DILUTION OF PARASITES AND DISEASE MITIGATION

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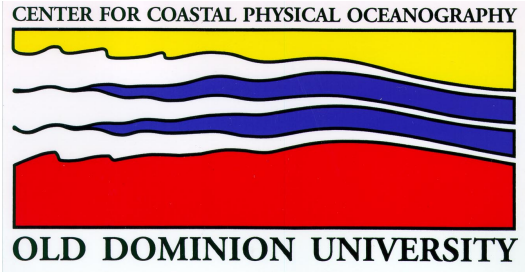
"Development of a Theoretical Basis for Modeling Disease Processes in Marine Invertebrates"

NSF Ecology of Infectious Diseases Research Coordination Network



Motivation

The water column provides a 'reservoir' for pathogens and these are added to it or lost from it (dilution).

The interaction between the water column and host population is crucial in this process

Models that incorporate such interaction can be important tools to explain the initiation/ termination of epizootics

Disease models

Pathogen: *Perkinsus marinus*

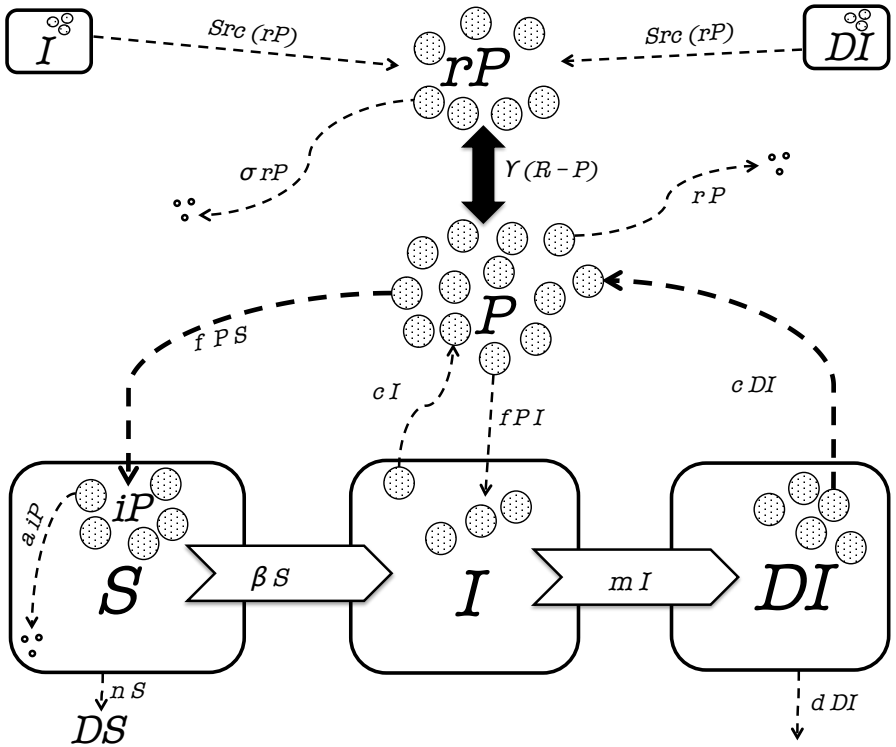
Host population: Eastern Oyster

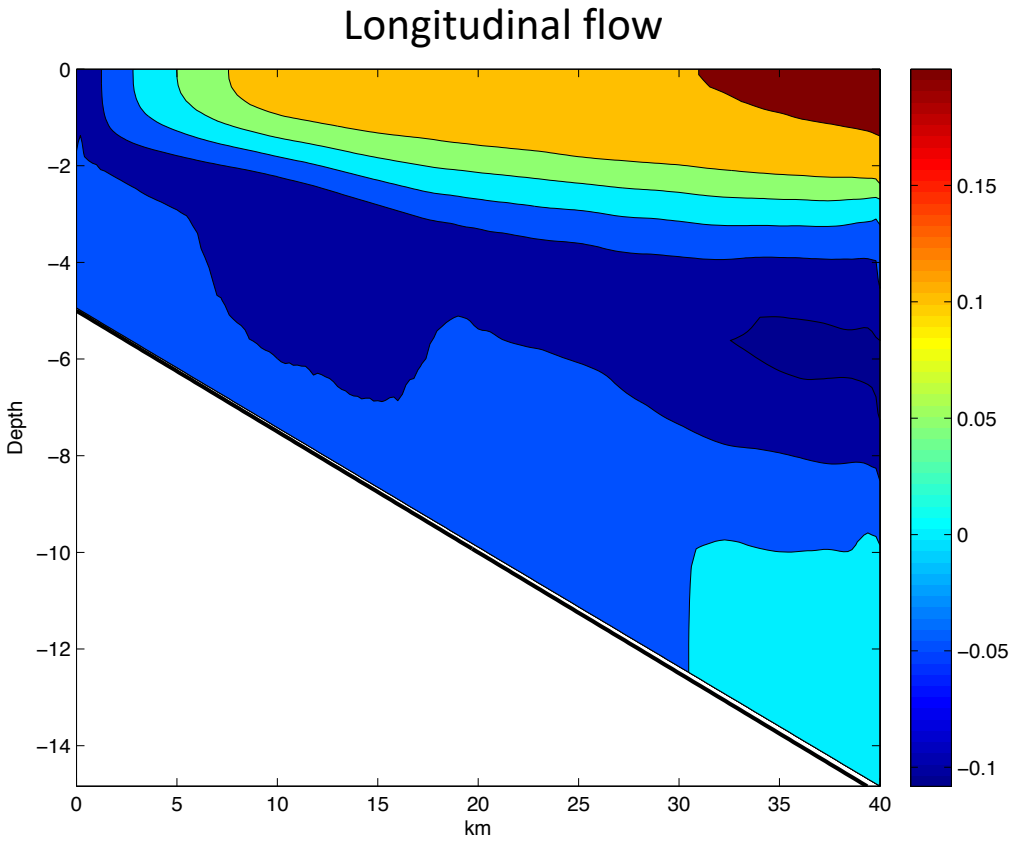
Interaction: horizontal advection and vertical diffusion of pathogens, oyster beds, harvesting

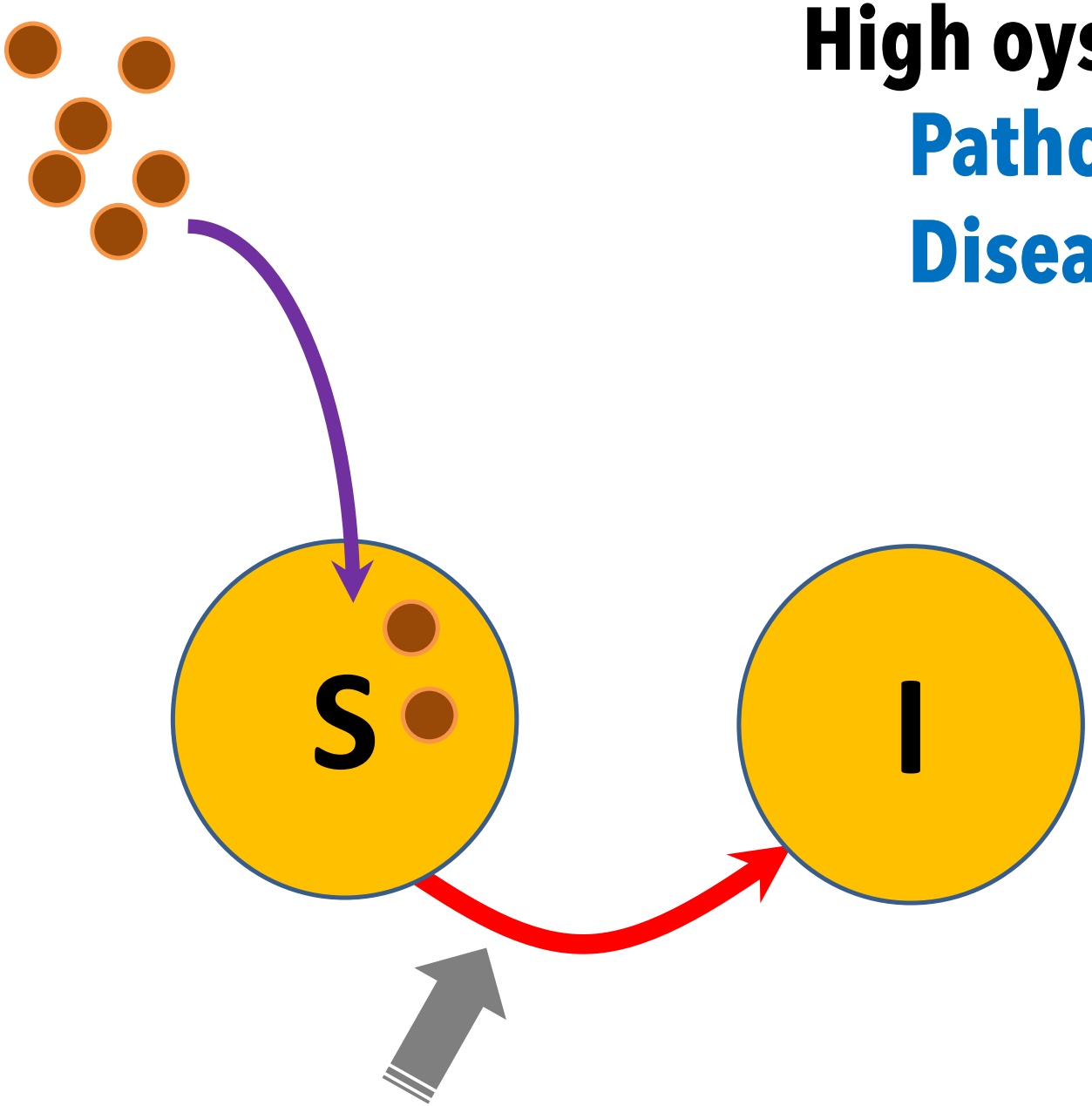
Effect on the infectious particles (IP) in the water column and Dermo disease mitigation

