Simulation of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence

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Outline

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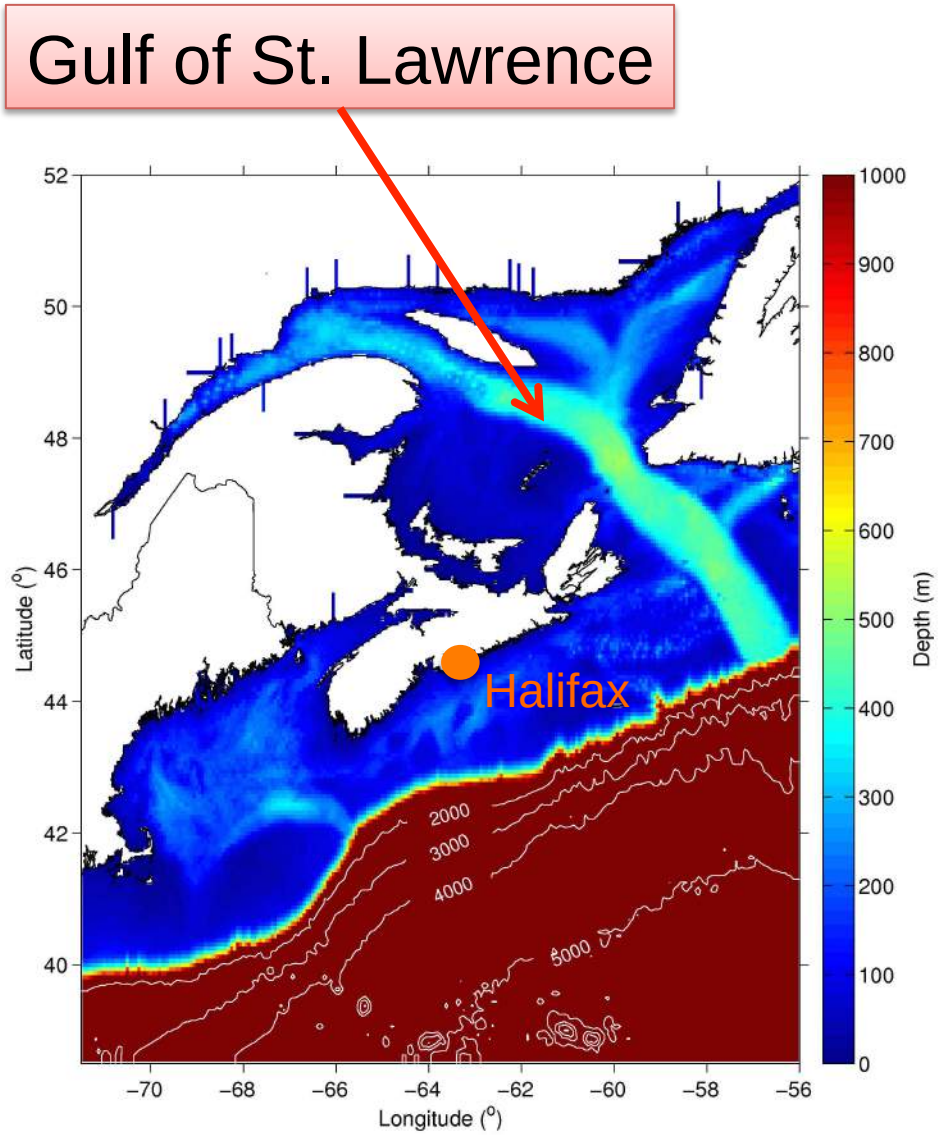
Individual-Based Models

