Simulation of juvenile Atlantic salmon movement in the Gulf of St. Lawrence using an individual-based model

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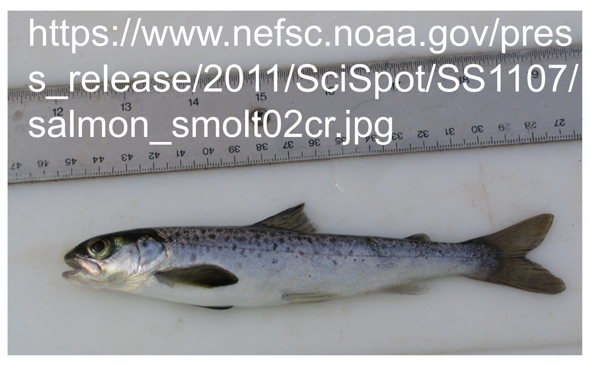
1. Objective

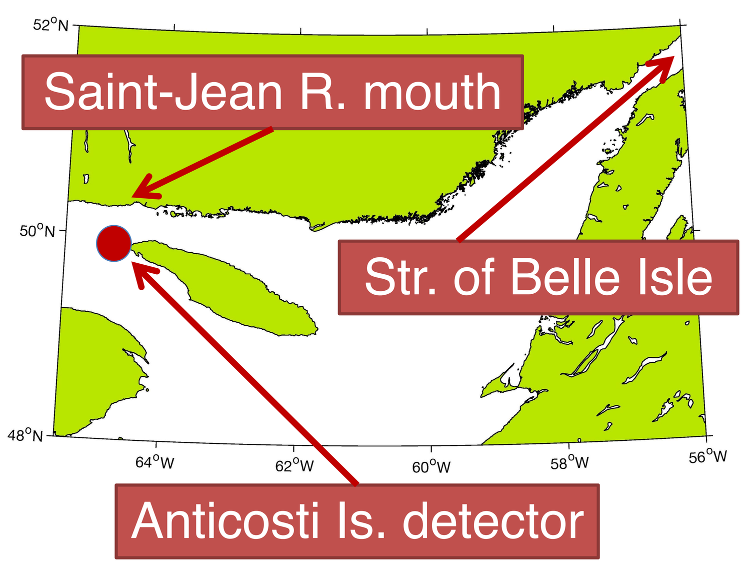
To use an individual-based model to examine the roles of swimming behaviours and environmental conditions in the movement of juvenile Atlantic salmon (*S. salar*) in the Gulf of St. Lawrence, Canada



- Juvenile *S. salar* migrating from their natal rivers to the ocean are called ***smolts*** while in fresh water and ***post-smolts*** when they enter salt water
- High mortality rates during juveniles' seaward migration may be a factor in the decline of *S. salar* populations
- Telemetry (observations using electronic tags and detectors) can provide information on animal movement, but detectors are often several hundred km apart
- Numerical simulations can complement observations by suggesting behaviours and environmental conditions that result in observed animal movements