Coupling

Disease model → ROMS







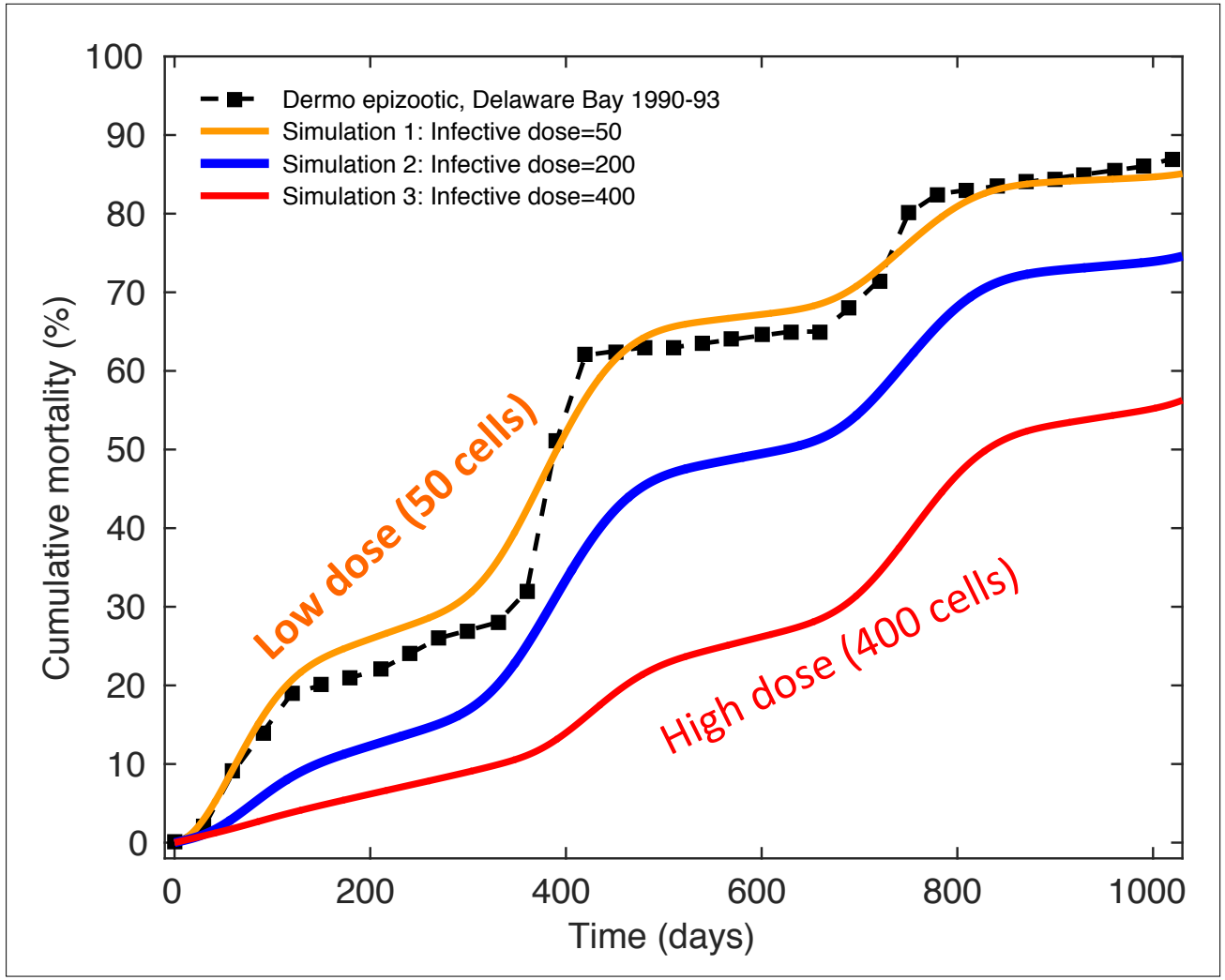
High oyster densities

Pathogen dilution

Disease mitigaion

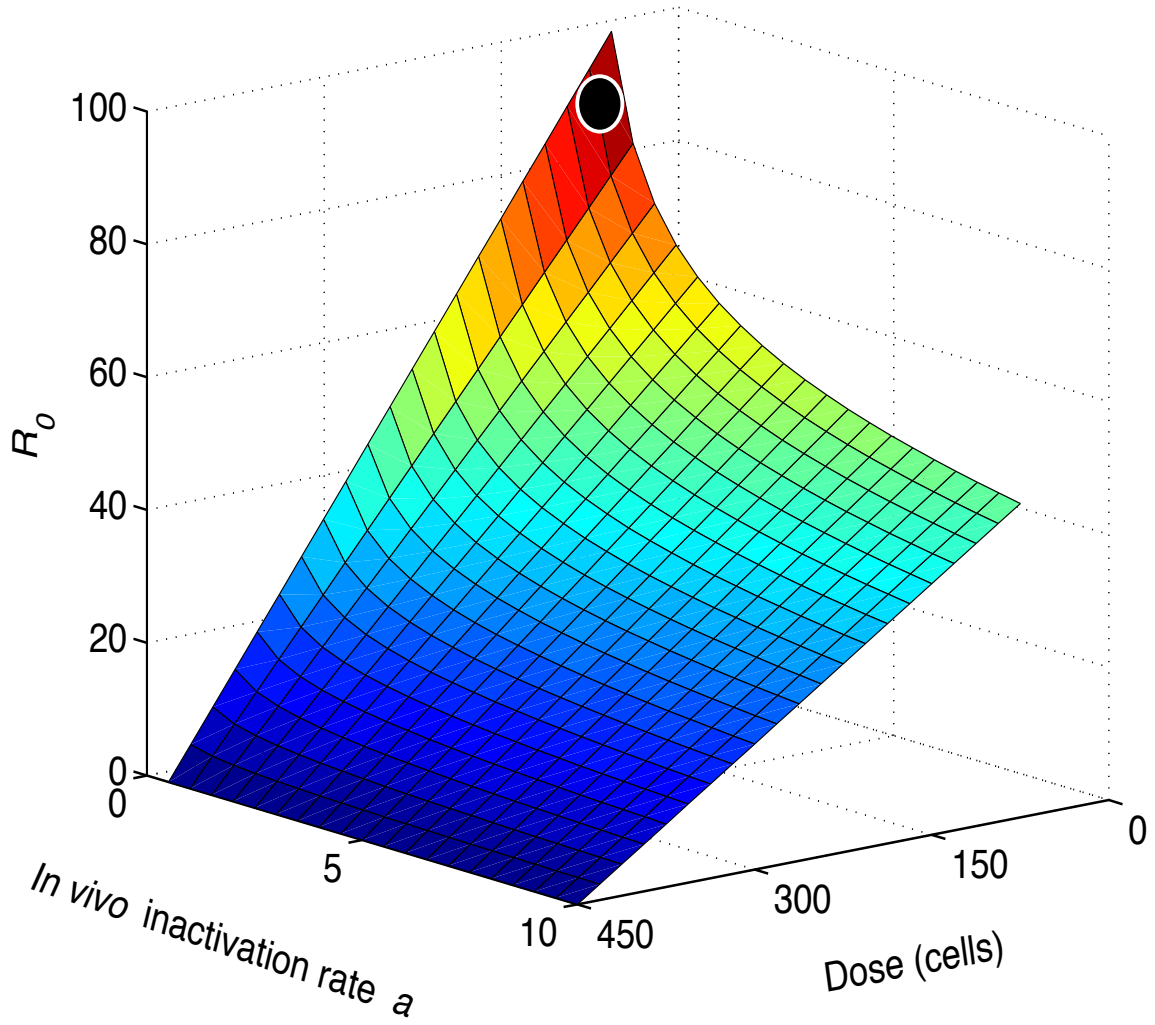
Model validation

Against observational data of mortality, Delaware Bay, 1990-1993 (Ford et al., 2006). For different infective doses (unknown parameter)