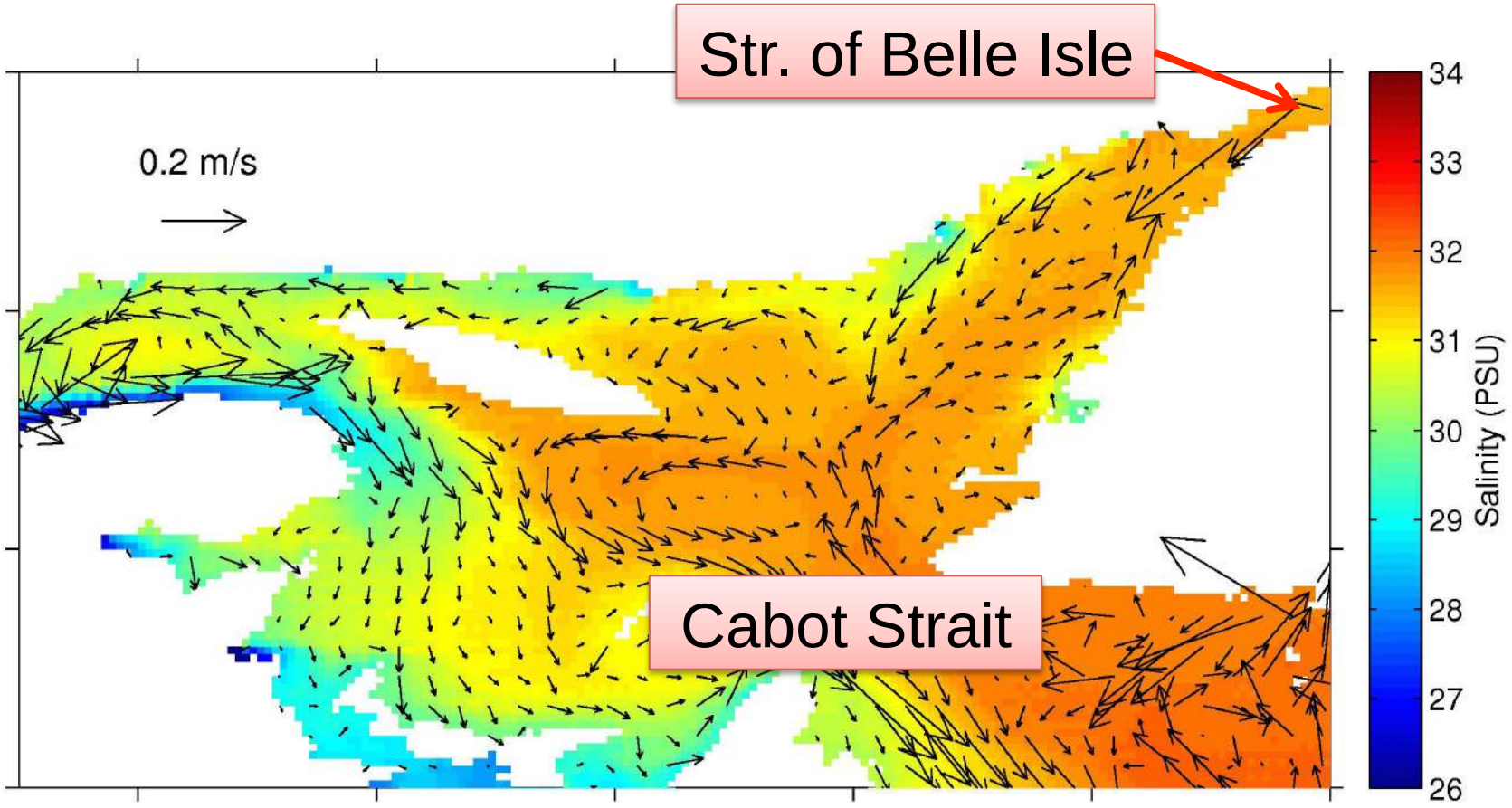
- Ecological models in which populations are represented as: (1) collections of individuals *or* (2) collections of groups of individuals, classified by age, size, etc.
- We use approach #1 in this study
- In contrast to traditional models, where populations are represented by their average properties
- Our model: Simulates movement of particles using: (1) ocean circulation model + (2) particle-tracking scheme + (3) definitions of swimming behaviours

Numerical ocean circulation model



- Simulates 3D fields of currents, T, S
- 1/16^{o} resolution
- Forced at surface by: winds, atm. pressure, heat & freshwater flux
- Forced at boundaries by: tides, long-term mean currents, T, S
- Includes freshwater input from rivers

