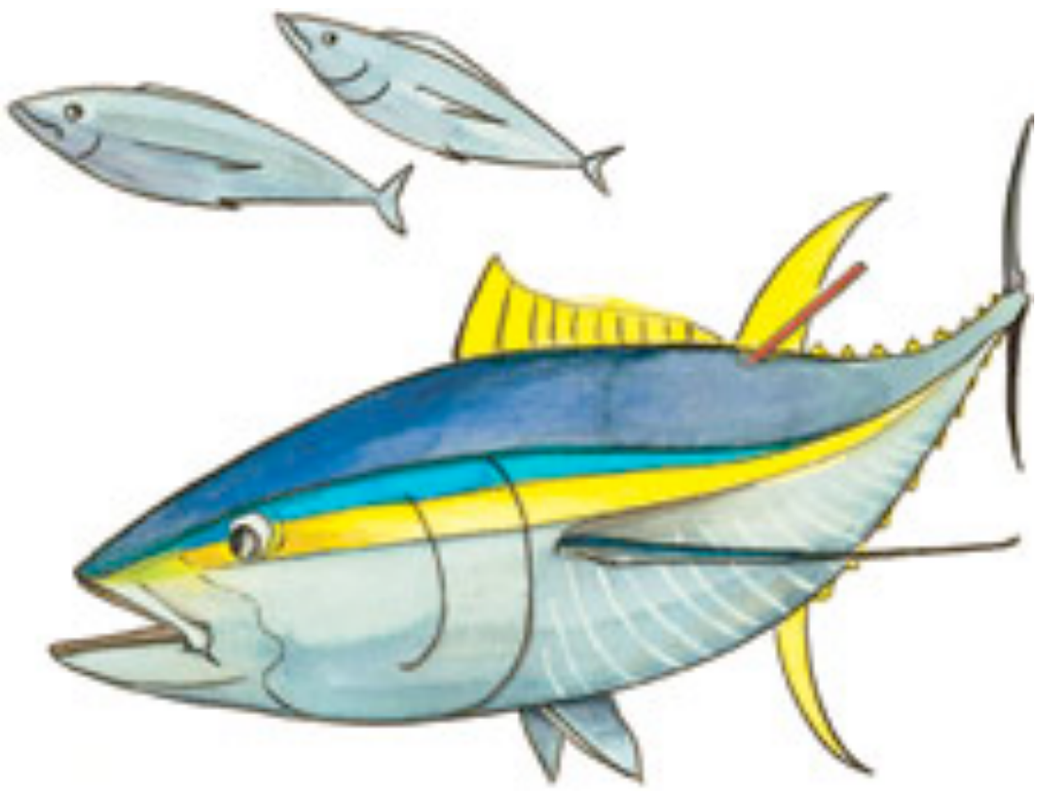
Simulating yellowfin tuna larval dispersal in the Hawaiian Region



Ana Carolina Vaz (UH/UMiami)

Kelvin Richards (UH)
Claire Paris (UMiami)
David Itano (PFRP)
Yanli Jia (IPRC)

2012 PFRP PI Meeting

Motivation

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Tagging studies:

Yellowfin tuna in Hawaii - restricted movement (Holland *et al.* 1990, Itano and Holland 2000, Dagorn *et al.* 2007)

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Objective

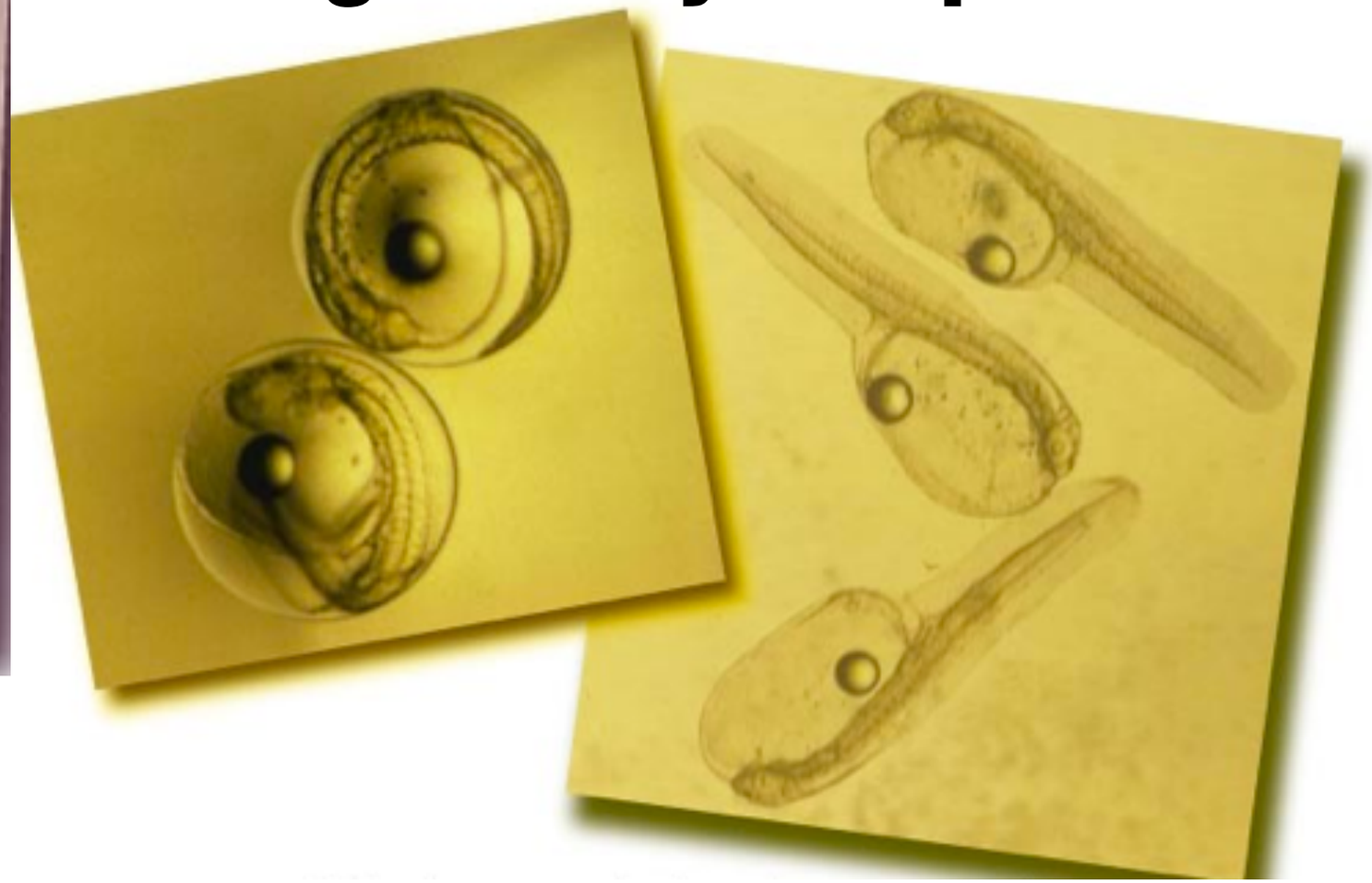
Patterns of YFT early life stages dispersal and retention

