native species in Polecat Creek, WY

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Abstract The invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) has been found to reach densities exceeding 500,000 individuals/m^2 in Polecat Creek, located in the Greater Yellowstone Ecosystem in Wyoming. The biomass of *P. antipodarum* in Polecat Creek has declined in recent years, suggesting the population "boomed and busted"; the population was booming in 2000-2001, but in 2011 the biomass had decreased by ~93%, suggesting a "bust" period for *P. antipodarum*. Native, net-spinning caddisflies (*Hydropsyche spp.*) have increased dramatically in biomass from 2001-2010, which may indicate that some native macroinvertebrates have increased in biomass due to release of suppression by *P. antipodarum*. I collected macroinvertebrate core samples in Polecat Creek to monitor any changes in macroinvertebrate biomass and performed field experiments to determine a possible mechanism by which *P. antipodarum* may have suppressed *Hydropsyche* caddisfly populations. I allowed *Hydropsyche* larvae to establish and build nets on tiles within experimental chambers in Polecat Creek and added "boom" and "bust" densities of *P. antipodarum* to chambers. Preliminary results showed no significant difference between the number of nets present in control chambers excluding *P. antipodarum* and chambers containing "boom" and "bust" densities of *P. antipodarum*. This suggests that *P. antipodarum* do not actively destroy nets, but may interfere with feeding by clustering upon nets.

Introduction

Non-native species that cause ecological or economic damage are referred to as invasive species (Lockwood et al., 2013). The invasive New Zealand mud snail (*Potamopyrgus antipodarum*) is native to New Zealand but has established populations in Australia, Europe, and North America (Zaranko et al., 1997). The snail first invaded streams and rivers in the Greater Yellowstone Ecosystem (GYE) in Wyoming in 1994, reaching exceptionally high population densities in some invaded streams and rivers (Kerans et al., 2005; Hall et al., 2006). At my study site, Polecat Creek WY, Hall et al. (2006) documented densities exceeding 500,000 individuals/m^2. Because of its abundance in Polecat Creek, *P. antipodarum* can control fluxes of carbon and nitrogen (Hall et al., 2003), dominate the flux of nitrogen from primary producers (Hall et al., 2003), represent 97% of invertebrate biomass (Hall et al., 2003, 2006), and consume 75% of gross primary production.

Potamopyrgus antipodarum may also alter the Polecat Creek ecosystem by negatively affecting native macroinvertebrate species. In laboratory experiments, for example, high biomass of *P. antipodarum* nearly ceased growth of a native snail (Thon et al. in prep). In field experiments conducted in Polecat Creek, *P. antipodarum* growth also outpaced growth of another native snail when the two species

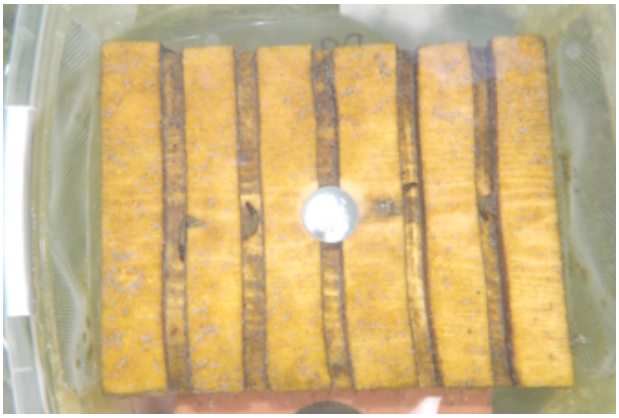

Figure 1. Wooden tile attached to bottom of experimental chamber. *Hydropsyche* caddisfly larvae can be seen in the grooves of the submerged tile.

Figure 2. Experimental chambers attached to bricks on stream benthos. Metal stakes in front of chambers intercepted floating algal mats.

were housed together (Riley et al., 2008). Other native taxa may also be negatively impacted through space or resource competition by *P. antipodarum*: mayflies in the genus *Ephemerella* prefer the same diet as *P. antipodarum* (Krist and Charles, 2012) and a field experiment in the Madison River of Yellowstone National Park showed that the number of native macroinvertebrates that colonized experimental tiles decreased with increasing *P. antipodarum* density (Kerans et al., 2005). Taken together, these negative effects of *P. antipodarum* on the growth of native taxa, along with their consumption of up to 75% of gross primary production (Hall et al., 2003), indicate the possibility of resource competition between *P. antipodarum* and native macroinvertebrates.

