How Does Environmental Heterogeneity Influence Widespread Populations? Examples from the St. Lawrence System

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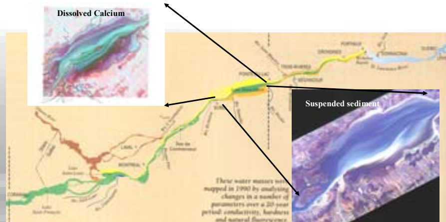

Figure 1. Environmental Heterogeneity (i.e. water masses) of the St. Lawrence[1].

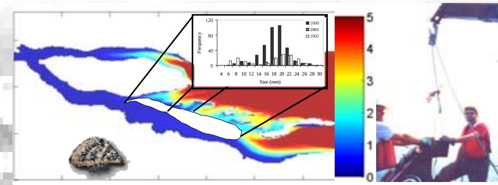

Figure 4. Spatial distribution and population demographics of zebra mussels in the estuarine transition zone, 2000-2002 (color corresponds to salinity in PSU)[2].

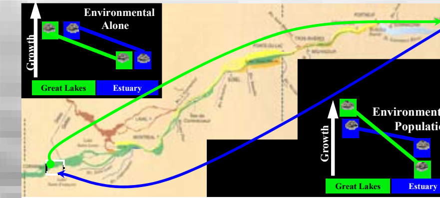

Figure 6. Mussel transplant locations and theoretical outcomes.

Study 1: The rising cost of living: growth, condition, & allometry in a river-estuary.

Objective:

Dreissena have colonized a gradient of river habitat-conditions that affect their growth. This study compared both allometric and physiological indicators of condition in the four principal water masses of the Saint-Lawrence River (Fig. 1). I suspected that growth [mm day^{-1} over ~60 days] would be largely uniform among the water masses, but bioenergetic costs of maintaining that uniformity (as measured by both the slope of a site specific length-biomass regression and as well as a mussel condition[AFDW/Shell Length*1000, n = 25]) would vary based on environment conditions.

Hypotheses:

H_0: No consistent differences in size-biomass or condition among sub-populations

H_{a1}: There is consistent co-variation in both allometry & condition : the poorest habitats are the low ionic Ottawa River & turbid Estuary waters.

H_{a2}: There are differences in condition but not allometry : physiological compensation for the local "cost of living" maintains growth in the the poorest habitats.

Results:

-Both mussel condition and growth rate do vary among water masses (Fig. 2).

-*But* growth is not positively correlated with condition in a intuitive manner (Fig. 2).

-Reject H_0, allometry suggests that the estuary is the best growth environment and the Great Lakes the worst (Fig. 3)

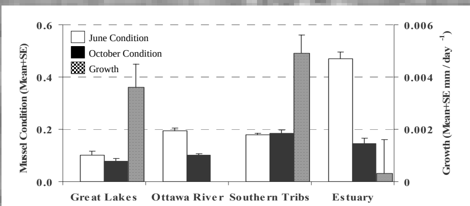

Figure 2. Changes in mussel condition (June in white and Oct in black) and summer growth (in gray) in the main water masses.

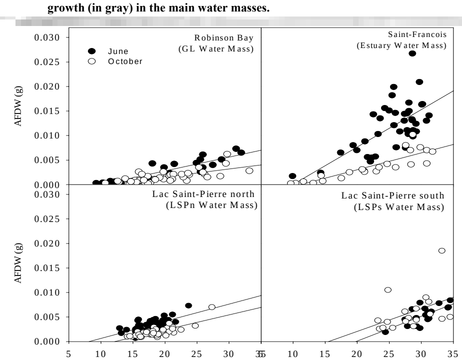

Figure 3. Seasonal allometric water mass relationship (June = white, Oct = black).

Study 2: Life on the edge: *Dreissena* in the estuarine transition zone.

Objective:

Dreissena passively regulate cellular salts, thus making ambient salinity a key factor limiting their distribution. Previous research has found dramatic fluctuations in the estuarine plankton community coinciding with *Dreissena*'s arrival. In order to evaluate whether *Dreissena* populations in this zone are responsible for the declines, we determined the spatial extent and population size of *Dreissena* with Ponar grab samples across the freshwater-saltwater transition. Following up we tested the effect of salinity on mussels directly with experimental analysis of different salinity regimes on mussel growth and condition [via a 32 day growth experiment under 3 salinity treatments, n = 360].

Hypotheses

H_0: Adult mussel growth and distribution in the estuary is limited to exposure (period of time and maximum PSU) of the tidal intrusion of the salt.

