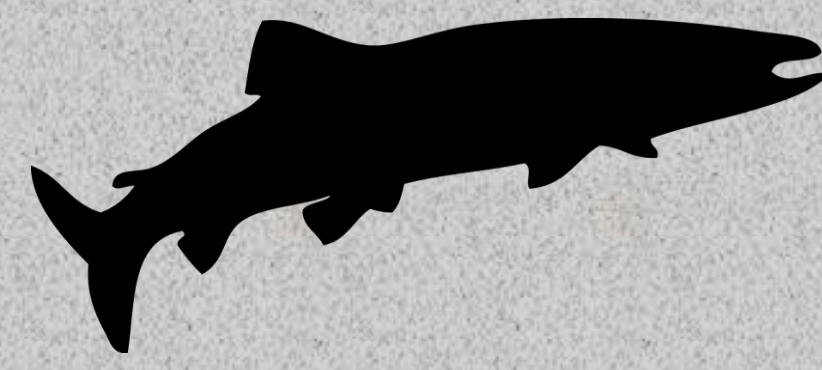


Rapid Adaptation of Early Life History Traits in Great Lakes Chinook Salmon



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Rapid Adaptation

Evolution is taking place all around us! Populations have been shown to develop genetic adaptations to rapidly changing environmental conditions on contemporary time scales. Organisms can also adapt via phenotypic plasticity. Our research focuses on the adaptive scope of Pacific salmon (*Oncorhynchus* spp) early life history traits to new or altered conditions.

Salmon in the Great Lakes

Chinook salmon (*Oncorhynchus tshawytscha*) were introduced to the Great Lakes in the late 1960's using embryos from the Green River, Washington. Since then, Chinook salmon have successfully colonized tributaries throughout the Great Lakes with the majority of salmon originating from natural reproduction (~80% [1]). These naturalized populations have had to adapt to a wide variety of environmental conditions specific to each natal tributary.

We are using three study sites located in two of the Great Lakes (Figure 1) to study various aspects of local adaptation and population divergence. Since each study site provides a unique environment, we can understand how salmon adapt in response to various environmental changes.