The density of *P. antipodarum* in Polecat Creek has significantly decreased since 2000-2001. My preliminary analysis of 2011 data shows a ∼93% decrease in the biomass of *P. antipodarum* since 2000-2001. *P. antipodarum* has undergone at least one other boom and bust in North America. Moore et al. (2012) documented a boom and bust of *P. antipodarum* in the Upper Owens River, California. They collected 10 years of data from the beginning of a *P. antipodarum* invasion through the resulting population bust. Directly following the invasion of *P. antipodarum*, native grazing invertebrates decreased in abundance by 80%, then doubled in abundance after *P. antipodarum* abundance declined (Moore et al., 2012). Similarly, my preliminary analysis of 2000-2001 (Hall et al., 2006) and 2011 (Tibbets unpublished data) abundance data collected from Polecat Creek shows that the biomass of several native macroinvertebrates has increased with the decline of *P. antipodarum* – most notably the *Hydropsyche* caddisfly (∼13-fold increase). *Hydropsyche* is a non-grazing taxon that filters food from the water column using silk nets that they spin, so resource competition is an unlikely mechanism by which *P. antipodarum* may have suppressed *Hydropsyche*. My research objective is to understand the consequences of the boom and bust of *P. antipodarum* in relation to native macroinvertebrates in Polecat Creek, especially *Hydropsyche* caddisflies.

Methods

Boom/Bust

To assess the extent of the "bust" of *P. antipodarum*, I collected invertebrate samples from Polecat Creek approximately 300 meters upstream of Polecat Hot Springs outlet in the John D. Rockefeller National Parkway. I will compare these samples with those collected from the same site in 2000-2001 ("boom" period; Hall et al., 2006) and 2011 (also "bust" period; Tibet's, unpublished data). I collected six samples per month in June, July, August, and September 2016 during the period of peak *P. antipodarum* abundance (Hall et al., 2006). I sampled

Figure 3. Experimental chamber one day after *Hydropsyche* establishment with *P. antipodarum* added.

Figure 4. *Hydropsyche* nets with clusters of *P. antipodarum* upon them.

benthic macro-invertebrates using a 20.3cm diameter stovepipe corer according to Hall et al. (2006). For each sample, I removed sediments (≤5cm deep), macrophytes, and water from the corer and then elutriated and collected the sample on a 500-μm sieve. I preserved all samples in 95% ethanol solution. I will pick all invertebrates greater than 1 mm in length unless the number of *P. antipodarum* exceeds 500 individuals, in which case I will subsample *P. antipodarum* by evenly distributing them on a 500-μm sieve and removing one-eighth to one-half of the snails for counting and measuring (Hall et al., 2006).

To document any changes in biomass of *P. antipodarum* and native invertebrates in Polecat Creek, I will calculate mean biomass of benthic invertebrates sampled in 2000-2001, 2011, and 2016. I will compare mean biomass of 18 core samples collected in September 2000, June 2001, and July 2001 to mean biomass of 18 core samples collected in June, July, and September 2011 and 2016. I have not decided what to do about the month of August because biomass of *P. antipodarum* was extremely high in August of 2001 and I lack data for August 2011, hence including August in my analysis could exaggerate any decrease in biomass of *P. antipodarum*. However, I collected invertebrate samples in August 2016 so I could compare August 2016 to August 2001. To take collection month into account, I will run a mixed-effects model of mean summer biomass with collection month as a random intercept (lmer function in program R) and use the resulting standard error when I plot my data.

Field Experiment

The substantial increase in abundance of *Hydropsyche* caddisflies following the decline of *P. antipodarum* suggests that *Hydropsyche* were likely severely affected by boom levels of *P. antipodarum*. To determine whether the apparent decrease in *P. antipodarum* since 2000-2001 (Hall et al., 2006) likely contributed to the dramatic increase in biomass of *Hydropsyche* larval caddisflies and identify possible mechanisms by which *P. antipodarum* may have suppressed populations of this native invertebrate, I conducted an experiment in Polecat Creek in July 2016 designed to assess interference by *P. antipodarum* with *Hydropsyche*'s ability to feed.

Hydropsyche caddisflies do not graze, but rather they collect and gather food with nets that they spin. I conducted a 10-day experiment to assess whether *P. antipodarum* interfere with *Hydropsyche*'s feeding ability by comparing the condition of *Hydropsyche* nets without *P. antipodarum* and with "boom" and "bust" levels of *P. antipodarum*. Pilot experiments showed that *P. antipodarum* collect in clusters upon *Hydropsyche* nets. Because fouling of nets by snails likely inhibits feeding by *Hydropsyche*, I defined net condition as the presence/absence of a snail cluster (>2 snails). I quantified "bust-level" biomass of *P. antipodarum* by taking 6 stovepipe samples in Polecat

Snail Density	Nets Start	Nets End	*Hydropsyche* Start	*Hydropsyche* End	Pupae	Clusters
Control	4.125	2.625	3.875	2.75	1.125	0
"Bust"	4.25	2.625	4	3.25	1.125	3.375
"Boom"	4.375	3.25	4	3.25	1	4.125

Table 1. Mean number of *Hydropsyche* nets, individual *Hydropsyche* larvae, pupating *Hydropsyche* larvae, and clusters of *P. antipodarum* on larval nets after 10 days of exposure to "boom" and "bust" densities of *P. antipodarum*.