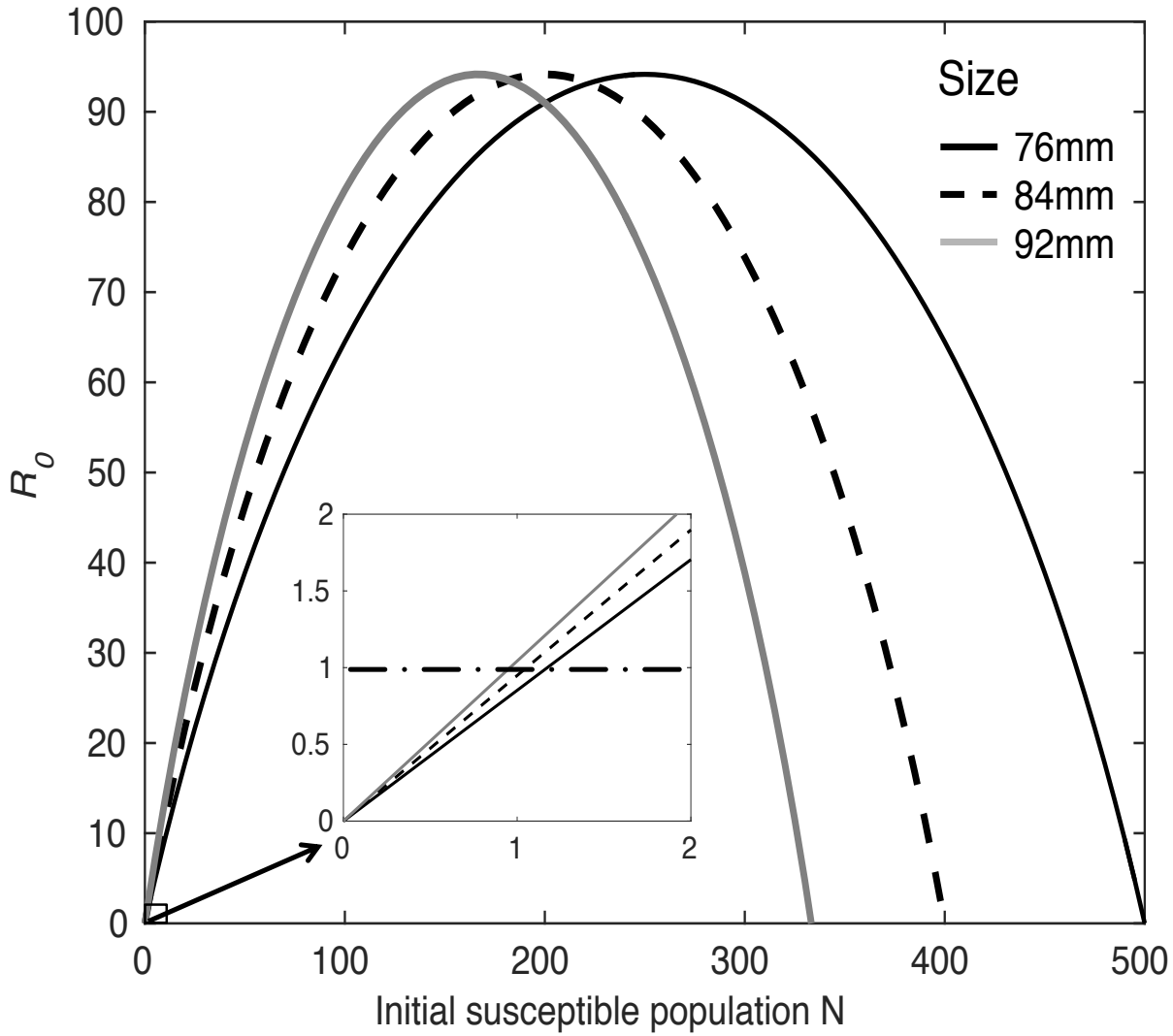


Disease risk

R_0



Increasing oyster density….and size of oysters…

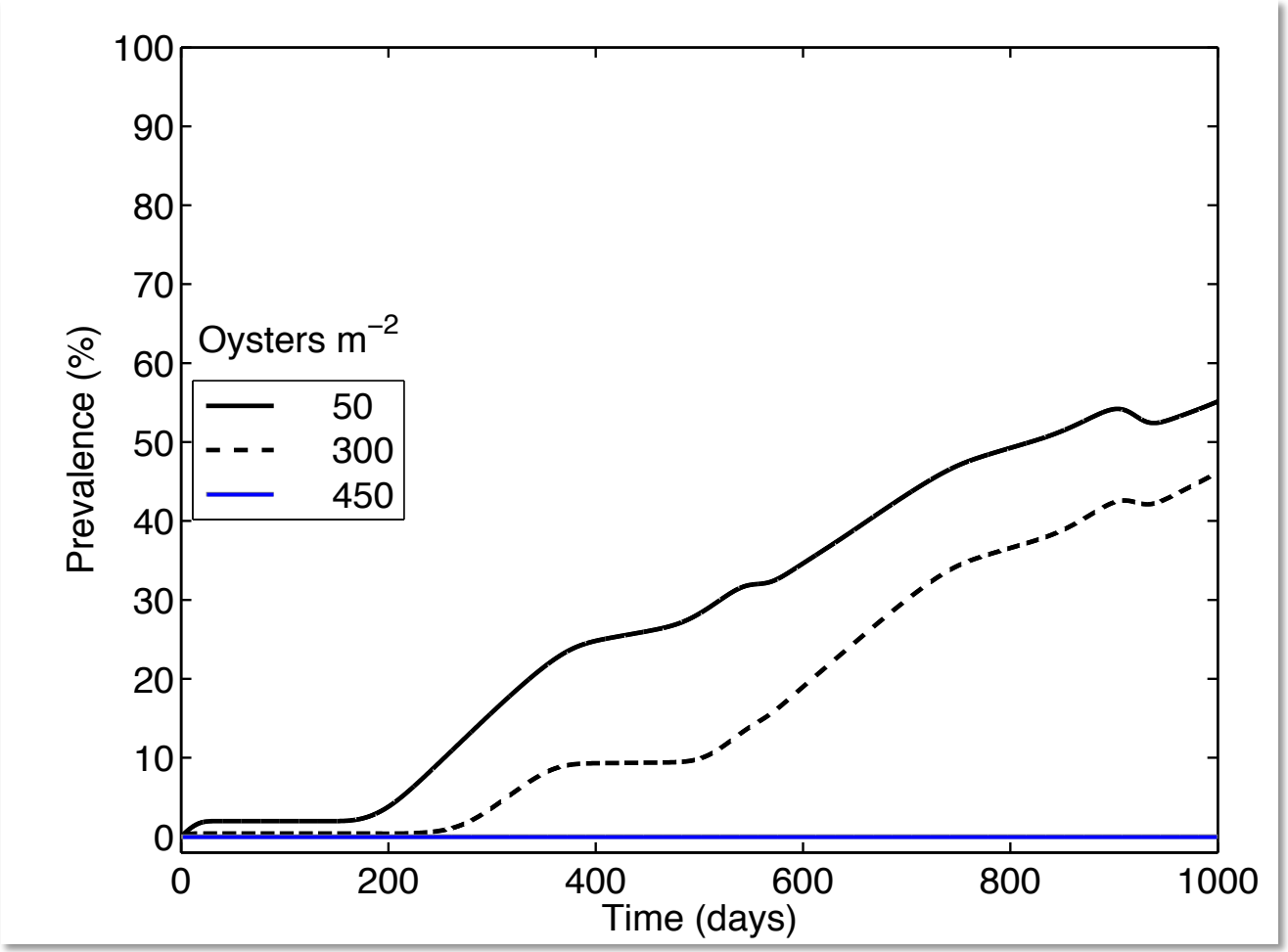


… neighbours compete for particles

… decreases per capita exposure to pathogens