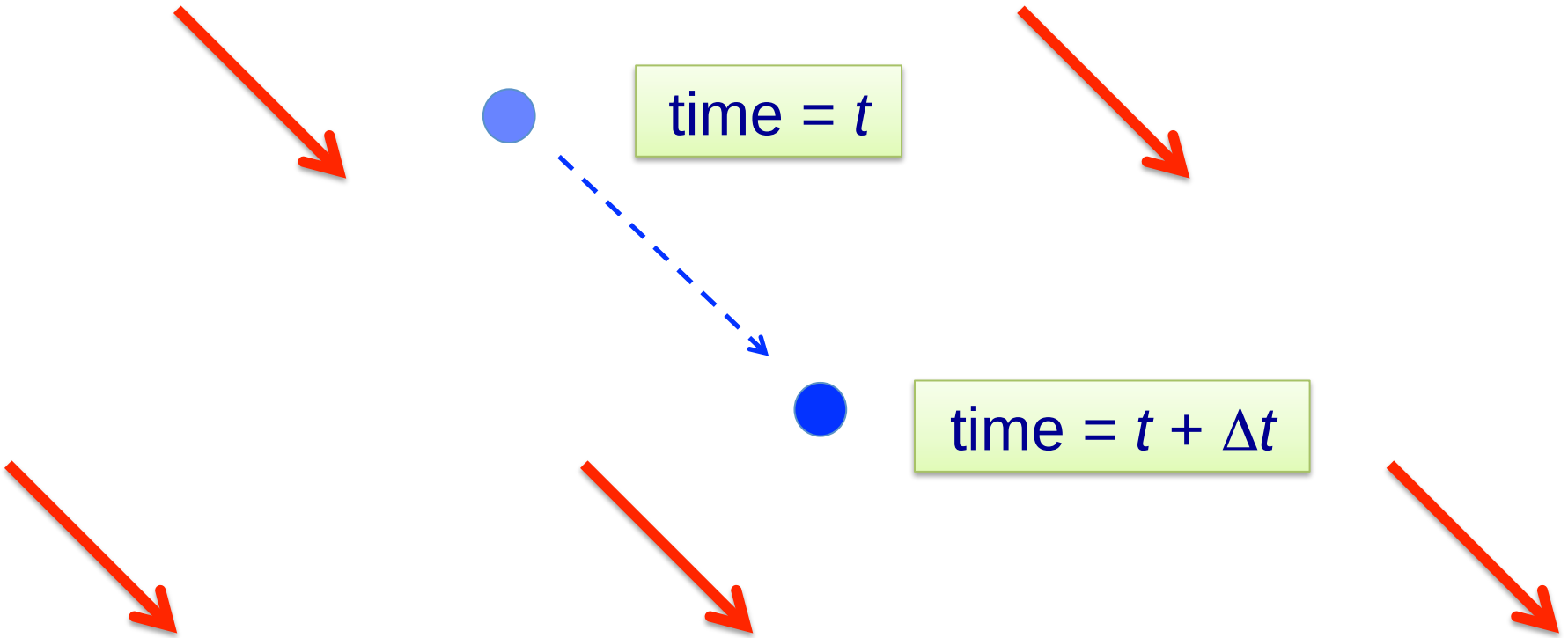
Mean 5-m salinity & currents, June 2010



- Westward currents along north shore

Particle-tracking scheme

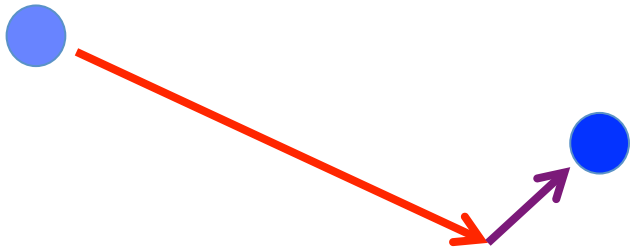
Calculates new position of a particle moved by simulated currents in a given time interval:



Movement of a particle

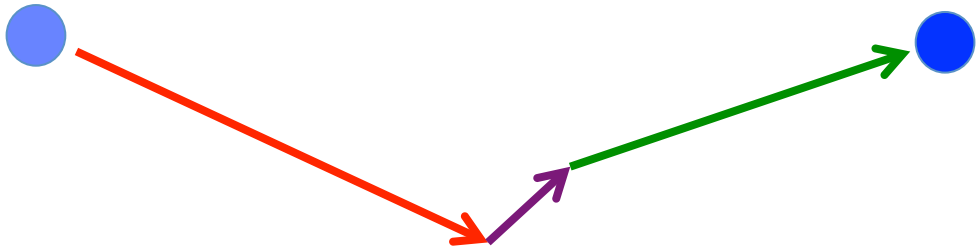
Passive case: Advection by currents + “random walk” (representing small-scale mixing)

time = t



time = $t + \Delta t$

Cases with swimming behaviour: Advection by currents + “random walk” (representing small-scale mixing) + displacement due to swimming



