# Does Rusty Crayfish (*Orconectes rusticus*) ability to resist current differ with home environment?

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**Abstract**

Rusty crayfish (*Orconectes rusticus*) have been invading northern Michigan waterways and displacing native species of crayfish for decades, aided by advantages in aggressiveness and ability to resist current. Previous studies have suggested that organisms of the same species can develop phenotypic differences depending on if they live in lentic or lotic environments. These changes are thought to result from adaptation to the difference in water velocity between the two systems. Our study investigated ability to resist current in *O. rusticus* from two sources in Northern Michigan, Carp Lake River and Burt Lake. We hypothesized that *O. rusticus* from Carp Lake River have a better ability to resist currents than Burt Lake *O. rusticus*. To test this, river and lake crayfish were placed in a propeller-driven laboratory flume and subjected to increasing water velocities in order determine the maximum flow they could withstand. Results from the study suggest no statistically significant difference in ability to resist currents between the two populations. Furthermore, no correlation was found between crayfish length, weight, tail width, and resistance to flow. Lack of a statistically significant difference between the two populations is hypothesized to be due to low water velocities, insufficient time for evolution, or absence of any evolutionary or developmental difference between the two populations.

**Introduction**

Evolution is often thought to occur over extremely long periods of time (Darwin, 1859). Recently, however, studies have shown that this is not always the case (Cameron et al. 2013; Candolin & Wong, 2012; Haas et al., 2010). Researchers have found that populations can evolve over the course of just a few generations when presented with significant environmental changes. This rapid evolution is theorized to help organisms respond and adapt to rapid shifts in environments (Candolin & Wong, 2012).

Organisms that reside in lakes are presented with different environmental conditions than those that reside in rivers (Wetzel, 2001). Given that rivers are lotic (have flow) while lakes are lentic (do not have flow) (Rosset et al., 2017), river organisms are more likely exposed to higher levels of water velocity than are lake organisms. River organisms may encounter challenges to movement and navigation which are not experienced by organisms in lakes. Past studies have already noted differences between populations of organisms of the same species that reside in lentic and lotic systems. An experiment conducted by Haas and colleagues in 2010 demonstrated phenotypic changes within *Cyprinella venusta*, a species of river fish, after a dam was put in and transformed part of the river into a lentic reservoir.

Our study focuses on the potential evolution or phenotypic plasticity of Rusty crayfish (*Orconectes rusticus*), a species of crayfish that is invasive to rivers and lakes in Northern Michigan. We hypothesized that *O. rusticus* collected from a river would be more resistant to flow than those collected from a lake. The difference between the two populations could be explained by one of two potential mechanisms. Crayfish from the river may have evolved adaptations that allow them to be more resistant to flow and thus better suited to their environment. In this case, the two populations of crayfish would be genetically different

(Futuyma, 2013). Increased current resistance in river crayfish may also be due to phenotypic plasticity resulting from the environment in which the organisms matured. River crayfish could, for example, develop stronger swimming muscles because they grew up in running water where swimming is more difficult (Haas et al., 2010).

Our study seeks to investigate flow resistance by testing crayfish from two environments, Carp Lake River and Burt Lake, and may be important for ecological reasons. *O. rusticus* have been effective invaders, in part because of their ability to withstand higher currents and outcompete native *Orconectes* species (Foster & Keller, 2011). Further investigation may provide insight into whether this trait can continue to evolve and give *O. rusticus* an even larger advantage over native crayfish species. This study also has the potential to add to the current body of evidence supporting the occurrence of evolutionary changes on a short time scale (i.e. Cameron et al., 2013).

This study looks at impedance velocity, which is the velocity of flow against which crayfish can move upstream, and serves as an indicator of flow resistance ability (Foster & Keller, 2011). We hypothesize that crayfish taken from Carp Lake River will have a higher maximum impedance velocity than those taken from Burt Lake due to differences in environment.

## Methods

**Study Sites.** We studied *O. rusticus* found in the Carp Lake River and Burt Lake, located in Emmet County and Cheboygan County, Michigan, respectively. At Carp Lake River, crayfish were collected at a culvert that ran under Munger Road (45°40'48.2"N 84°48'49.7"W). Burt Lake crayfish were retrieved just off the shore of the lake (5°32'23.0"N 84°39'44.0"W).