….lead to a lower Ro (lower oportunities for an epizootic)

Increasing oyster density….



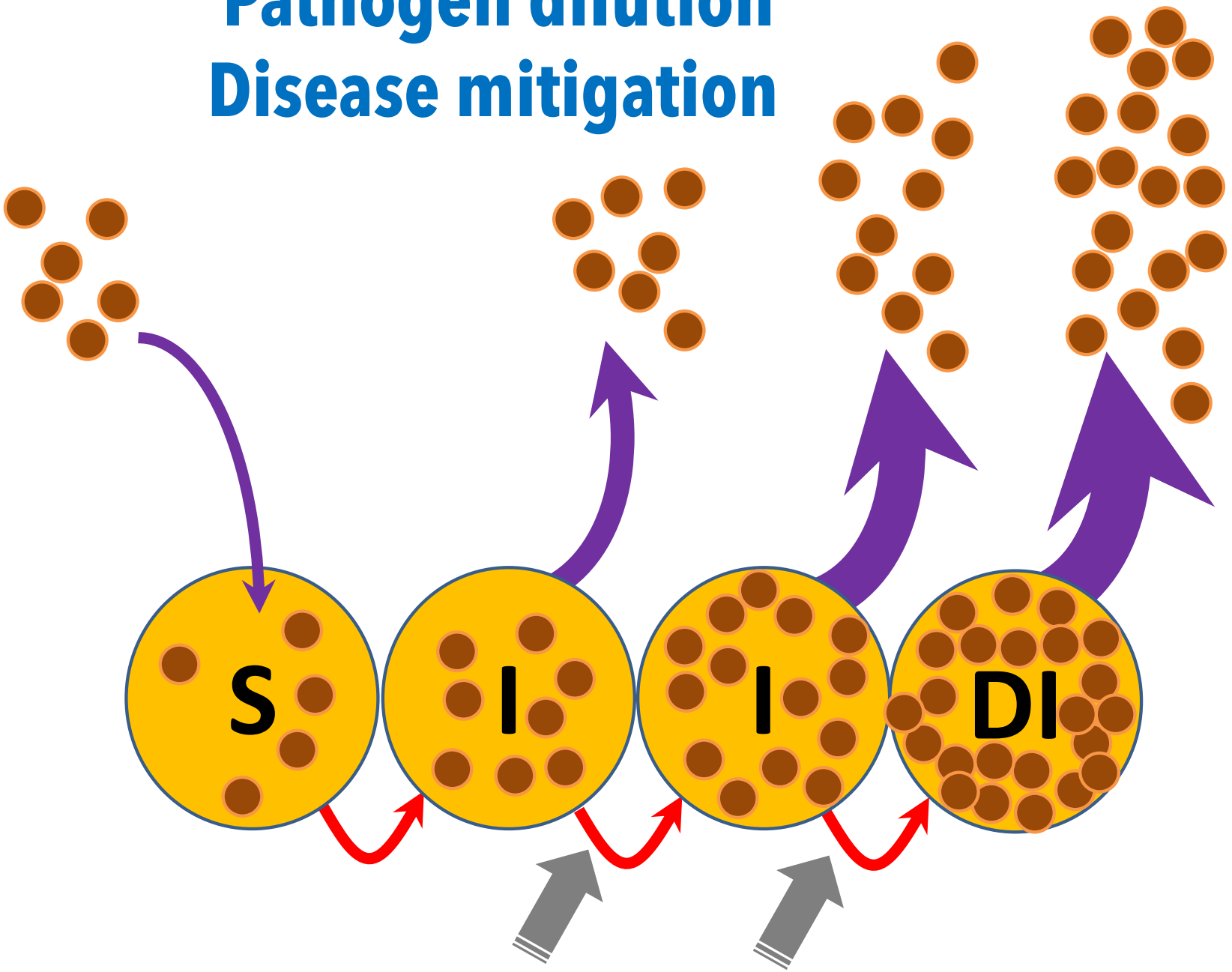
…decreases disease incidence

Confirmed by a mesocosm experiment (Ben-Horin et al. 2015)