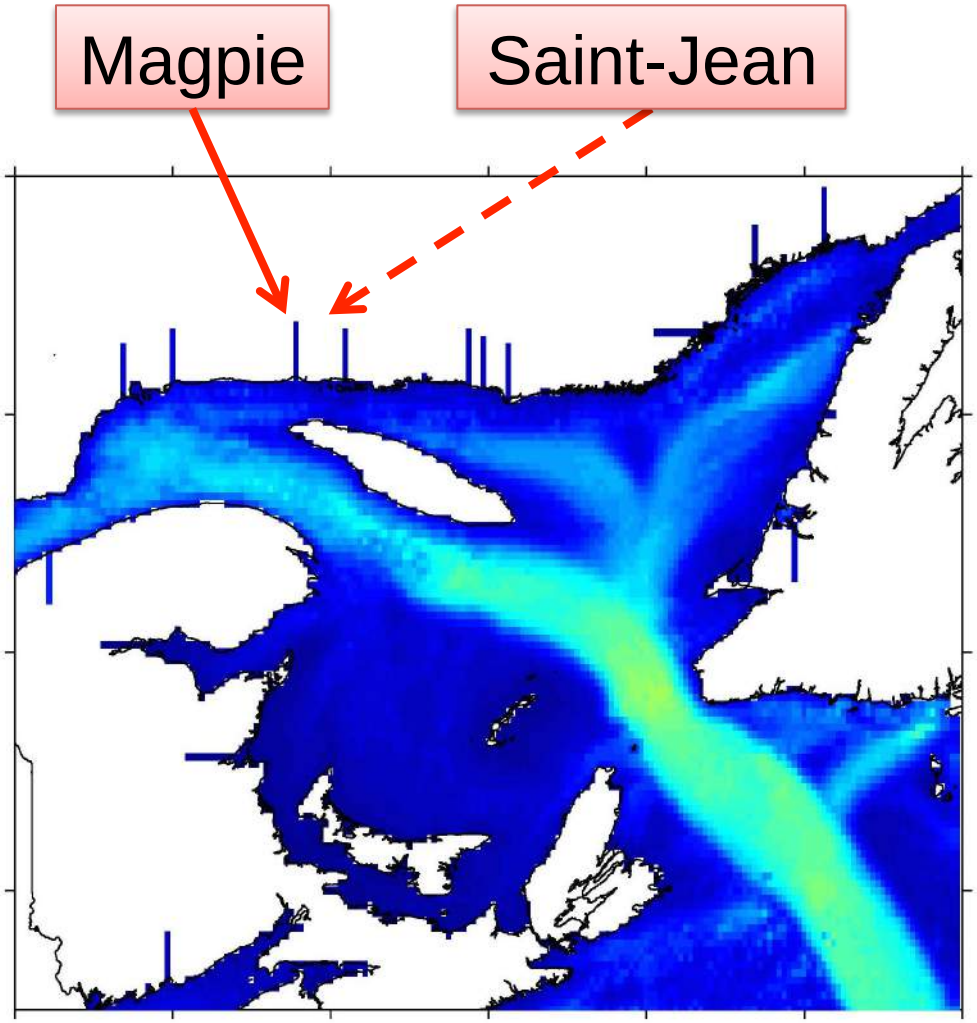
Atlantic salmon (*Salmo salar*)

~18 cm (~7")

- Juveniles starting migration from natal rivers to North Atlantic = smolts
- Smolts that have entered saltwater environment = *post-smolts*

- > 40 salmon rivers along north shore of GSL
- Between 1993 and 2007, number of mature individuals in north shore populations decreased by 14-24% (COSEWIC, 2010)

Study area



Lefèvre et al. (2012):

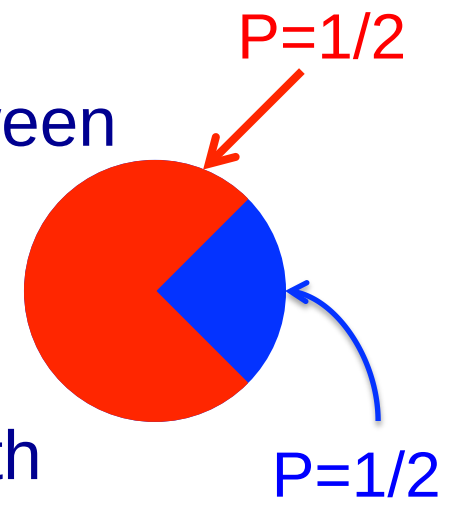
- June 2010: tagged & released Atlantic salmon smolts from Saint-Jean R.
- One was detected at Str. of Belle Isle 44 days after last detection near Saint-Jean R. mouth
- Our model does not include Saint-Jean R. ➔ use Magpie R.