**Study Organisms.** In Carp Lake River, crayfish were collected using sardine-baited minnow traps, nets, and fishing by hand. *O. rusticus* were retained, and other species returned to the source. We transported study crayfish in a bucket to the UMBS Stream Research Facility (45°33'52.7"N 84°45'03.6"W) where they were kept and tested. *O. rusticus* from Burt Lake that were previously collected by other researchers were used. We allowed lake crayfish to roam freely in a tub supplied with running water from the East Branch of the Maple River. In contrast, river crayfish were kept individually in perforated plastic containers in the same tub. We contained river crayfish so we could differentiate between individuals from the two collection sites, but keep water conditions, food source, and other factors consistent between the groups. Both river and lake crayfish ate detritus that entered the the tub naturally with running water. After testing, crayfish from both sources were kept in containers labeled with subject number and test date for later identification.

**Measuring Impedance Velocity.** We measured impedance velocity for 39 *O. rusticus* (n = 21 river crayfish, n = 18 lake crayfish). We alternated between testing river and lake crayfish. Crayfish were randomly selected from the tank, and no individual was tested more than once. Immediately before testing in the flume, physical measurements of each crayfish were recorded. We measured crayfish length from eyes to end of tail, as well as the width of spread tail to the nearest millimeter using a ruler. Masses were taken using a Sartorius Basic scale balance. Any visible physical impairments were noted (e.g. missing appendages, obvious wounds).

Impedance velocity was evaluated using a propeller-driven laboratory flume originally designed by Foster and Keller (2011). The body of the flume consisted of an acrylic tank through which Maple River water was circulated. Flow velocity within the flume was manipulated with a rheostat-controlled propeller. A digital tachometer displayed RPM of the propeller. We inserted a plastic collimator (25.0 cm long × 15.0 cm high × 17.8 cm wide with 0.7 × 0.7 cm openings) designed by Foster and Keller (2011) in the upstream portion of the flume to limit fluctuation in water velocity due to propeller rotation. The working segment of the flume was 1 m long, however, we inserted screens to create a 50 cm testing section in which crayfish could be easily contained and observed.

Crayfish were placed in the screened off portion of the flume and oriented against the current. We began flow at 800 RPM (28.24 cm/s) and increased speed approximately 100 RPM every 30 seconds. We determined maximum impedance velocity to be the point when crayfish could not longer make progress upstream. Slipping was not considered a stop in upstream movement if the crayfish recovered and made forward progress past the point where the slip occurred. If an individual swam downstream for more than 30 seconds, we reoriented them using a net, and gave an additional 30 seconds to recover forward progress before increasing RPM. Crayfish that refused to swim upstream at all were removed from the study after several attempts at reorientation. We recorded RPM at the halt of upstream progress. RPM data were converted to water velocity using the linear regression model laid out in Foster and Keller (2011): flow rate = 0.0004(RPM) - 0.0376 ($R^2$ = 0.99). Foster and Keller’s (2011) model was assumed to be applicable to our data due to the use of the same flume system, including the same propeller and motor.

**Analysis.** We used SPSS (IBM, North Castle, NY) for statistical analysis. Regression tests and ANOVA tests were run to look for correlations between length and maximum impedance velocity, weight and maximum impedance velocity, and tail width and maximum impedance velocity.

**Results**

The length of each crayfish did not correlate with its maximum flow impedance (ANOVA, $R^2$ = 0.087, *p* = 0.068; Figure 2). Individual mass also did not correlate with its maximum flow impedance (ANOVA, $R^2$ = 0.065, *p* = 0.117; Figure 3), nor did tail width (ANOVA, $R^2$ = 0.043, *p* = 0.205; Figure 4).

Average maximum impedance flow (± SE) for Carp Lake River crayfish was 60.166 ± 2.57 cm/s, and average impedance flow for Burt Lake crayfish was 64.747 ± 3.16 cm/s. The means did not differ significantly between the two sites (Welch's t-test, *t* = 0.276, *p* = 0.392; Figure 1).

**Discussion**

According to our data, mass, length, and tail width did not correlate significantly with individual crayfish's maximum flow impedance. It is possible that as crayfish get larger and stronger (Mather & Stein, 1993), their increased surface area also increases drag. The increased drag limits any benefits to mobility that a crayfish may gain from being larger. However, the ANOVA test comparing individual body length and mass to maximum flow impedance returned *p*-values of 0.068 and 0.065, respectively. While these are too high to be considered statistically significant, they are close to our alpha of 0.05, warranting further study with larger sample size. We concluded from these results it was not necessary to group crayfish based on mass and length because they appeared to have no influence on maximum impedance velocity.