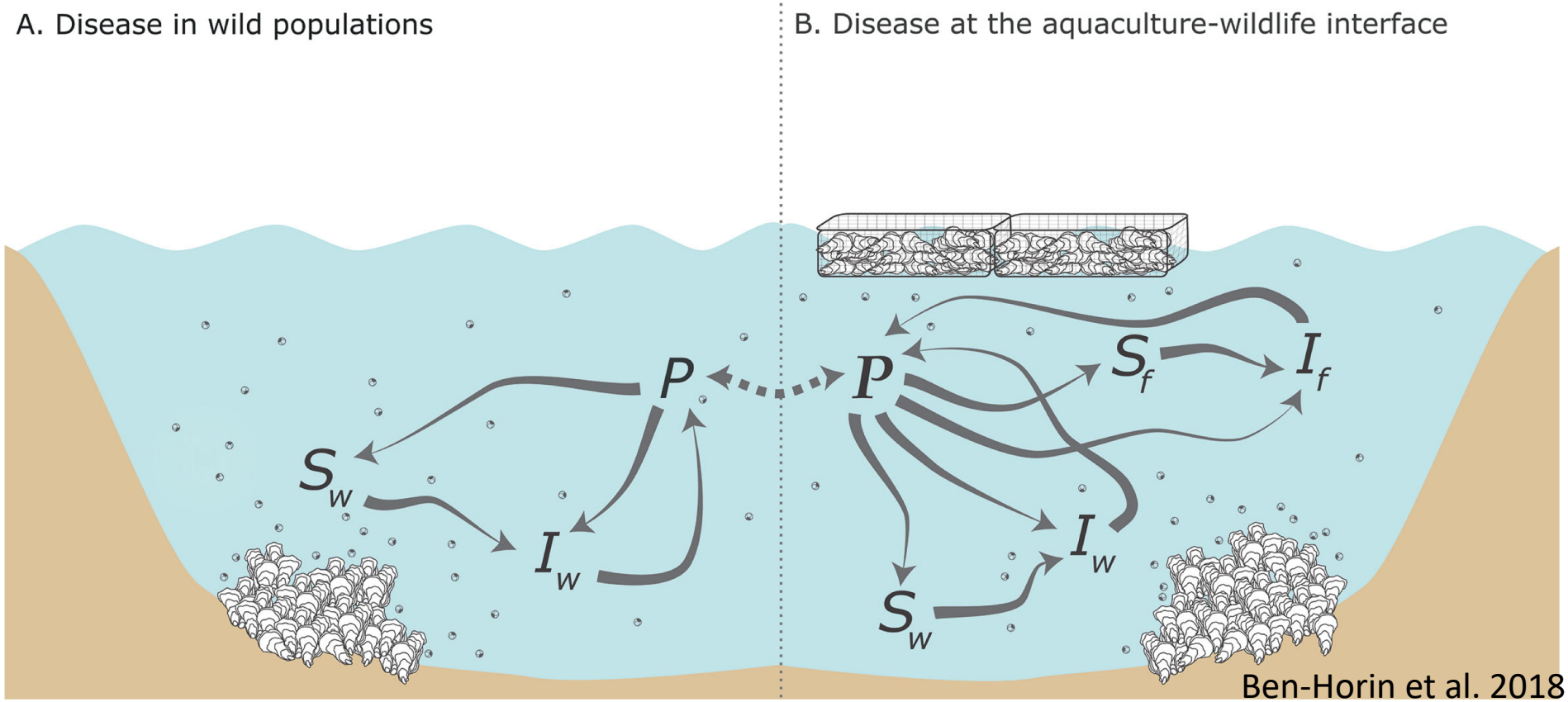
Oyster removal, Hydrodynamics

Pathogen dilution

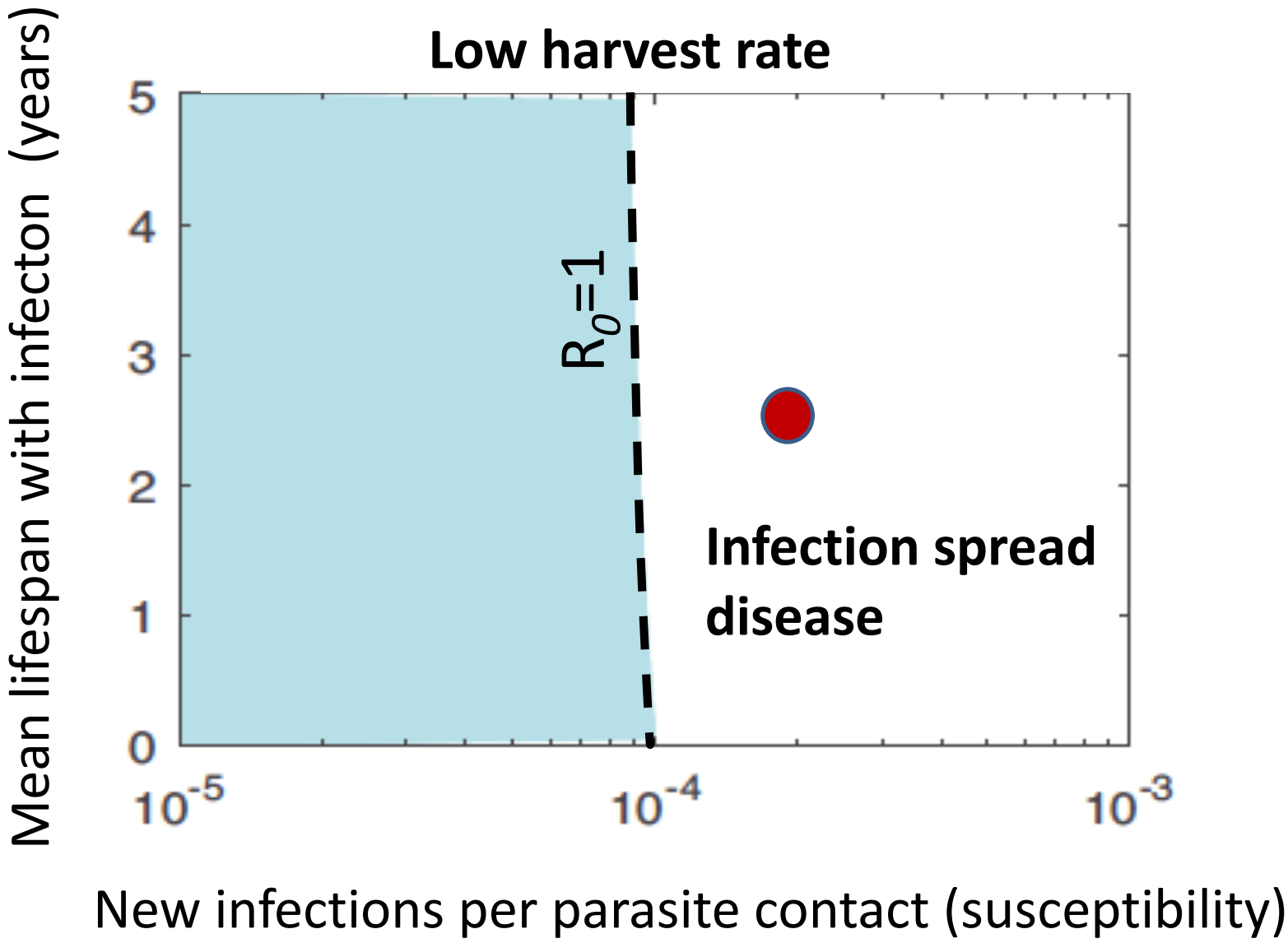
Disease mitigation

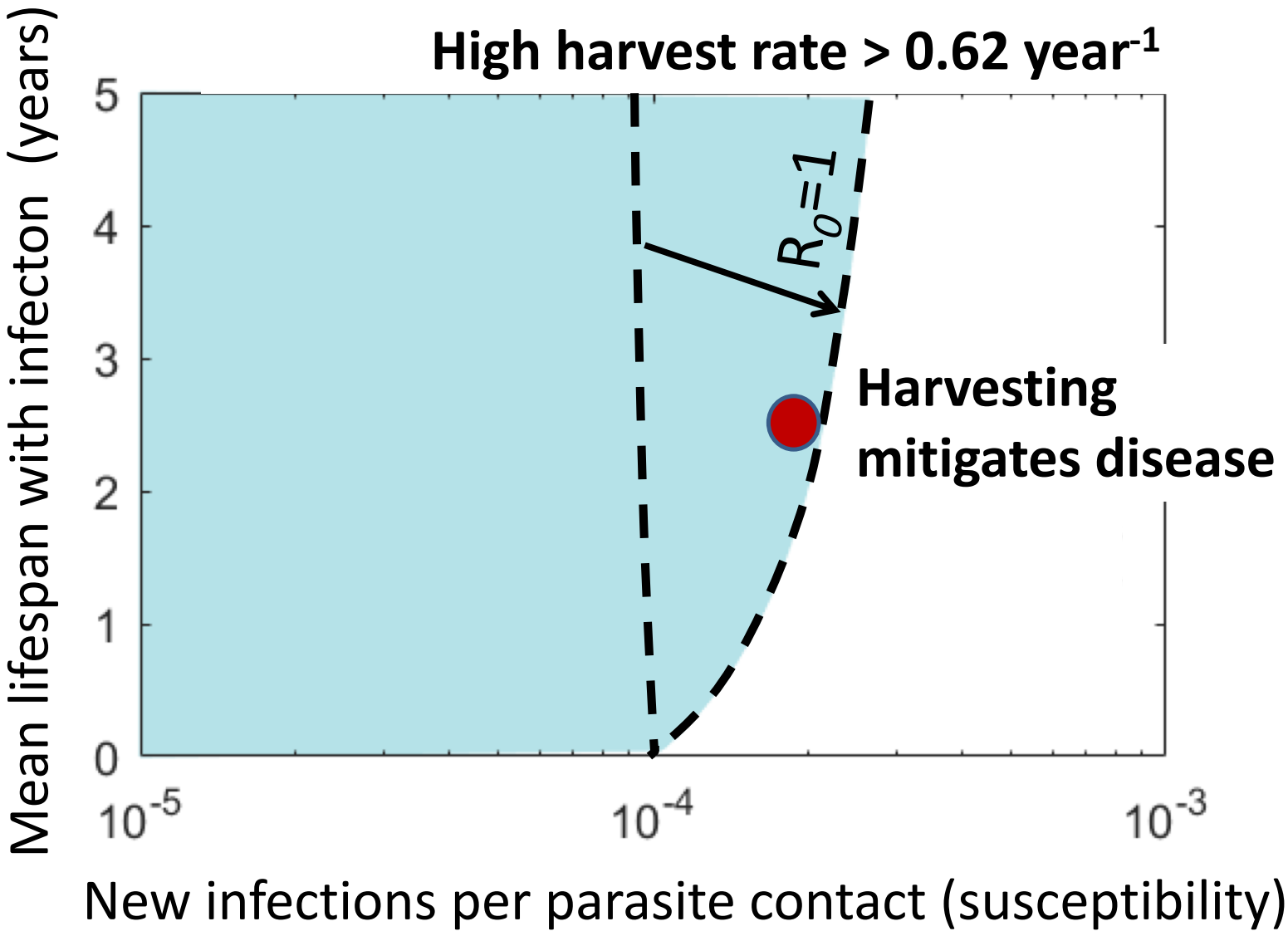


Does intensive aquaculture (high densities) reduce parasite concentration? When?