Retention affected by:
Biological traits? Seasonality? Major dispersal pathways?

Larval dispersal

Larval dispersal

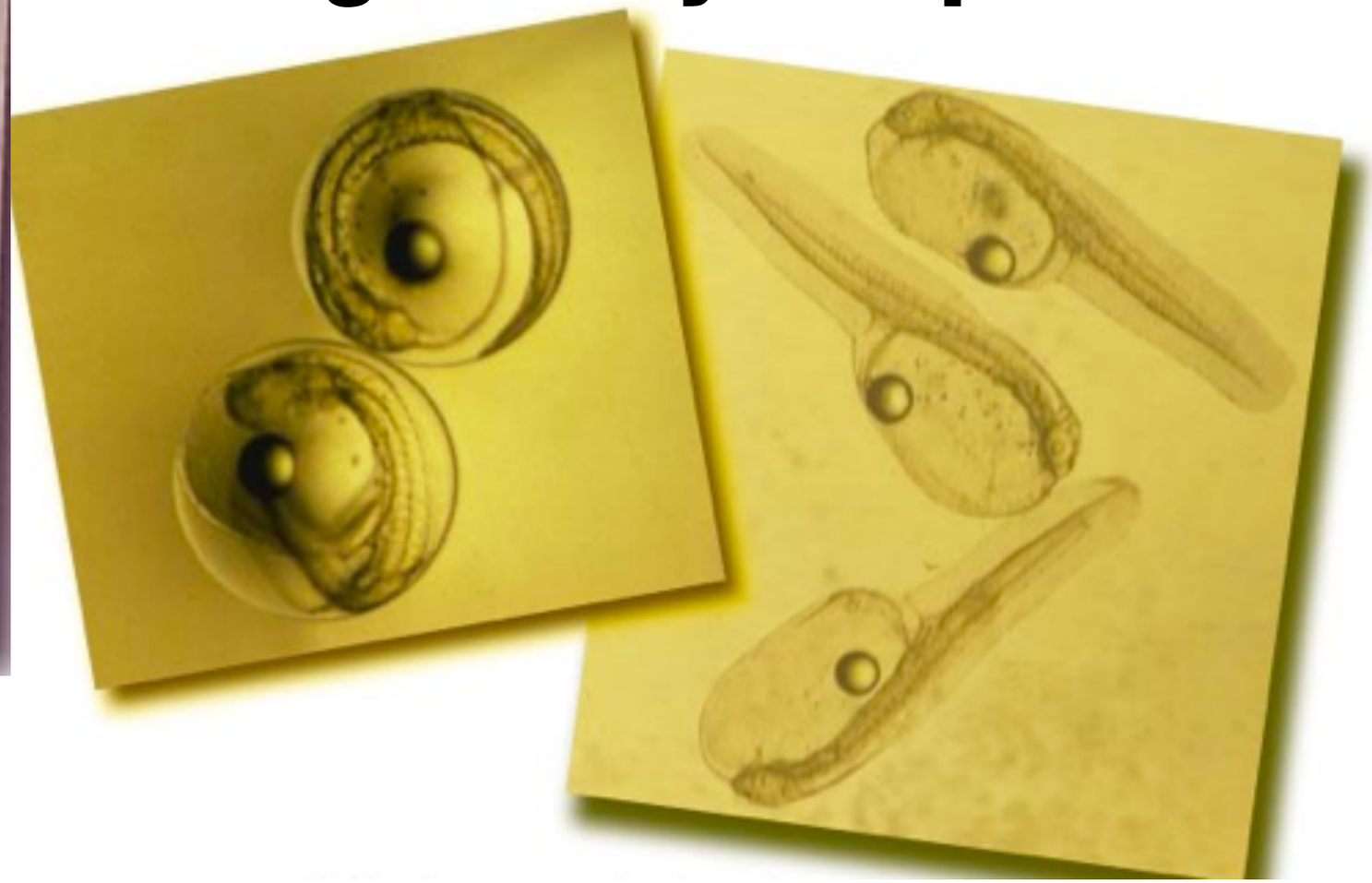
Pelagic early life phase



www.iattc.org/achotineslab/

Larval dispersal

Pelagic early life phase



www.iattc.org/achotineslab/

Physical Mechanisms + **Biological Traits**

How to study?