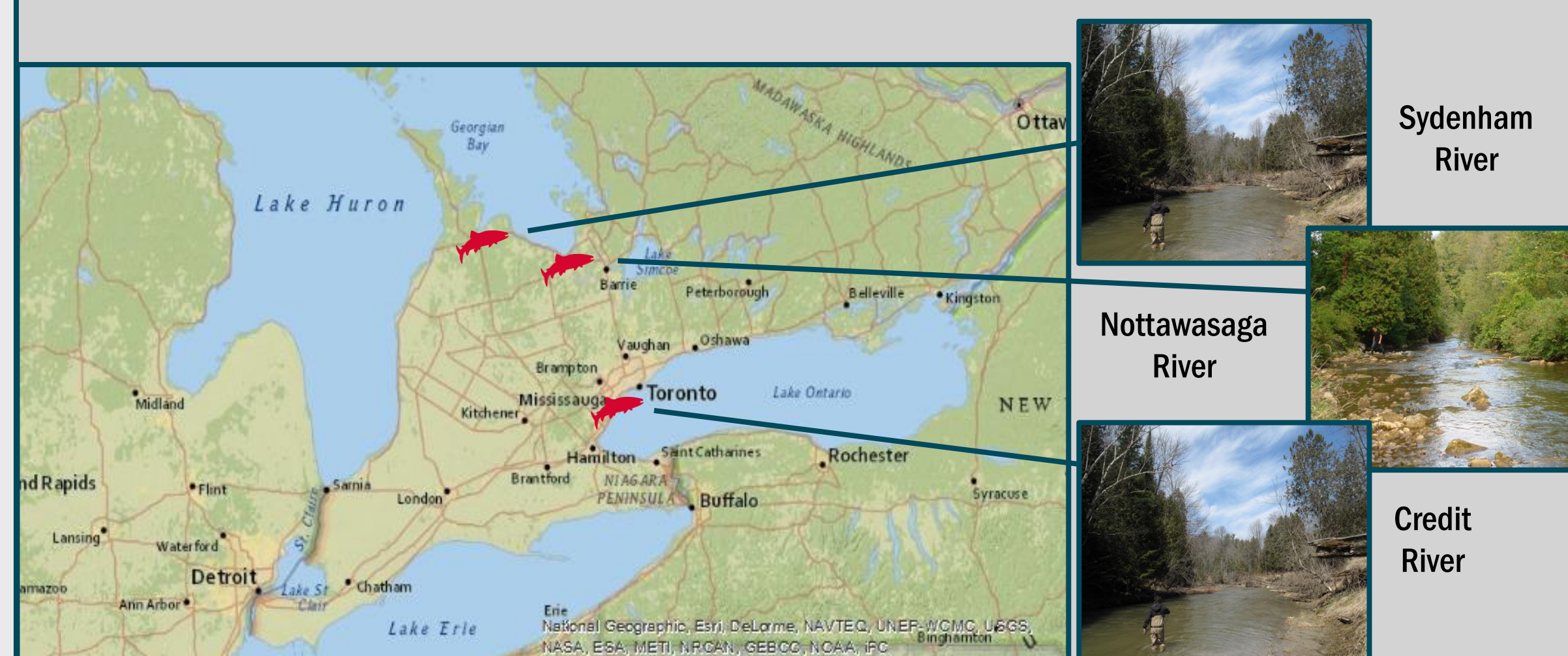


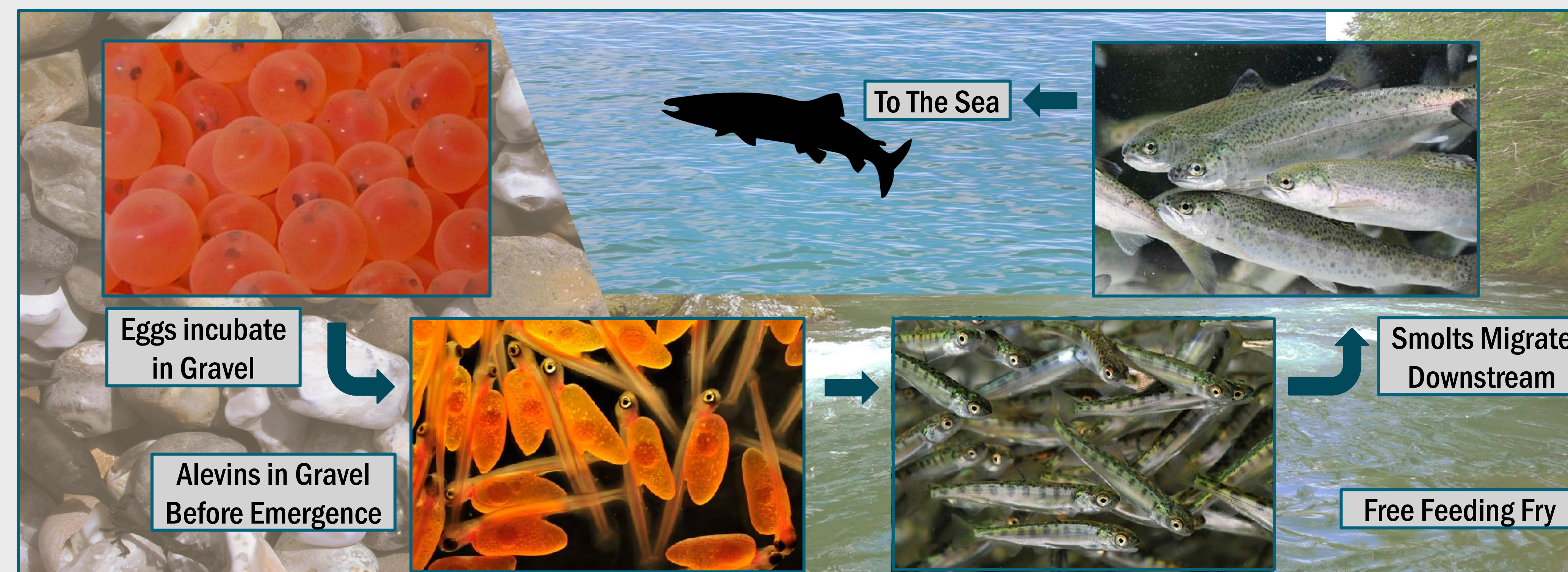
Figure 1. Map of the Great Lakes and the locations of our three main study sites (top to bottom): Sydenham River, Nottawasaga River, and Credit River.