We found no significant difference between the average impedance velocity of Carp Lake River crayfish and Burt Lake crayfish. This led us to conclude that there was no difference in ability to resist currents between crayfish from the two collection sites. These findings did not align with our original hypothesis, which predicted higher flow resistance in river crayfish.

A potential explanation for the results found may be that the water velocity in Carp Lake River is too low to necessitate a change in the river crayfish. If the velocity of the water is not very high, it may not be important for those crayfish to develop mechanisms to better withstand faster currents. It is possible that if river crayfish were taken from a river with very high velocity, there would be more of a discrepancy between maximum impedance velocity of the lake and river crayfish, since river crayfish would have increased flow resistance.

It is also possible that because *O. rusticus* is an invasive species, it may not have been present in Carp Lake River for long enough to evolve changes in flow resistance. The average lifespan of a *Orconectes spp.* is three years (St John, 1976; Momont, 1967). Given this fact, it would take almost a decade for a crayfish population give rise to just a few generations. If *O. rusticus* were recently introduced to Carp Lake River, they may have not had sufficient time to evolve better flow resistance than that seen in Burt Lake crayfish. *O. rusticus* in Carp Lake River could still be evolving, and, in the future, might demonstrate abilities different than those of lake crayfish.

Lastly, it is possible that no evolutionary or developmental difference in current resistance exists between the two crayfish populations. *O. rusticus* could have basic physiological states that allow them to withstand a certain range of water velocities across the species. These base abilities would mean that they do not need to evolve mechanisms to withstand higher currents. River *O. rusticus* and lake *O. rusticus* may possess the same ability to resists flow, but it may only be utilized in lotic environments.

This study was subject to several limitations. Size distribution and number of crayfish were limited to what we were able to catch within the time frame of study, leading to small sample sizes. Additionally, we did not run tests at night, when crayfish are more active (Helfrich & DiStefano, 2009). While this should not have a large effect on their ability to resist flow, it is possible that performance would be improved by testing later in the day. Another potential problem was the unpredictability of crayfish behavior. We did not put food or odor in the water to encourage upstream movement, and relied on crayfish choosing to swim in the desired direction. This led to some complications when individuals refused to move upstream and had to be repeatedly redirected, or even excluded from the data. The environment in which tests were performed could also have affected crayfish behavior. The flume did not contain the same type of environmental conditions that would be experienced by crayfish in a lake or river. To correct this in the future, we could attempt to create an environment more similar to the one in which crayfish typically reside. Continuing studies could improve upon these issues.

Further study of this topic is important and relevant to our understanding of the *O. rusticus* as an invasive species, and our understanding of the heritability of flow resistance. In addition to the aforementioned improvements to our methods, studies could examine the potential for crayfish to be trained to have a higher impedance velocity. This would reveal whether crayfish flow resistance abilities are being developed by living in lotic environments, or if genetic differences have arisen in different populations. In addition, the velocity of the water from which the crayfish were collected from could be determined. This would give insight as the whether the flow rate of the river corresponds to the maximum impedance velocity of the crayfish.