Study set-up

- Objective: To reproduce the observed post-smolts' travel time of 44 days between Saint-Jean River mouth & the Strait of Belle Isle
- In each model experiment, ~700 particles are released from an area ~6 km^2 near the Magpie River mouth, at z=-5 m, on June 3, 2010
- Hourly simulated currents are used to calculate horizontal movement of particles. There is no vertical advection (i.e. vertical movement is due to "random walk" only)
- In experiments with swimming behaviour, the swimming speed = 0.2 m/s (~1.33 BL/s for a 15 cm fish)

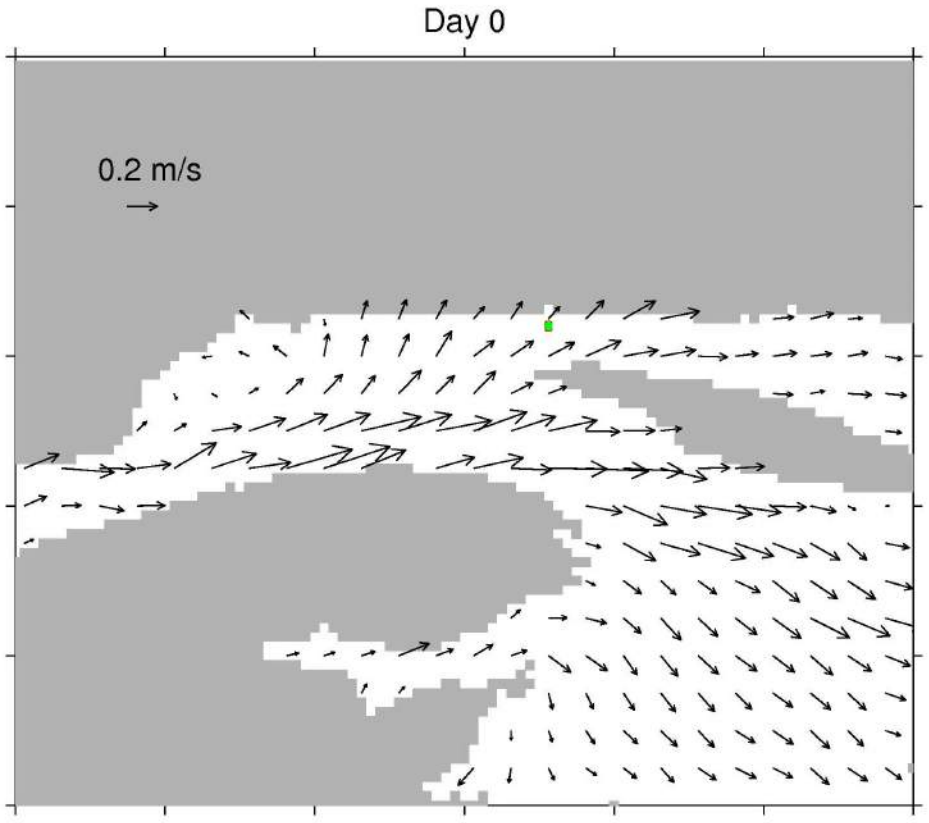
Experiments

1. Passive: No swimming behaviour. Particle movement is due to advection + random walk
2. Swimming in random directions
3. Swimming with directional preference: Probability of swimming in 90^{o} range between SE-ward & NE-ward = 1/2