Creek on June 14, 2016 and calculating the mean biomass (5331 mg/m^2) of *P. antipodarum* using a length/mass regression formula (Hall et al., 2006). Because I sampled in June 2016, I quantified "boom-level" biomass of *P. antipodarum* by calculating mean biomass (14,170 mg/m^2) of *P. antipodarum* from June 2001 data (Hall et al., 2006).

I set up the field experiment approximately 0.5 km downstream from the location on Polecat Creek where I collected macroinvertebrate samples. I attached wooden tiles (12x8.5x2 cm) with 5 mm x 10 mm longitudinal grooves to the bottom of experimental chambers (Figure 1). For experimental chambers, I used modified, square plastic sandwich containers (144 cm^2) with mesh (600-μm) windows on the top and sides to keep invertebrates in the chamber and allow fresh, oxygenated water to flow through the chamber. I anchored all 24 chambers to the streambed of Polecat Creek by attaching them to bricks (Figure 2). I drove metal stakes into the streambed approximately 0.5 meters upstream of chambers to collect floating algal mats that could obstruct water flow through the chambers. I calculated the mean length of 51 adult *P. antipodarum* collected from Polecat Creek and used a length/mass regression equation (Hall et al., 2006) to determine average biomass of an adult snail. In this way, I determined the number of adult snails to add to the cages to simulate "boom" (430 snails) and "bust" (162 snails) densities of *P. antipodarum*. I collected *Hydropsyche* larvae from Polecat Creek and placed four individuals into separate grooves on each wooden tile within 24 chambers (Figure 1). After allowing 24 hours for *Hydropsyche* larvae to establish on the tiles and build nets, I recorded the number of nets on each tile. I then added the appropriate number of snails to eight "boom" density chambers and eight "bust" density chambers, leaving the remaining eight cages without any *P. antipodarum* as controls (Figure 3). I recorded the condition and number of nets present following 10 days of exposure to "boom" and "bust" levels of *P. antipodarum* and controls with *P. antipodarum* absent. After 10 days in Polecat Creek, I counted the number of remaining nets in each treatment and whether an existing net had more than two snails attached to it (a cluster; Figure 4).

Preliminary Results

Boom/Bust

Unfortunately, the arduous task of sorting, identifying, and measuring macroinvertebrates from core samples I collected is ongoing, so I cannot report the biomass of macroinvertebrates from Polecat Creek at this time.

Field Experiment

After 10 days, the mean number of *Hydropsyche* nets decreased across all treatments. However, the mean number of *Hydropsyche* nets present on tiles after 10 days differed little among treatments (Table 1). In fact, more nets remained on tiles exposed to the highest density of *P. antipodarum*. The mean number of individual *Hydropsyche* larvae present after 10 days also decreased, but showed little variation among treatments. The mean number of clusters that occurred on *Hydropsyche* nets did not differ significantly between the two treatments that included *P. antipodarum*.

Conclusions

The results of this experiment show that *P. antipodarum* do not actively destroy *Hydropsyche* nets. The presence of *P. antipodarum* had no significant effect on the number of remaining *Hydropsyche* nets present after 10 days in Polecat Creek (Table 1). Considering the high density of snails in the "boom" level treatment (430 snails/cage), this is surprising. Many of the nets present, however, had clusters of snails on them. Because *Hydropsyche* larvae eat food trapped in their nets, clustering of snails may inhibit their ability to feed, even if the net is not entirely destroyed.

Unexpectedly, some *Hydropsyche* larvae began pupating during the course of the experiment. So their silk nets, and the snail clusters upon them, acted as puparia, not structures used for feeding. It is possible that snail clusters inhibit feeding by larvae and prompt early pupation/emergence to escape poor feeding conditions. But my results showed no significant difference in the number of pupating larvae among treatments.

Future Work

Even though my experimental cages were sufficient to allow *Hydropsyche* larvae to establish and build nets on tiles, they still fell short in providing natural water flow and need to be improved. Larvae built nets facing the opposite direction of the water flow in the creek, whereas under natural conditions they build nets that face into the flow. This alone suggests that the conditions inside the experimental cages were much different than the outside environment. Because containing animals in a specific area is required to manipulate snail density, an artificial stream setup may be required for future experiments. In that way, flow can be undeterred by mesh screens similar to what I used, but still adequately contain animals for manipulation of snail density.

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