**Acknowledgments**

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Figures

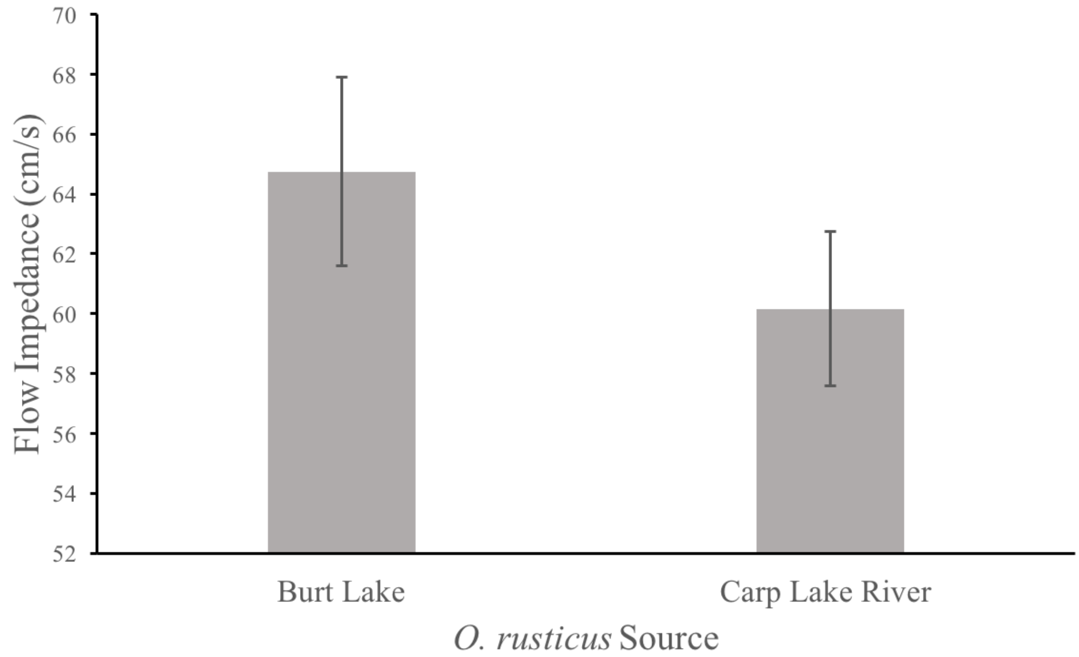


Figure 1. Means and standard error of flow impedance of *O. rusticus* from Burt Lake and Carp Lake River

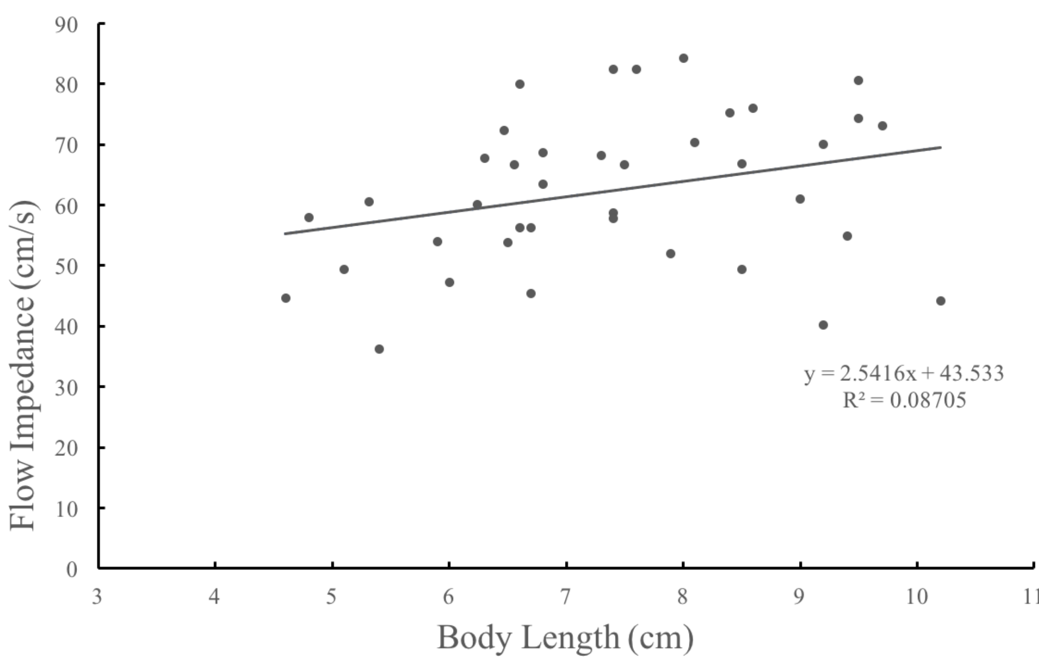


Figure 2. Line of best fit between *O. rusticus* body length and maximum flow impedance. The ANOVA test found no significant correlation between the two variables ($p = 0.068$).