www.iattc.org/achotineslab/

How to study?

www.iattc.org/achotineslab/

Simulate larval dispersal

How to study?

www.iattc.org/achotineslab/

Simulate larval dispersal

↓

hydrodynamic to biophysical models

How to study?

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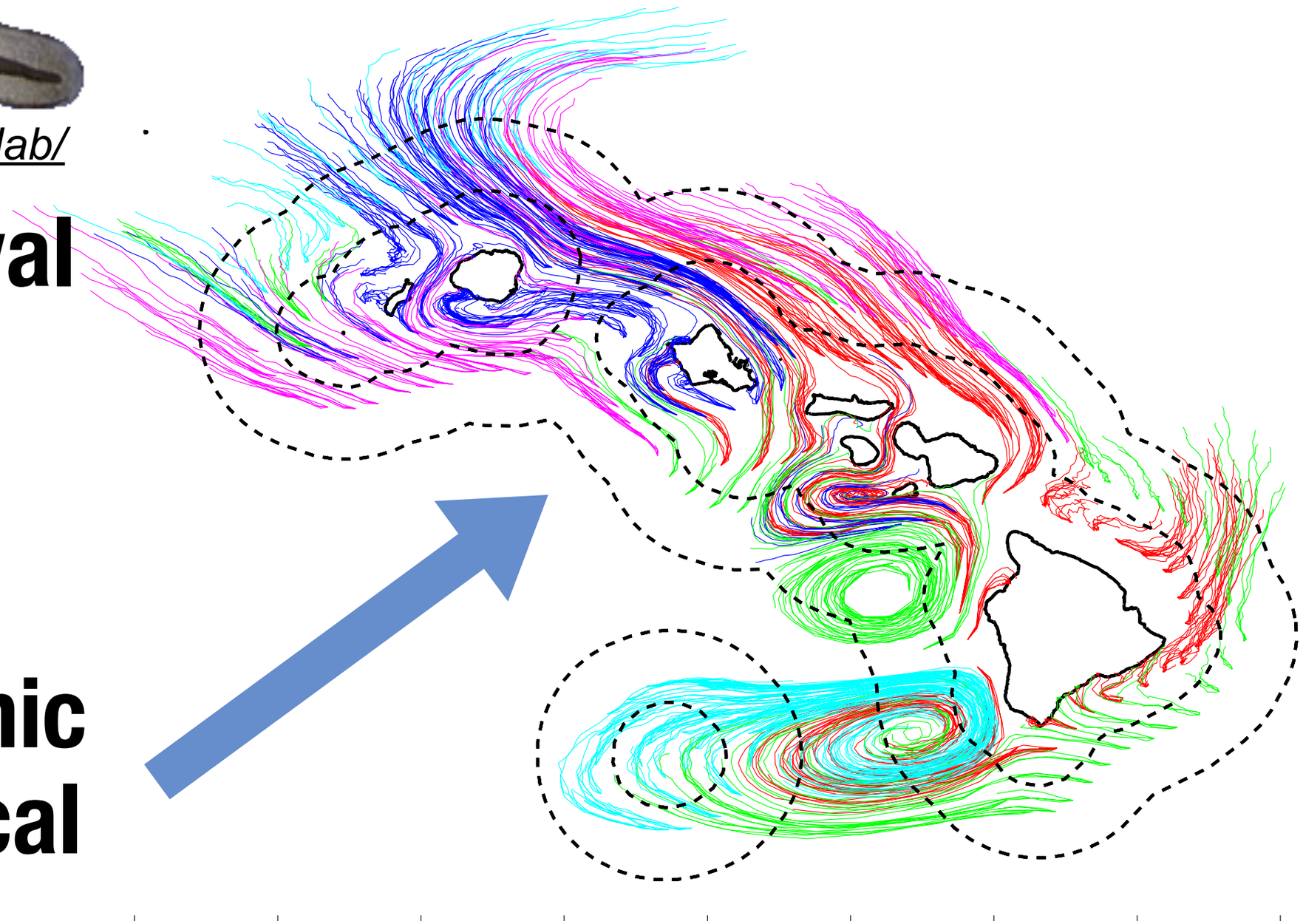
Simulate larval dispersal