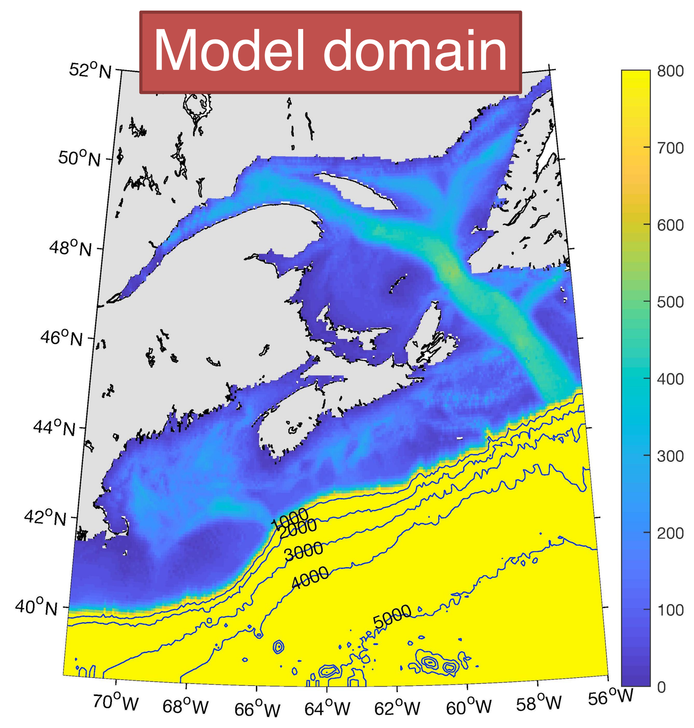
2. Observations

- Lefèvre et al. (2012) tagged and released juvenile *S. salar* from the Saint-Jean River on the north shore of the Gulf of St. Lawrence
- **2009**: 44 smolts were tagged between 14 and 25 June
  - None were detected at the Strait of Belle Isle; detector was not in place at Anticosti Island
- **2010**: 49 smolts were tagged between 3 and 21 June
  - Two left the Saint-Jean R. mouth on 14 June, were detected near Anticosti Is. ~2 d. and ~6 d. later
  - One left the Saint-Jean R. mouth on 9 June, was detected at the Str. of Belle Isle on 23 July (44 d. later)



3. Ocean circulation model

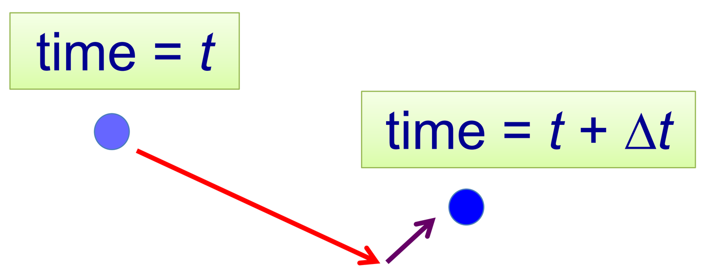
- We use a three-dimensional model based on the Princeton Ocean Model
- Horizontal grid size = 1/16°
- Inputs include tides, atmospheric forcing, freshwater input from rivers
- Simulations have been compared against observations (Ohashi and Sheng, 2013)



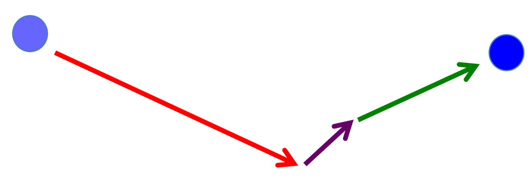
4. Particle-tracking

- The 4th-order Runge-Kutta method is used to track particles' movements due to hourly simulated currents
- Random displacements are added to represent small-scale mixing and other processes not resolved by the ocean circulation model

Passive case:
Advection by currents + "random walk" (representing small-scale mixing)



Cases with swimming:
Advection by currents + "random walk" + displacement due to swimming