Common Garden Experiments

We raise Chinook salmon in our fish research hatchery at Western from gametes collected in the wild. Each of the three recirculating tank systems is set at a different temperature while all other factors are held constant between systems. This allows us to model the parental, temperature, and growth effects on focal traits.



Early Life History of Chinook Salmon



Phenotypic Divergence

The early life history (ELH) stage of salmon development is highly vulnerable to environmental change and there is growing concern about how salmon populations will respond to increasing environmental disturbance (i.e. climate change). To address this, we are investigating the adaptive potential of ELH traits by studying the patterns of phenotypic divergence among Great Lakes Chinook salmon populations. We are especially interested in how egg size mediates the adaptive response of ELH traits.

Our approach uses hatchery experiments to compare ELH traits among populations and to separate the sources of variation influencing these traits such as egg size, genetic, and environmental effects (Figure 2).

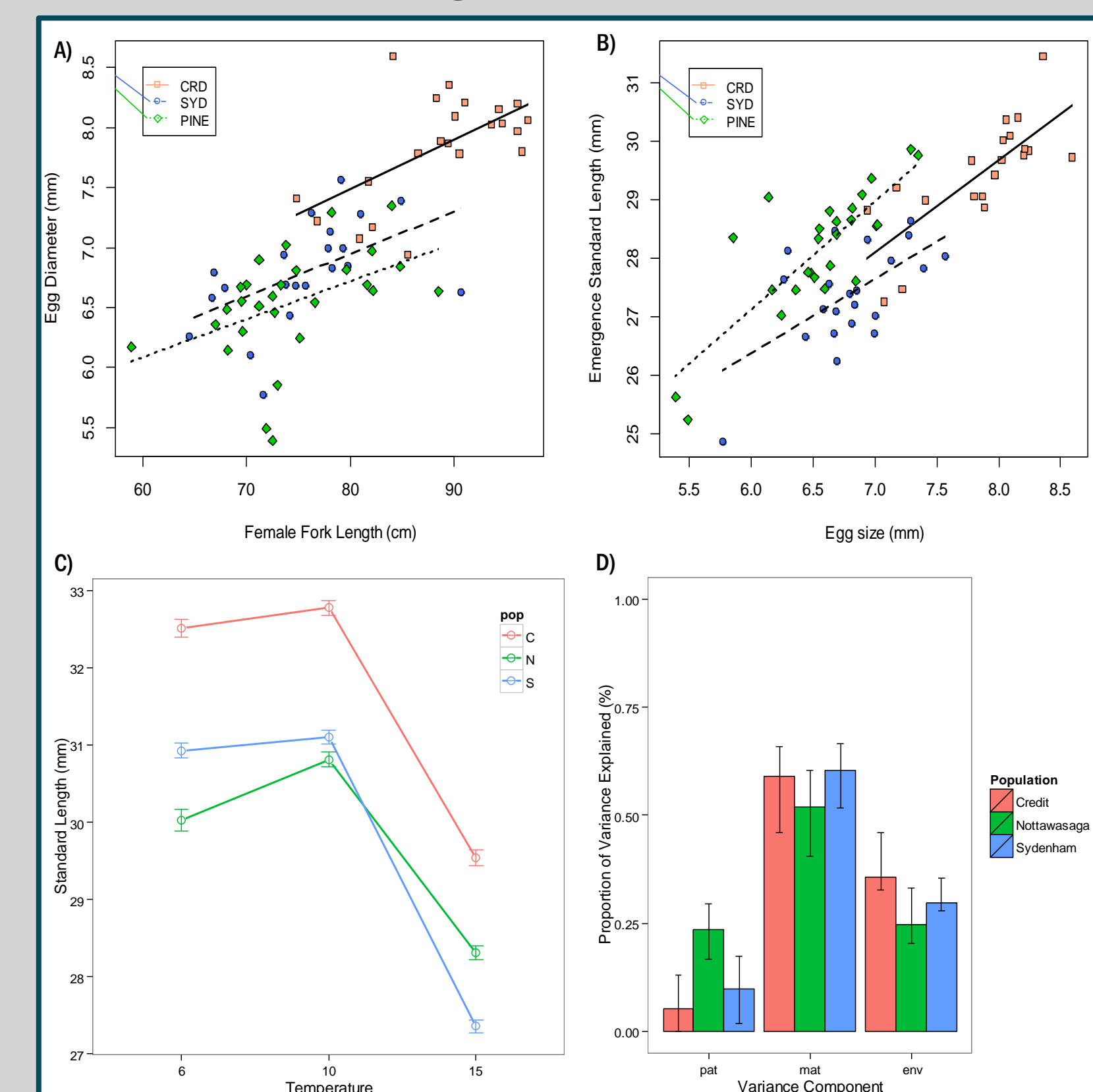


Figure 2. Plots from a 2012-2013 hatchery study comparing: A) egg size; B) standard length at emergence; C) the reaction norm of emergence length; and D) the genetic architecture of emergence length among the Credit, Nottawasaga, and Sydenham Rivers. The three variance components are paternal, maternal and environmental effects.

Selection Regimes

Salmon bury their fertilized eggs within the gravel substrate of a tributary. During this time, the developing embryos are sensitive to changes in fine sediment deposition, dissolved oxygen content, and temperature. We are using in-situ rearing experiments to tackle two questions: 1) how does rearing habitat influence Chinook salmon embryonic survival; and 2) how is selection acting on egg size among Great Lakes populations? Using in stream incubators, we are rearing embryos in three river systems and tracking their environmental conditions until they hatch. These incubators are removed 10 days post hatch and the hatched alevins counted (Figure 3).



Figure 3. Pictures from the 2012-2013 incubator study showing: A) eyed embryos prior to placement in incubator; B) an incubator ready for installation; C) M. Thorn measuring environmental conditions; and D) live alevins in incubator at cessation of study.

Migration Timing

Ocean-type Chinook salmon, like those introduced to the Great Lakes, migrate downstream in their first year after hatching. This drastic niche shift allows them to access the greater abundance of food in the lake, where >90% of their biomass is achieved before returning to freshwater to spawn. Smoltification is the suite of morphological, behavioural and physiological transformations in freshwater to prepare them for the migration and survival in the ocean. The success of this niche-shift depends a match between the optimal environmental conditions and the timing of smoltification and migration.