hydrodynamic to biophysical models



Connectivity Modelling System

Paris *et al.* 2005, 2007, 2012;
Helgers and Paris 2011

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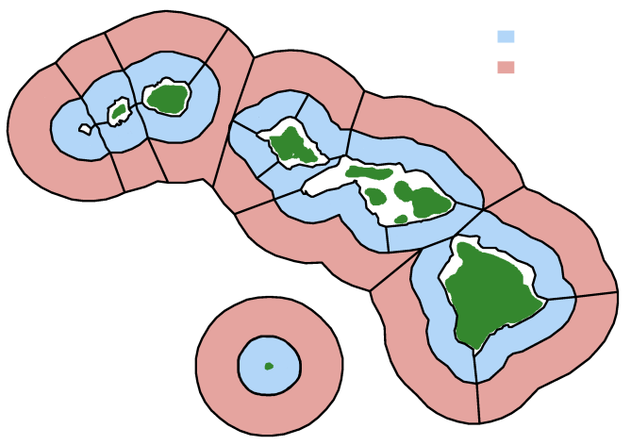
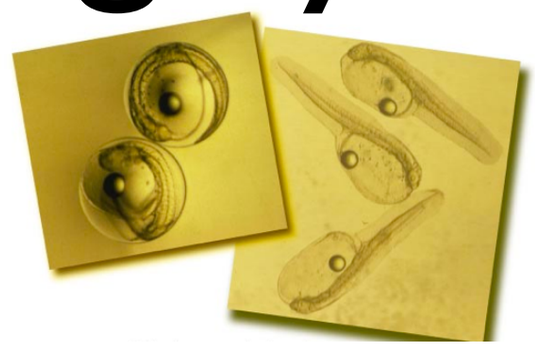
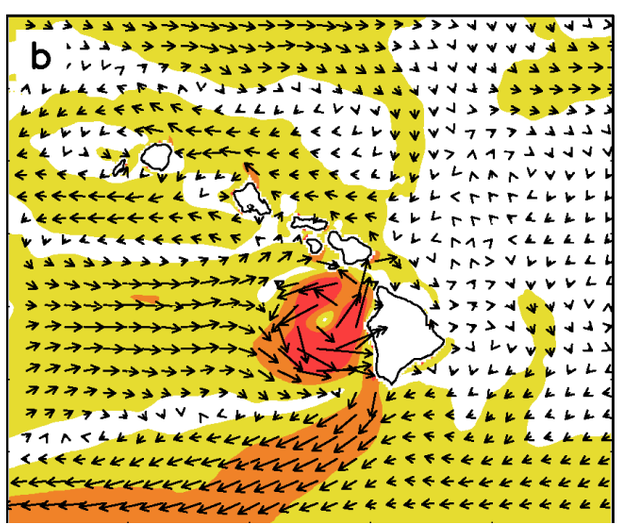




Biology: Spawning, Behavior

Seascape: Habitat Production



Oceanography: Physical fields

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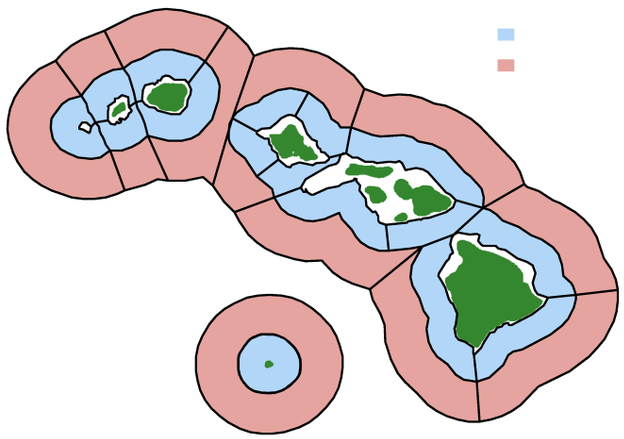