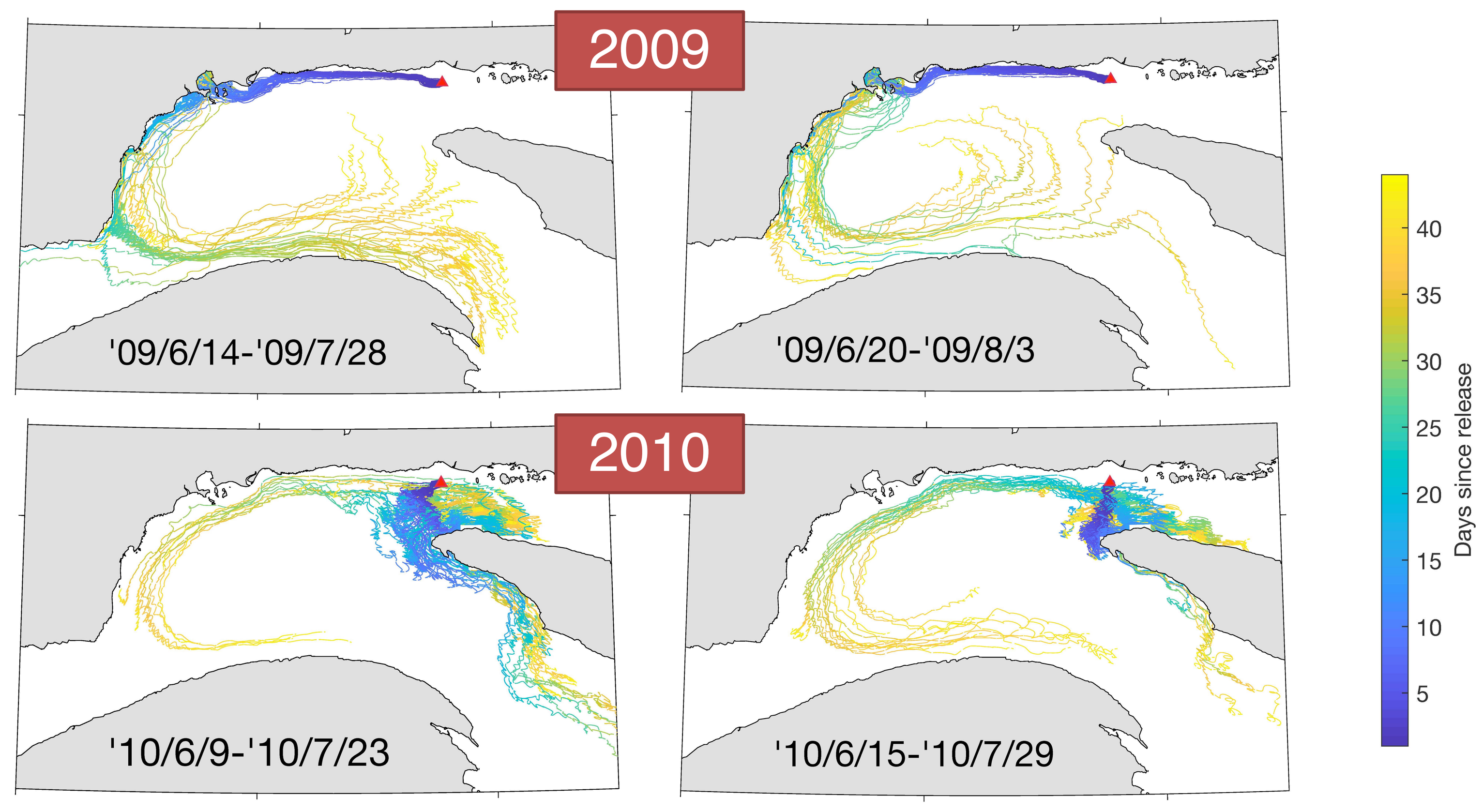
5. Experimental set-up

- Particles were released near the Magpie R. mouth, ~10 km west of the Saint-Jean R. mouth (our model does not include the Saint-Jean R.)
- In cases with swimming behaviour, the swimming speed was 0.2 m s^{-1} (~1.3 BL s^{-1} for a fish of 0.15 m total length)
- Various swimming behaviours were tested; this poster shows some of the successful behaviours; a full discussion appears in Ohashi and Sheng (2018)