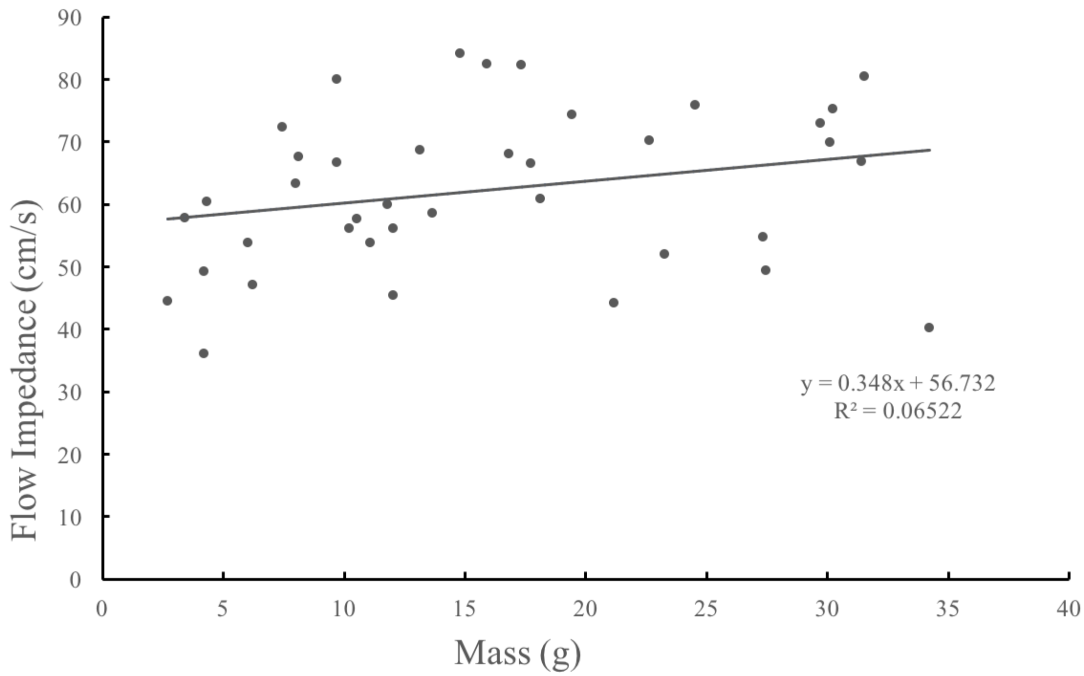


Figure 3. Line of best fit between *O. rusticus* mass and maximum flow impedance. The ANOVA test found no significant correlation between the two variables ($p$ = 0.117).

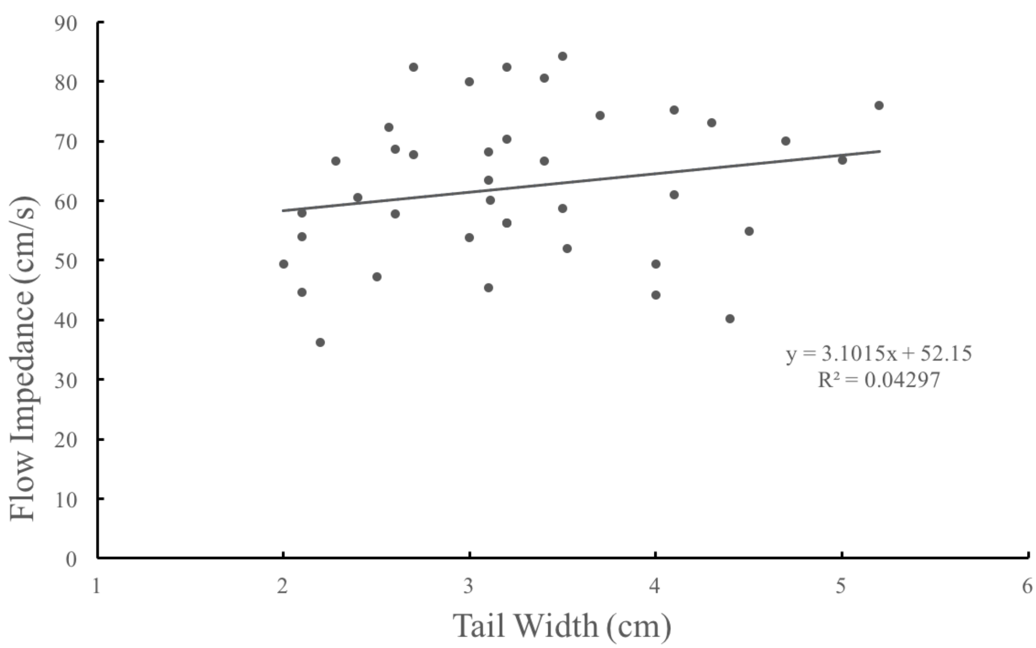


Figure 4. Line of best fit between *O. rusticus* body length and maximum flow impedance. The ANOVA test found no significant correlation between the two variables ($p$ = 0.205).