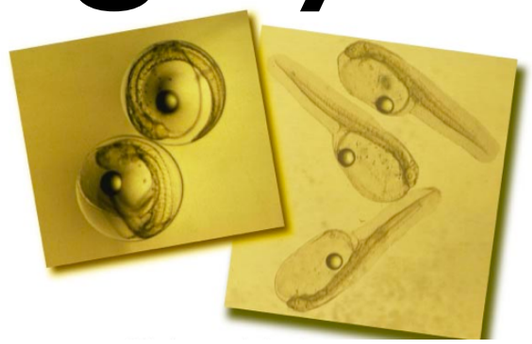

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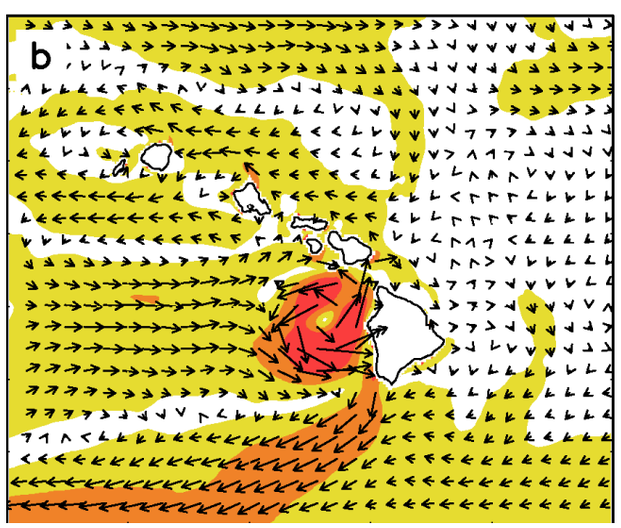
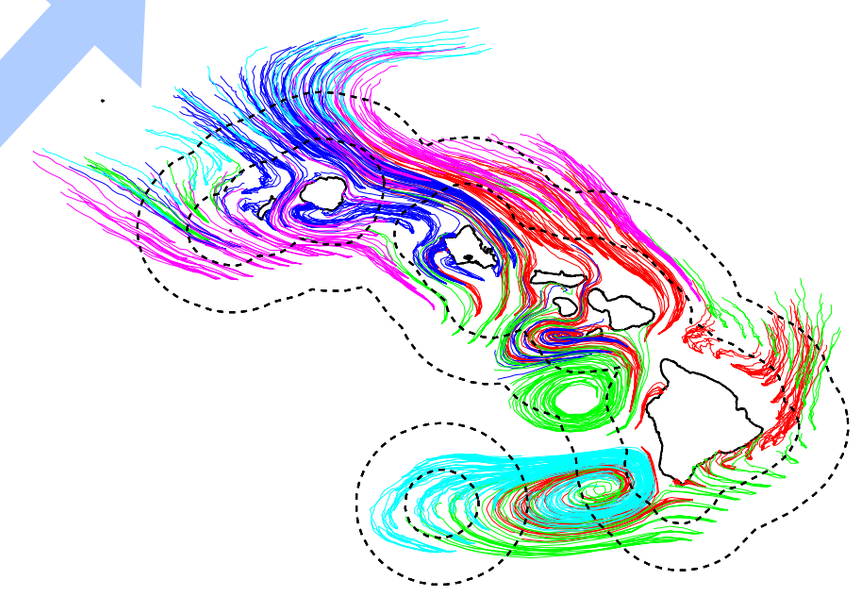
Individual-based Model: Larval Dispersal

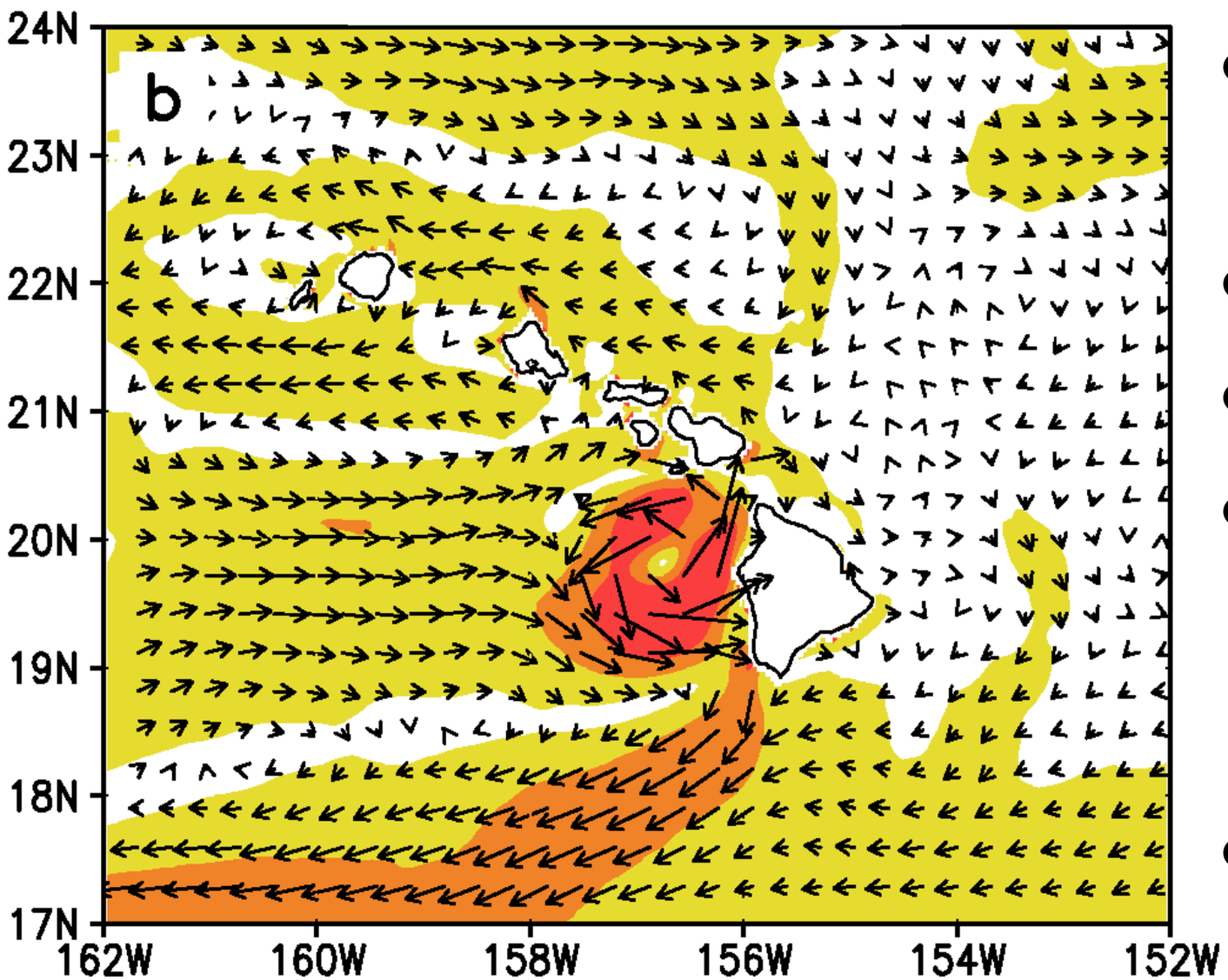




HYCOM Regional

Jia *et al.* 2011

2009-2011



- Around Main Hawaiian Islands
- ~4 km resolution
- 32 vertical layers
- Winds from regional atmospheric model (WRF 0.06°)
- No data assimilation