Results:

-*Dreissena* distribution in the estuary corresponds to the limit of the salt intrusion (Figure 4).

-However recruitment in this zone is inconsistent and the population is aging and declining (Figure 4 inset).

-Reject H_0, experiments indicate highest shell growth rates in a fluctuating salinity environment similar to the estuarine transition zone (Figure 5).

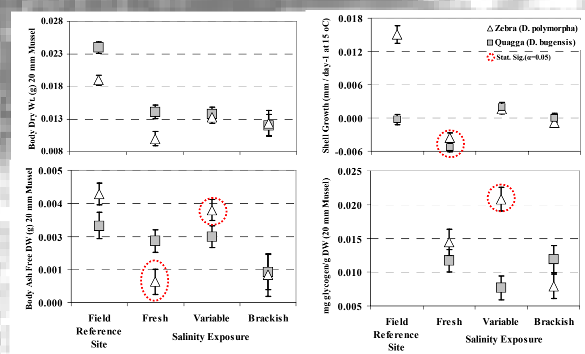

Figure 5. LS Means and SE (n_{trt} = 16) from a 30 day growth/salinity experiment. (fresh = continuous 0 PSU, variable = 0 – 2 PSU, brackish = continuous 2 PSU).

Next steps for this research program?

- Look for larger-scale/continent-wide clines?
- Explore bioenergetic trade-offs (explore somatic vs shell growth)?
- What about native versus invasives(Qaugga, *Mytilopsis*) – same pattern?
- Mechanism of population differentiation? selection on larvae, developmental or individual plasticity, genetic isolation?

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Study 3: Acclimation, adaptation, or plasticity? Evidence from reciprocal transplants.

Objective:

With its large-scale physical-chemical heterogeneity (Fig. 1), the St. Lawrence River is a natural model system for asking questions about phenotypic plasticity and population divergence in aquatic species. Adult and larval *Dreissena* are present throughout the principal water masses and its pelagic stage is roughly equal to the transit time between the Great Lakes and the estuary. This strong gene flow should be a barrier to local genetic adaptation. However a developmental bottleneck that reduces the contribution of drifting larvae to downstream populations is possible[3]. Comparison of the growth of reciprocally transplanted of adults [n = 100 per source-destination combination] constituted a test of phenotypic and genotypic differentiation between sub-populations.

Hypotheses

H_0: Uniform growth of all populations with only site differences = plasticity.

H_{a1}: Varied growth, local mussels will out-perform all others in local environments = local adaptation/acclimation.

Results:

-Summer transplants: Reject H_0 - significant source/destination interaction suggests spatial variation and local acclimation/adaptation (Fig. 7).

-Summer vs Winter transplants: Reject H_0 - seasonal-source specific differences in growth also suggests potential local acclimation/adaptation (Fig. 8a &b).

-Caveat: Growth estimated from changes in shell length are the reverse of results from biochemical methods looking at somatic growth (RNA/DNA ratio) (Fig. 9).

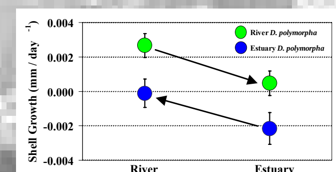

Fig 7. LS Means/SE for daily summer growth rate (60 days).

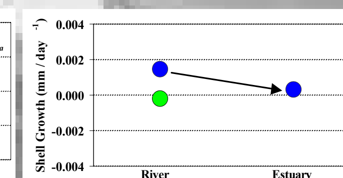

Fig 8a. LS Means/SE for daily winter growth rate (152 days).

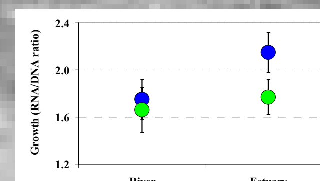

Fig 9. LS Means/SE for summer RNA/DNA ratio.

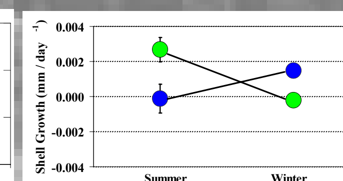

Fig 8b. Comparison of summer and winter *at the river site*.

References:

1) St. Lawrence Centre. 1996. State of the Environment Report on the St. Lawrence River. Quebec Region, Environ.Canada.
2) Simons, RL & S Monismith. Unpublished dissertation data, Stanford University.
3) Schneider, DW et al. 2003. A developmental bottleneck in dispersing larvae implications for spatial population dynamics. Ecol. Lett. 6352-360.