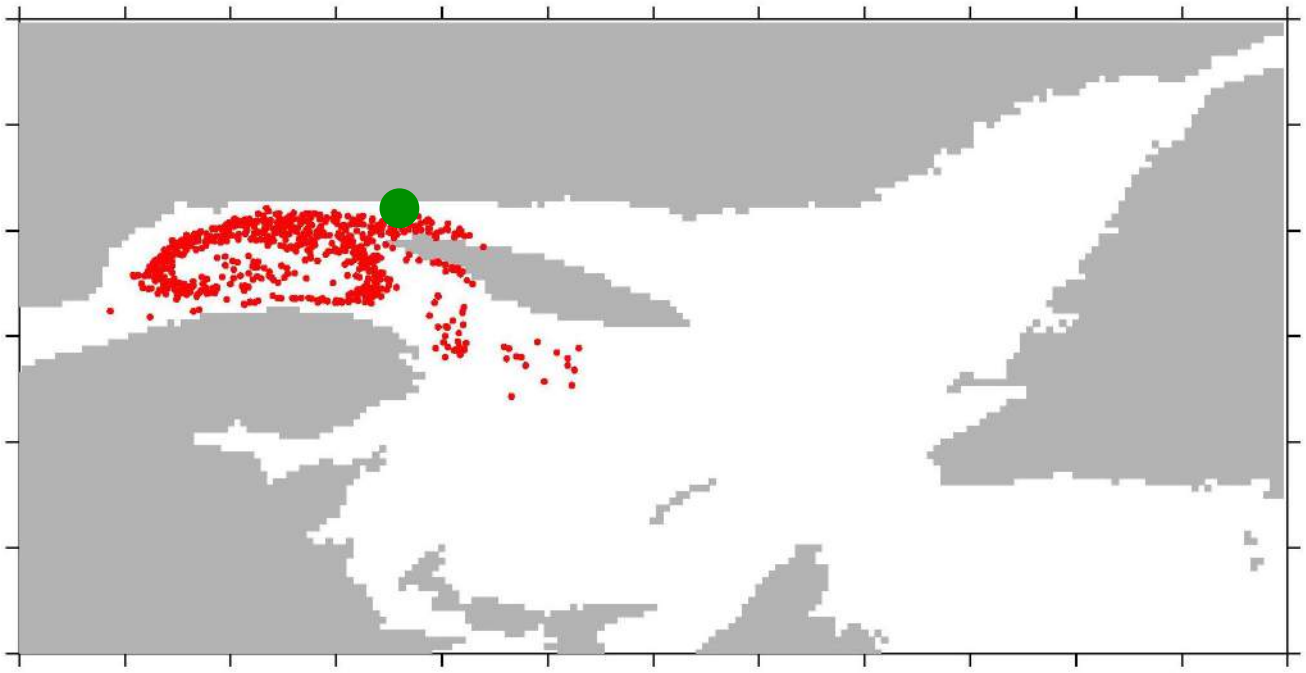


4. Swimming with/against currents: Swim with currents if there is an E-ward component, against currents if there is a W-ward component