available at: http://apdrc.soest.hawaii.edu/

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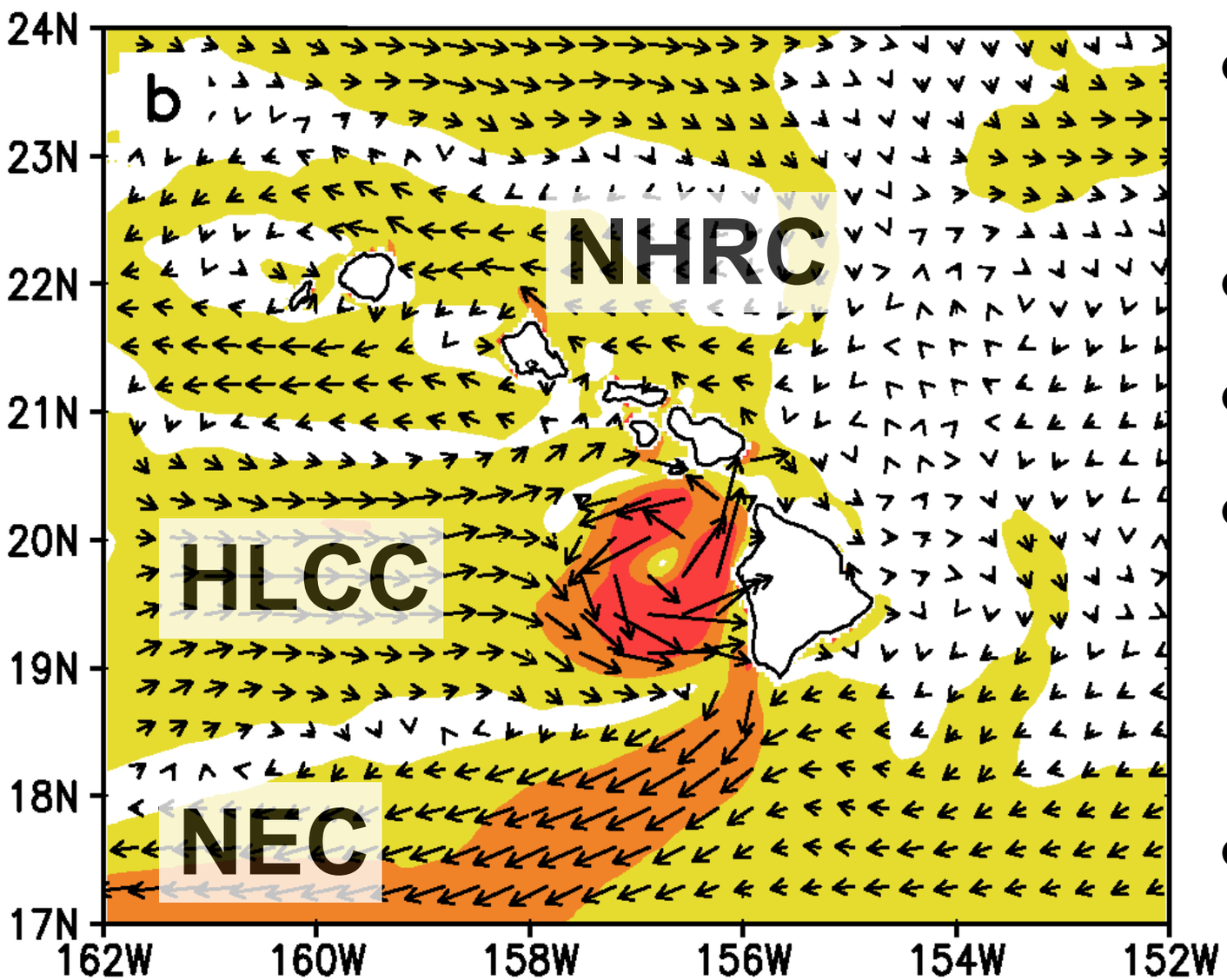