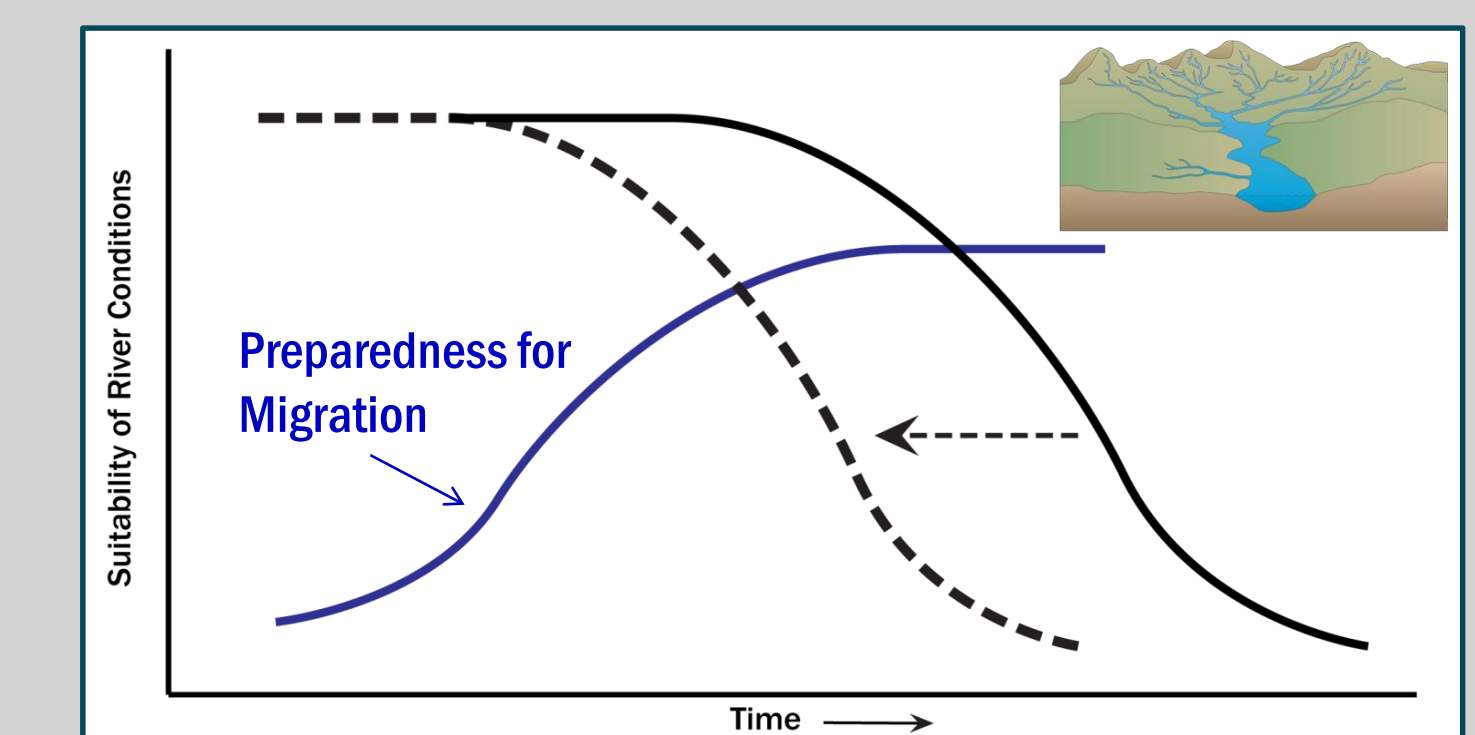


Figure 4. Warming temperatures are expected to lead to earlier deterioration of river conditions (i.e. the ecological window closes earlier). It is unknown how juvenile preparedness (i.e. the opening of the physiological window) for the migration will change.

Climate change in the Northern hemisphere is expected to bring warmer temperature. This will lead to earlier deterioration of river conditions for salmon, such as low flow and high temps (Figure 4). The pressure will therefore be on individuals to smolt and migrate earlier. We are studying whether there is a seasonal decline in size as smoltification and migration because of the trade-offs between deteriorating conditions and the need to reach a size threshold. There is already evidence from other rivers that early migrants have higher fitness in other Chinook populations [2] but no study into the smoltification, size or seasonal decline (Figure 5).