Passive case

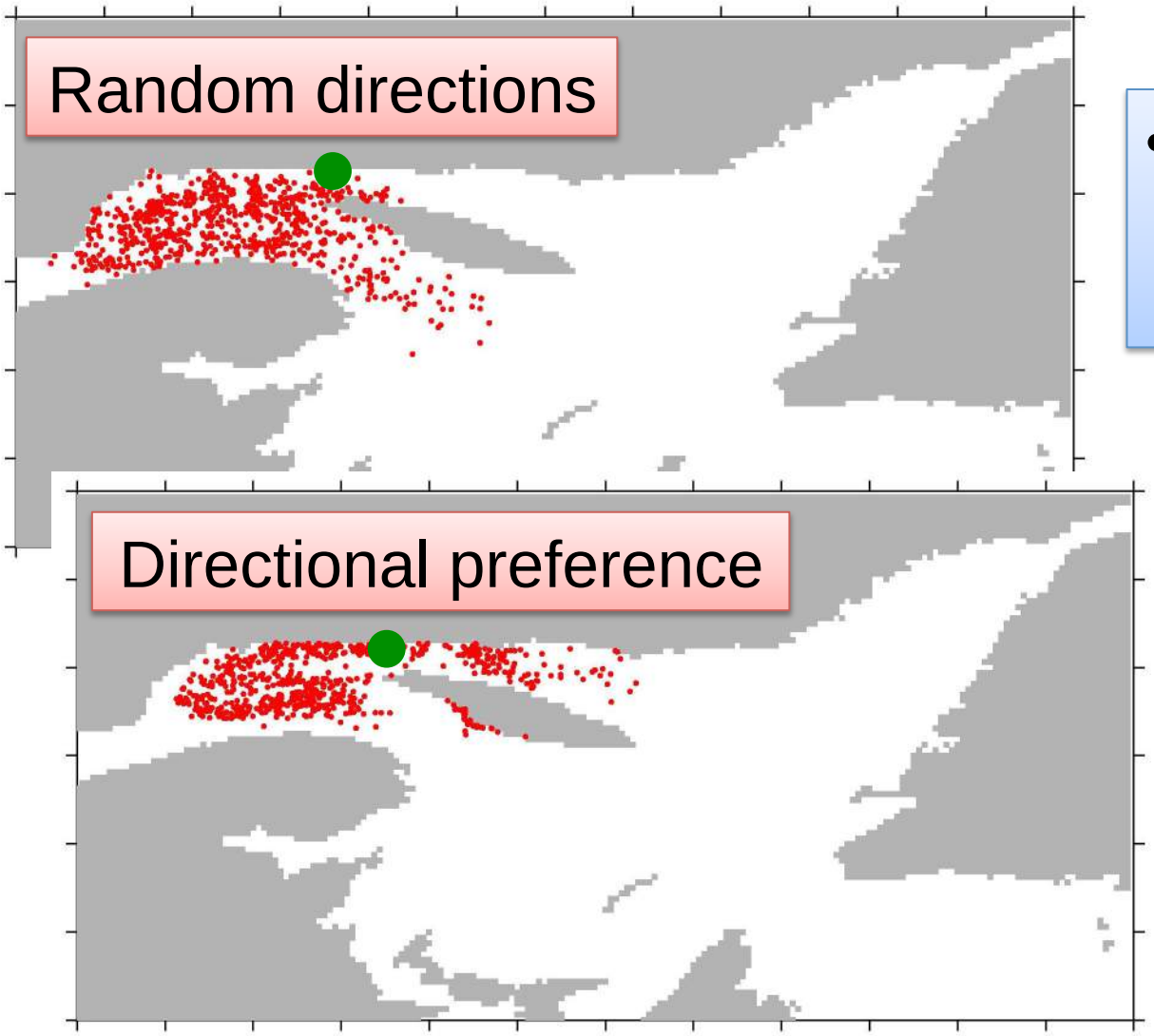


Passive case after 44 days



- 14% of particles are east of release area

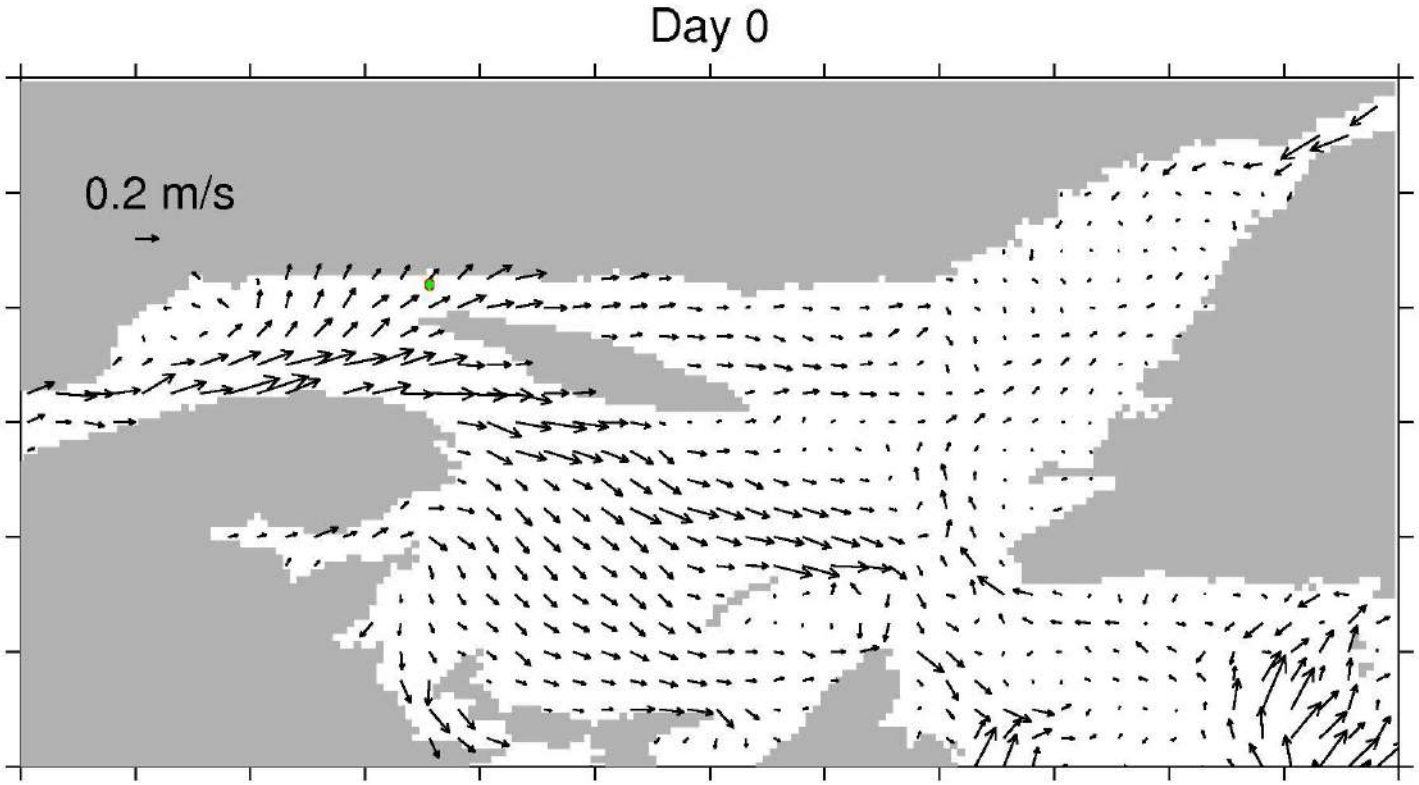
With swimming, after 44 days



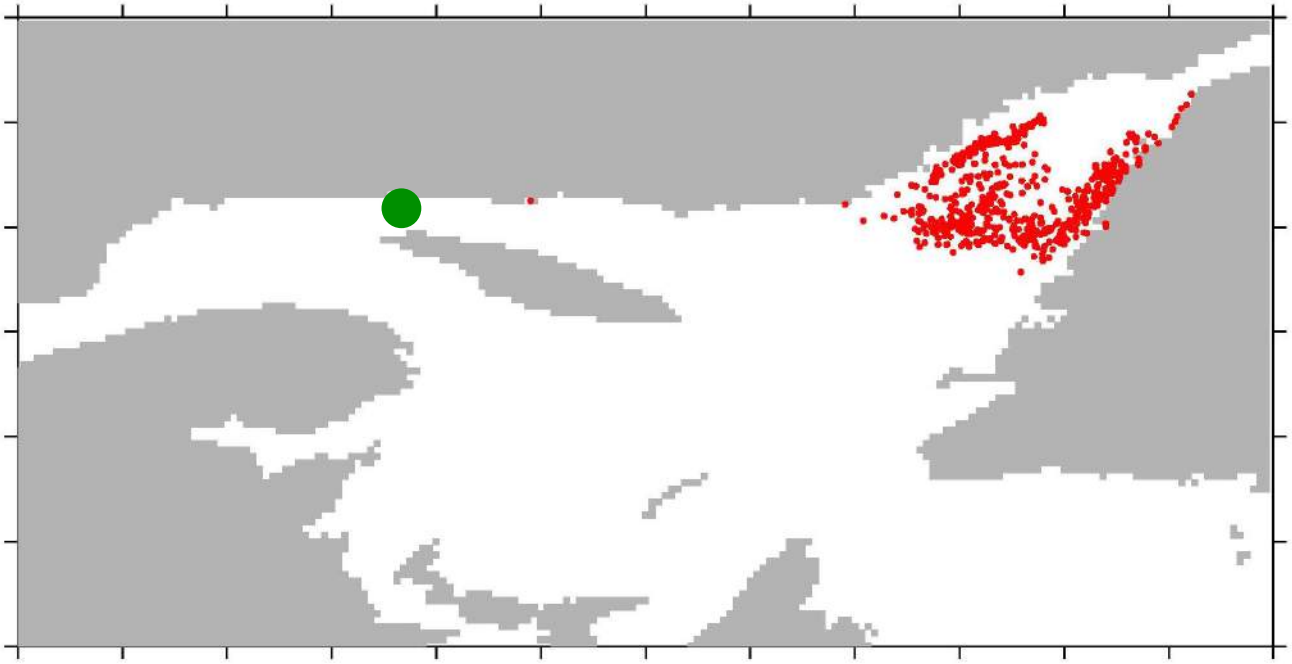
- 16% of particles are east of release area

- 29% of particles are east of release area

Swimming with/against currents



Swimming with/against currents, after 44 days



- All particles are east of release area
- Particles are starting to reach Str. of Belle Isle

Conclusions

- An individual-based model of Atlantic salmon post-smolts was set up and tested for the Gulf of St. Lawrence
- Preliminary results indicate the post-smolts have to swim against currents part of the time to reach the Strait of Belle Isle in the observed time frame
- Collaborations with fish telemetry scientists can lead to more validation and potential new insights on the post-smolts' migration to the open ocean