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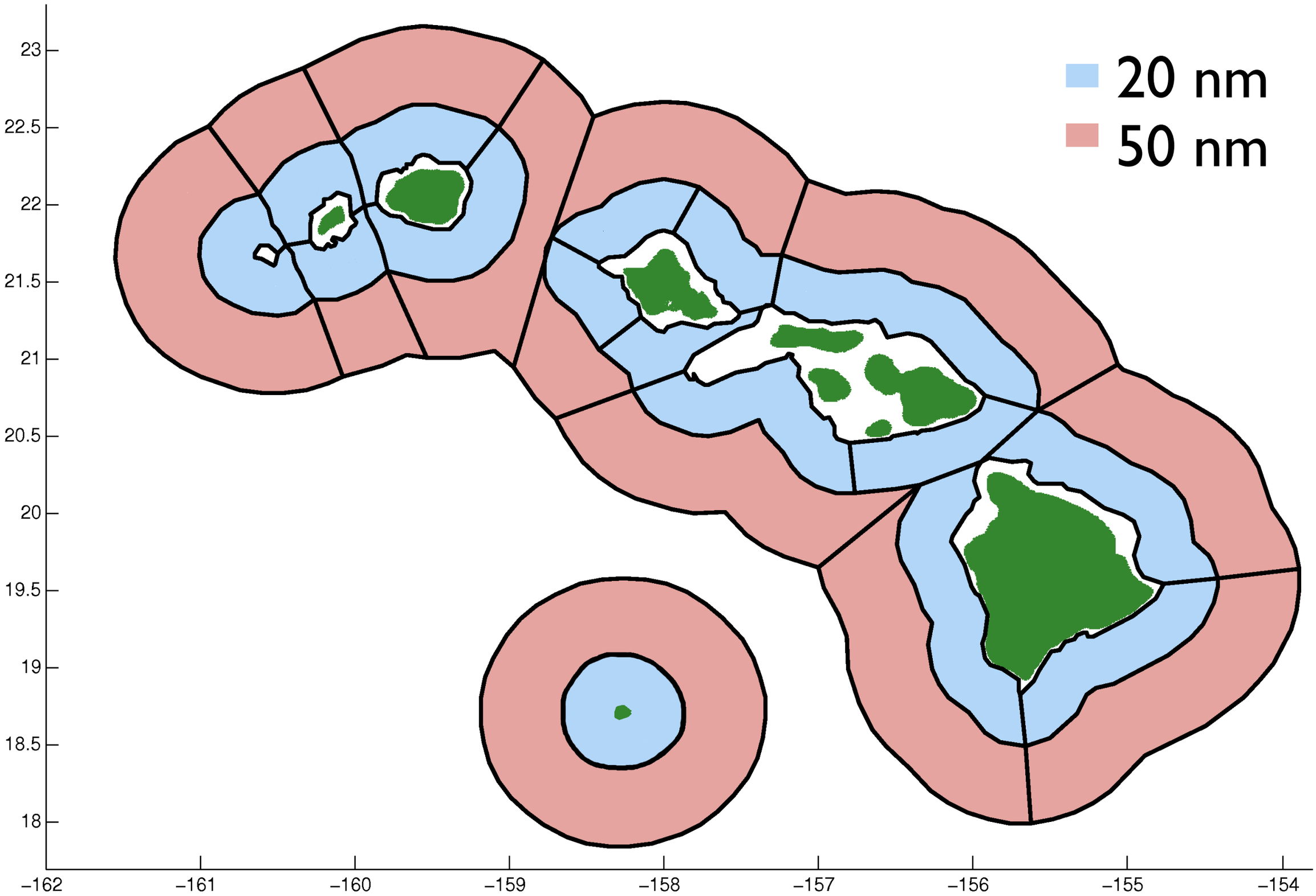
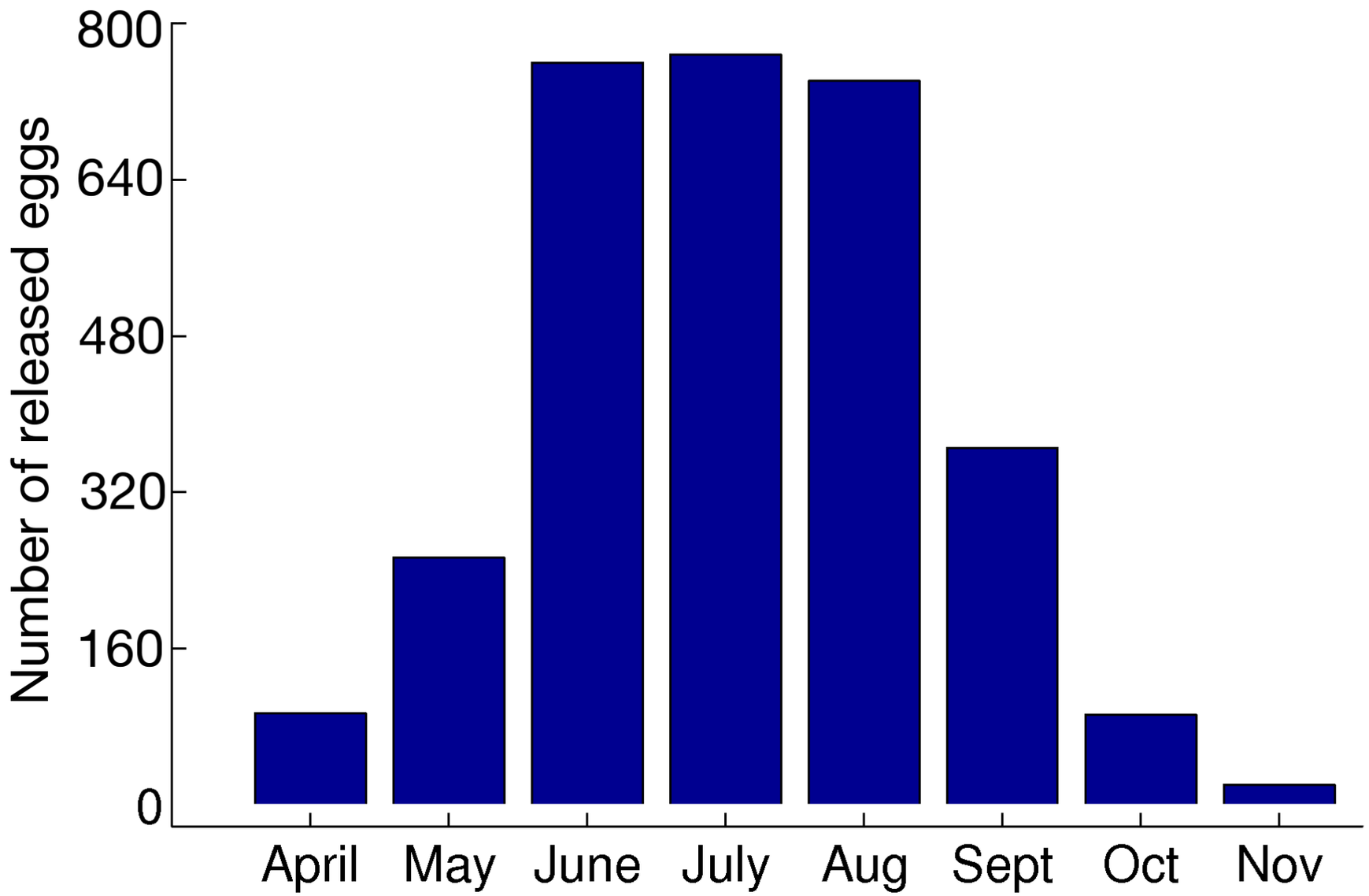
Yellowfin Tuna Dispersal 2009-2011