Ben-Horin et al. 2018


Low harvest rate
Mean lifespan with infecton (years)
5
4
3
2
1
0
R_0=1
Infection spread
disease
10^{-5}
10^{-4}
10^{-3}
New infections per parasite contact (susceptibility)



Increased survival, benefit?

Longer infection periods → release more parasites

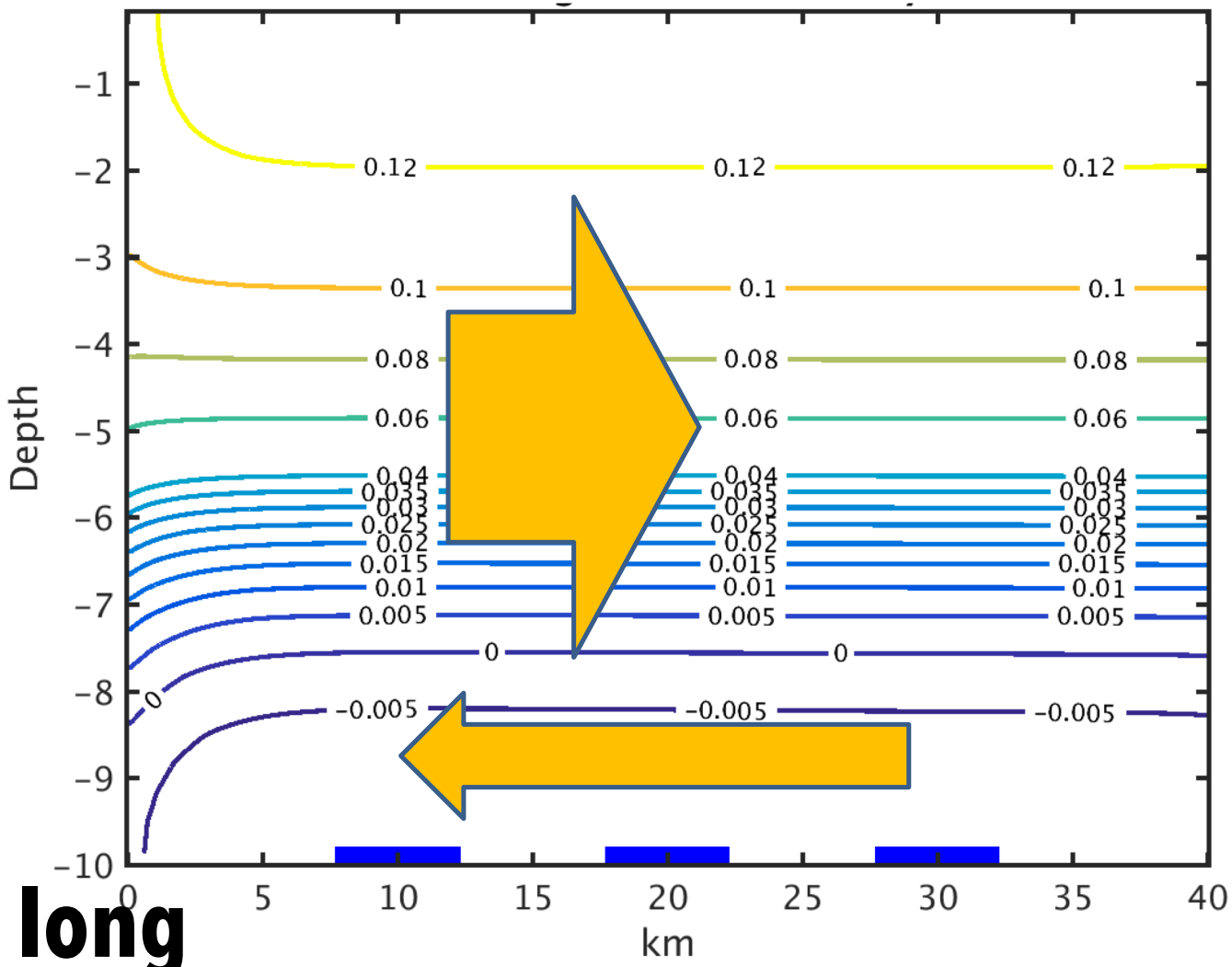
We need to harvest fast!!! to mitigate disease impact

And what about hydrodynamics?

Model estuary: 40 km long, 300 wide,10m deep

Longitudinal flow

Surface Outflow 12 cm/s
Bottom inflow 0.5 cm/s.