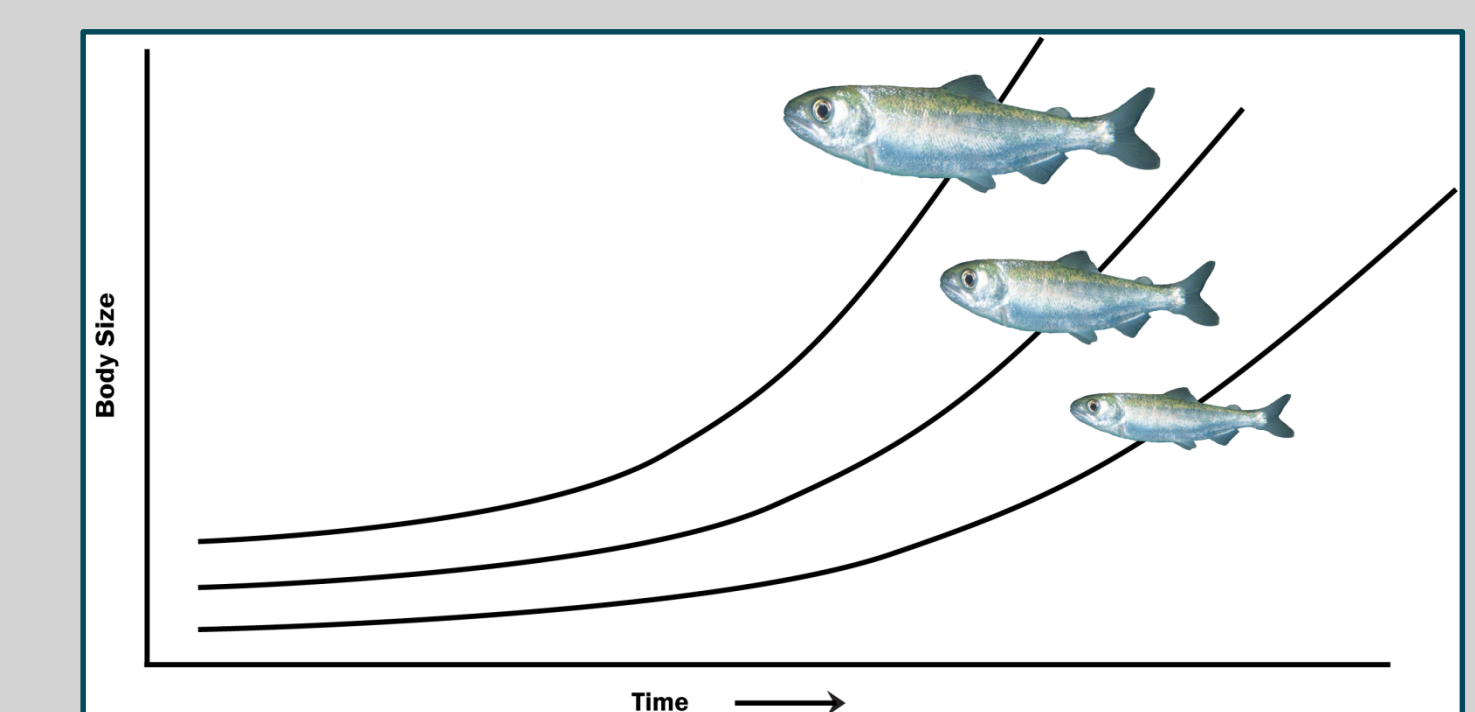


Figure 5. There are many reasons for differential growth rates between individuals of a cohort. Those individuals with slower growth are expected to smolt at smaller sizes because of a plastic response to seasonal progression and the closing of the ecological window for downstream migration.

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- Johnson, J.E., DeWitt, S.P., and Gonder, D.J.A. (2010). *Journal of Great Lakes Research* 30(2): 518-529.
- Scheuerell MD, Zabel RW, Sandford BP (2009). *Journal of Applied Ecology* 46: 983-990.