6. Results

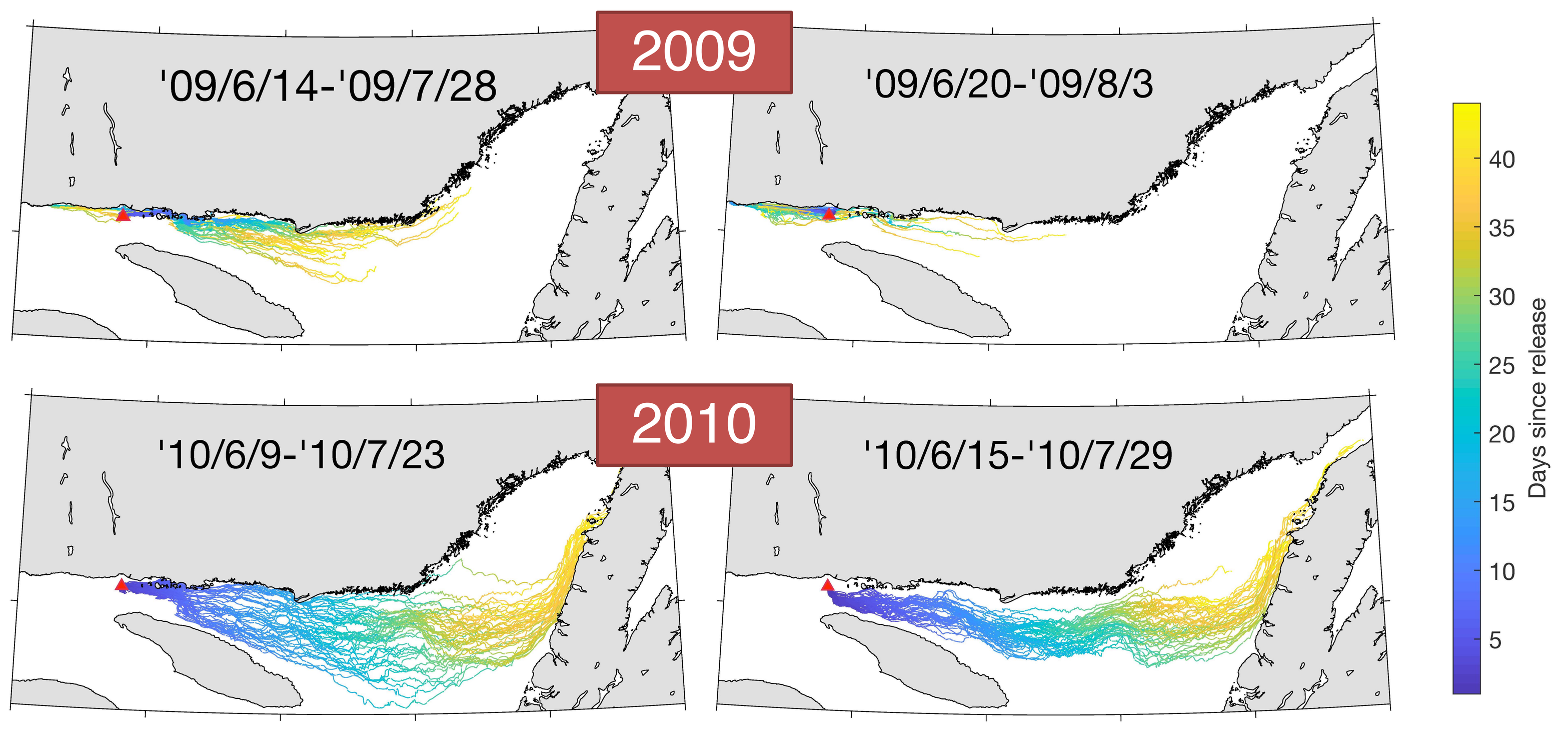
Movement toward Anticosti Island

- Particle trajectories from the passive case are shown below
- They reflect differences in near-surface circulation between 2009 and 2010
- Because of the anomalous southward currents in 2010, passive particles can reach the Anticosti Is. detector location in a few days (similar to observations)
- Behaviours such as swimming in random directions or with a preference for the south also result in travel times similar to observations (not shown here)



Movement toward the Strait of Belle Isle

- Particle trajectories shown below are from the case in which particles swim with favourable (eastward) currents & against unfavourable (westward) currents
- Even with this efficient swimming behaviour, the anomalously weak westward currents in 2010 are necessary to reproduce the observed travel time (44 days)



Conclusions

1. For travel from the Saint-Jean R. toward Anticosti Island in 2010, passive particles as well as particles using a variety of swimming behaviours result in simulated travel times similar to observations
2. For travel from the Saint-Jean R. to the Strait of Belle Isle, simulations need to combine the favourable circulation pattern of 2010 and an efficient swimming behaviour to reproduce the observed travel time
3. The possibility that post-smolts from the north shore of the Gulf of St. Lawrence are sometimes unable to migrate to the open ocean is consistent with past observations (e.g. Dutil and Coutu, 1988)

References

Dutil, J.-D. and Coutu, J.-M., 1988. Early marine line of Atlantic salmon, *Salmo salar*, postsmolts in the northern Gulf of St. Lawrence. Fishery Bulletin 86(2), 197-212.

Lefèvre, M.A., Stokesbury, M.J., Whoriskey, F.G., Dadswell, M.J., 2012. Atlantic salmon post-smolt migration routes in the Gulf of St. Lawrence. ICES Journal of Marine Science 69 (6), 981–990.

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