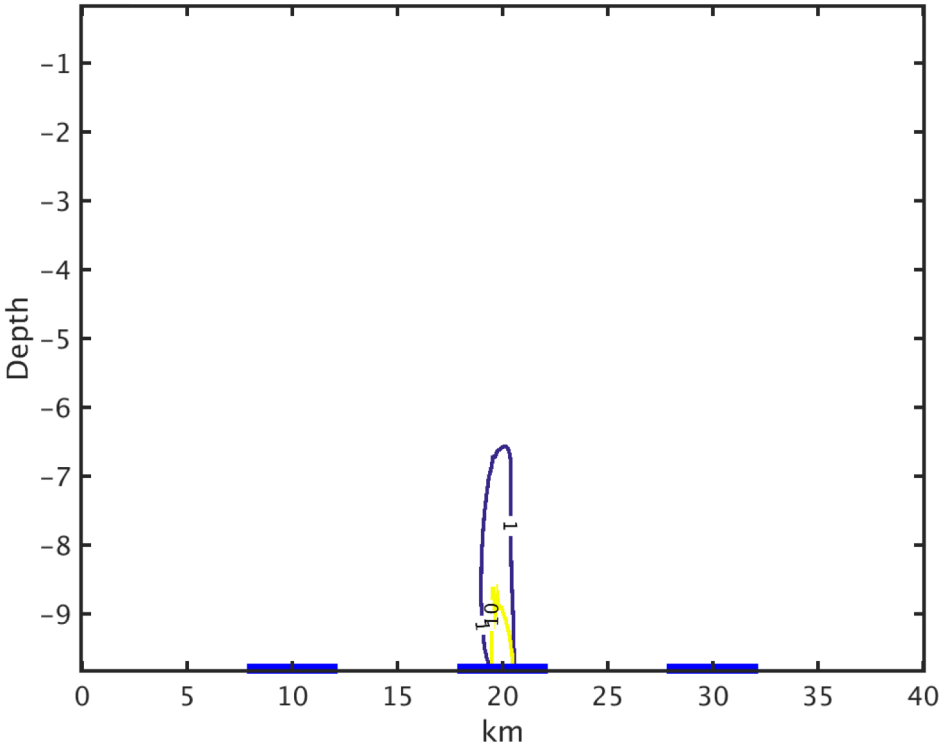
Reefs
10 km long

Low diffusivity (vertical mixing) case

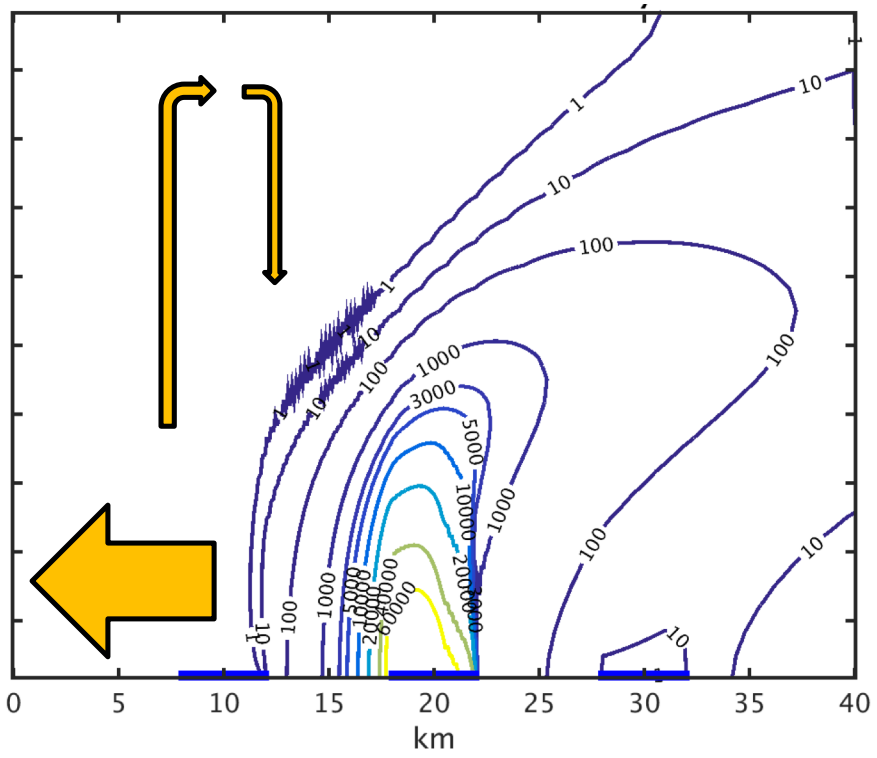
Low density 50 oysters/m^2

10^{-5} m^2/s

Infectious Particles, Day 2



Infectious Particles, Day 50



Central reef: fully infected

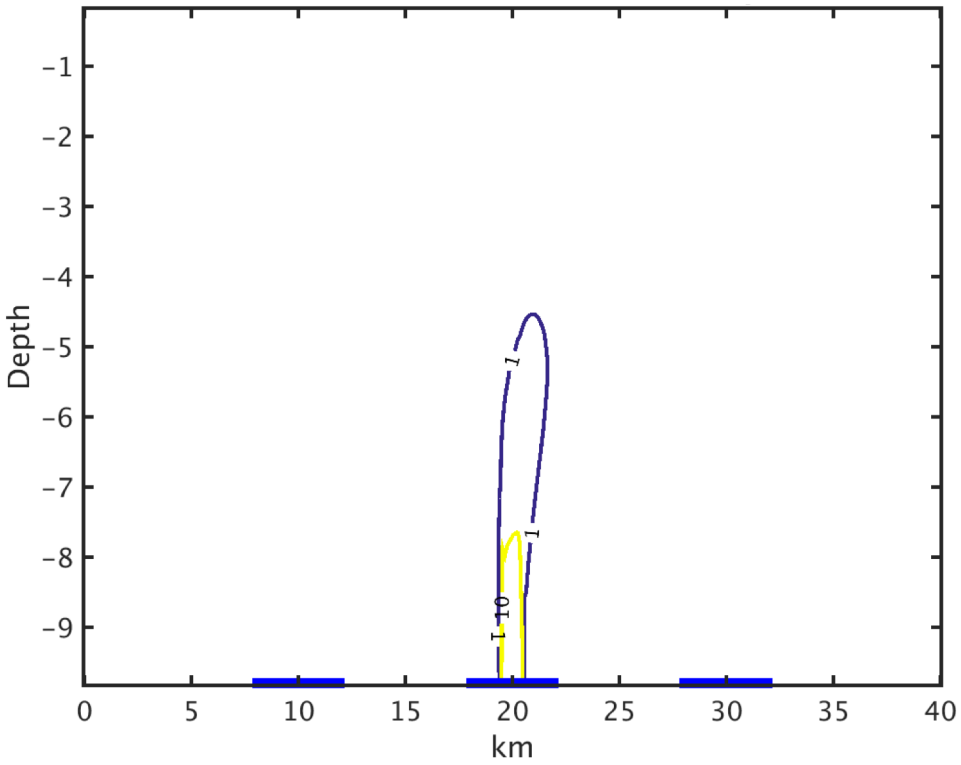
Upstream reef: infection initiated

Moderate diffusivity (vertical mixing) case

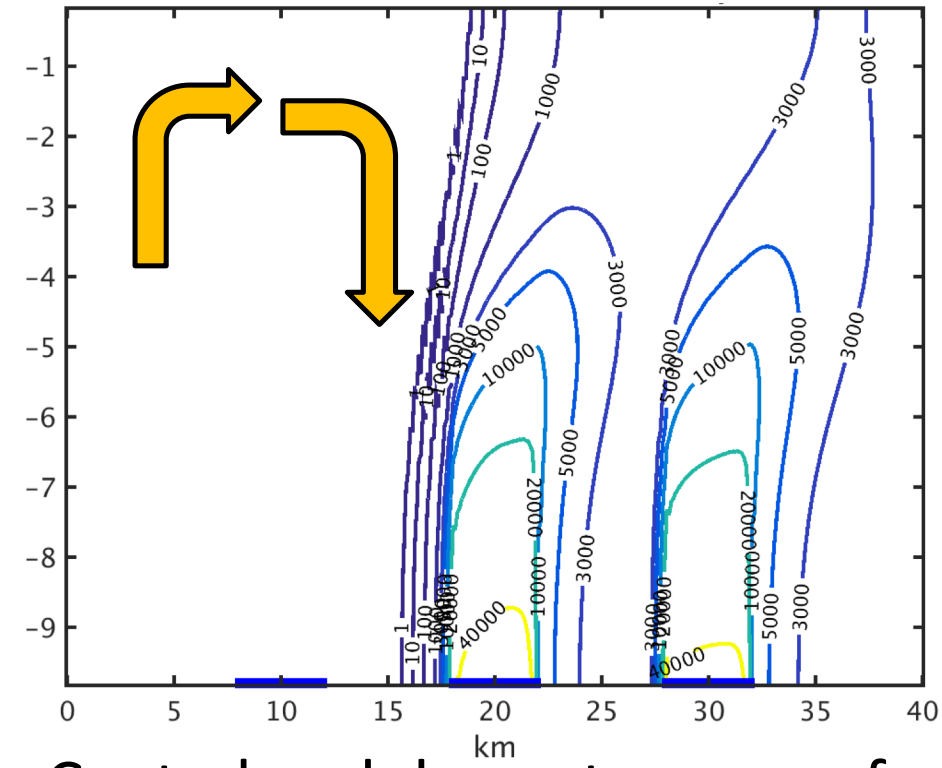
10^{-4} m^2/s

Low density 50 oysters/m^2

Infectious Particles, Day 2



Infectious Particles, Day 50

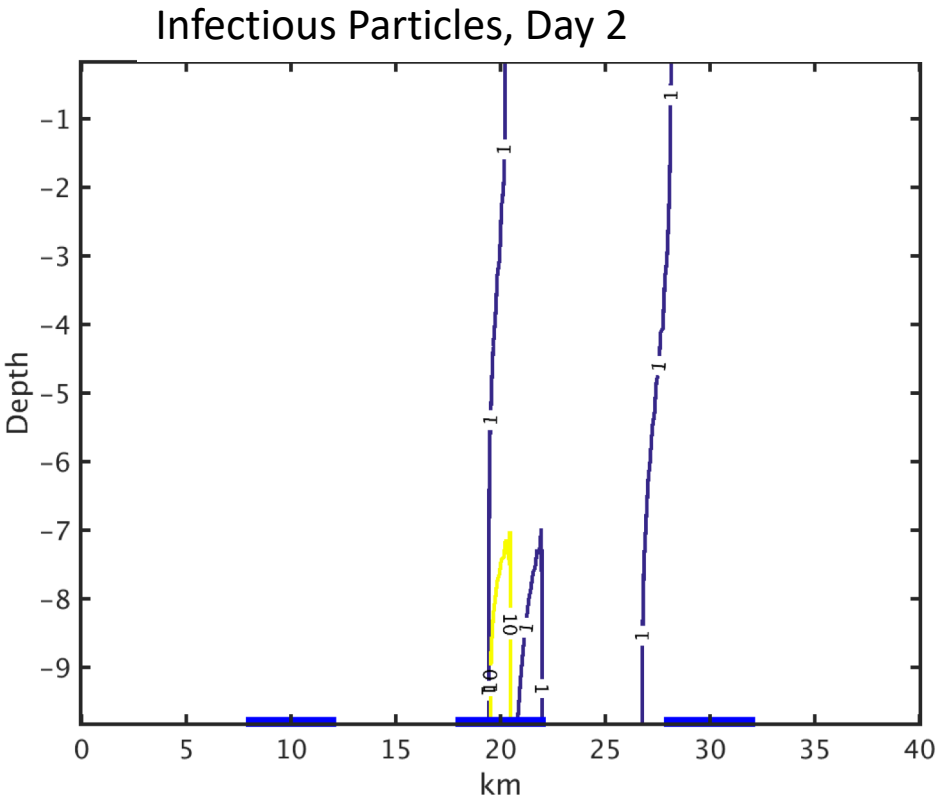


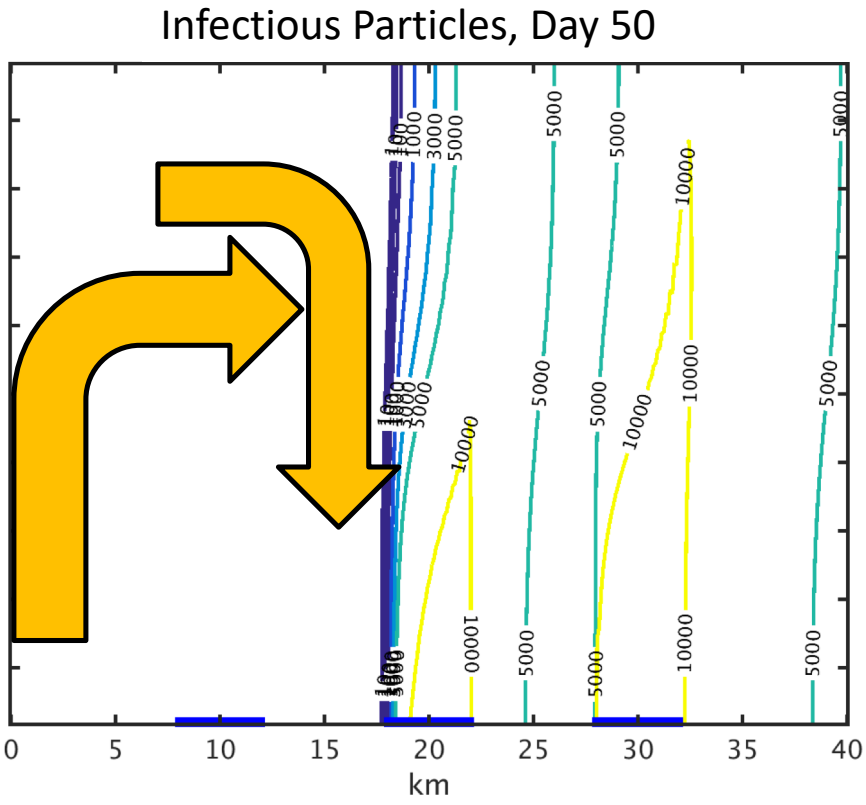
Central and downstream reefs: Fully infected

High diffusivity (vertical mixing) case

Low density 50 oysters/m^2

10^{-3} m^2/s

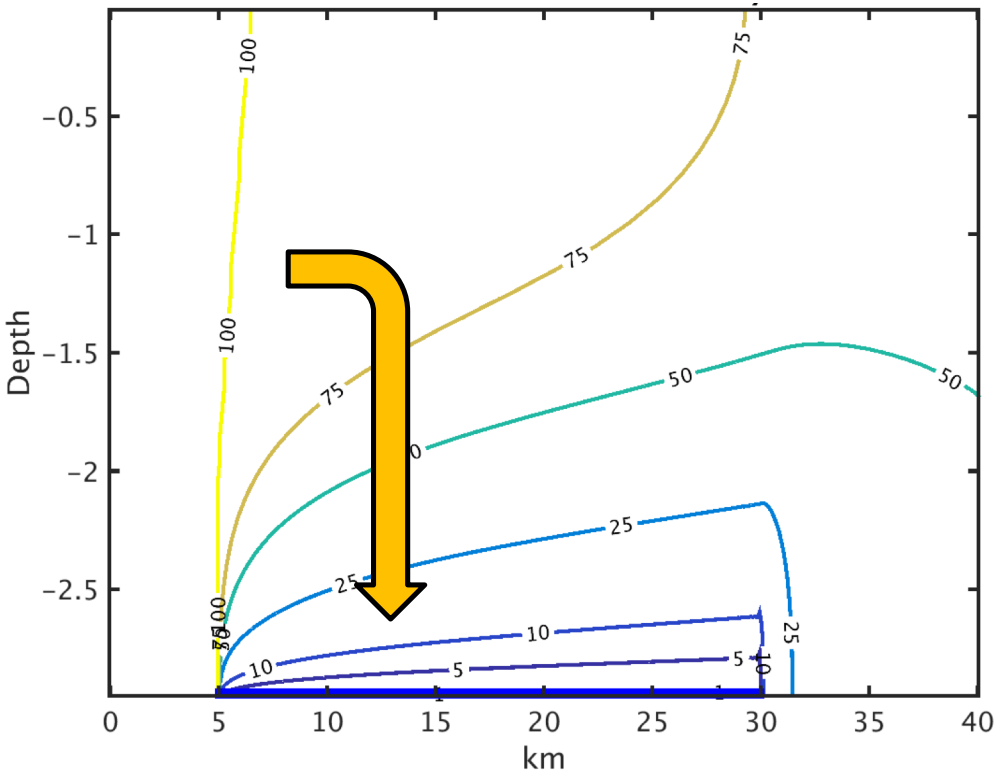




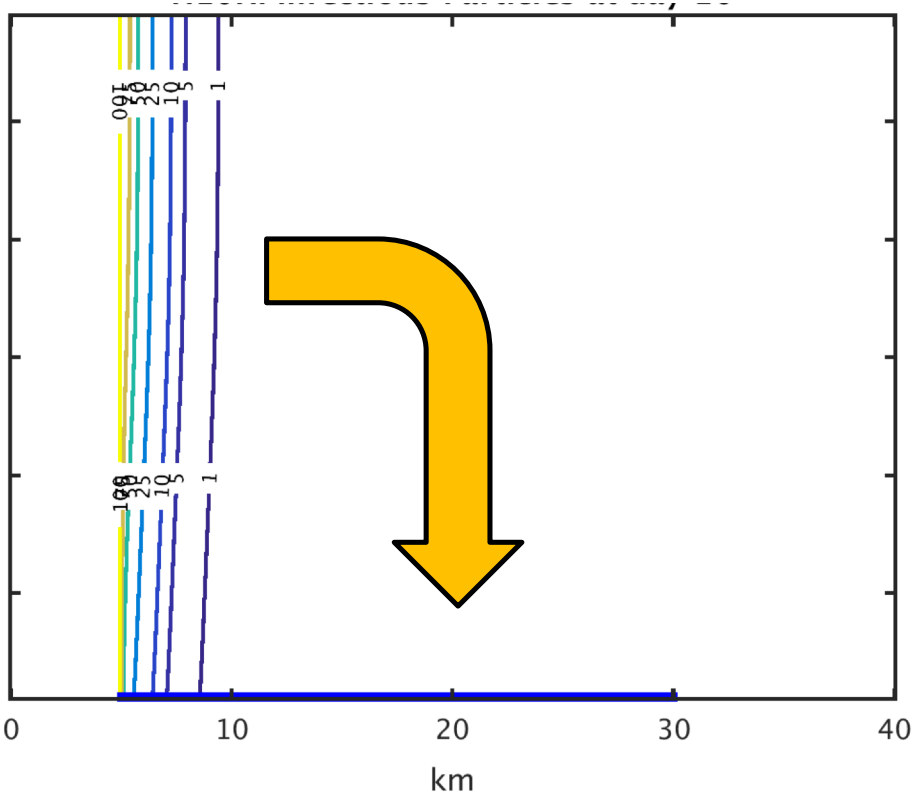
Central and downstream reefs:
Fully infected

What happens if we increase density of oysters and reef length?

Low diffusivity case



High diffusivity case



Parasite dilution by consumption with no infection and disease mitigation

Conclusions

Increasing oyster densities and removal of oysters before massive release of infective particles decrease environmental concentration of pathogens and mitigate impact of disease

Vertical mixing intensity (together with advection) is an important factor determining upstream/downstream pathogen difussion and disease spread

Thanks

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