Spawning Areas

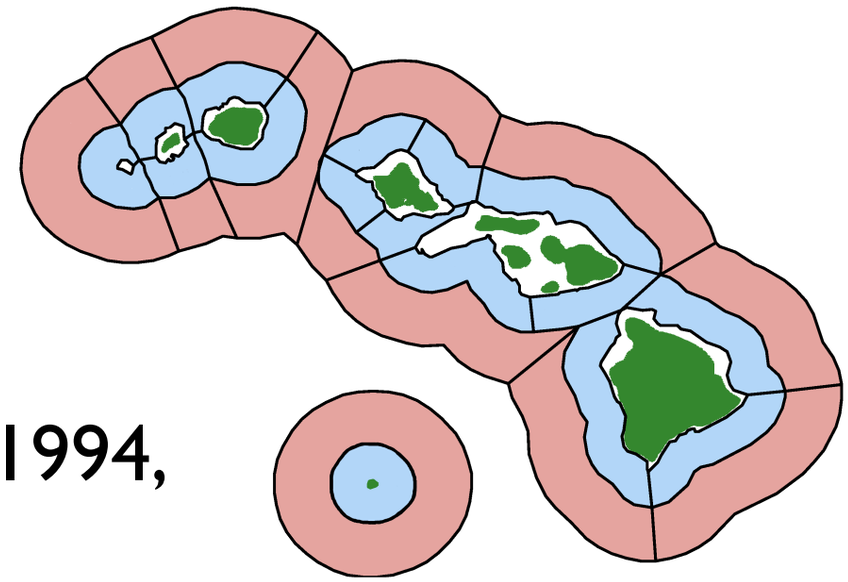


Spawning Season 2009-2011



Based on Itano (2001)

Ontogenic Vertical Migration



Matsumoto 1958, Leis 1991, Boherlet and Mundy 1994, Margulies *et al.* 2007, Llopiz 2009

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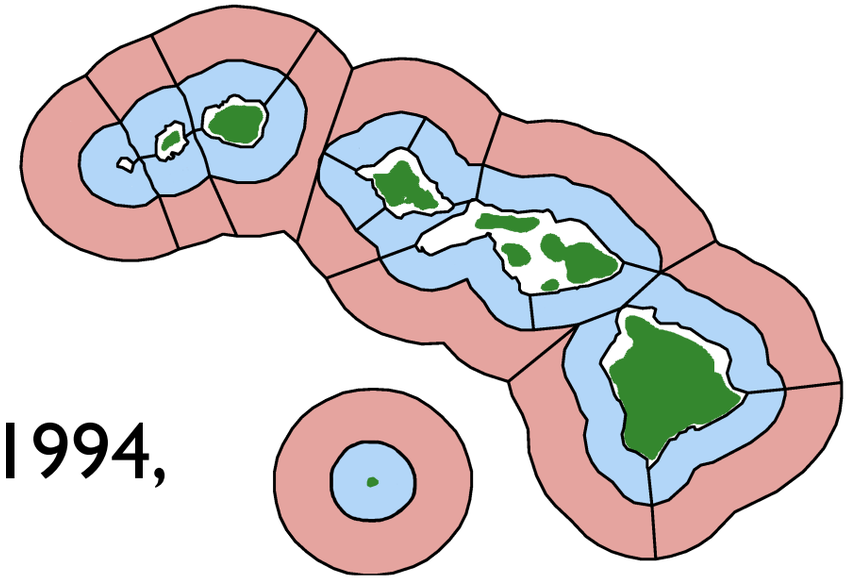

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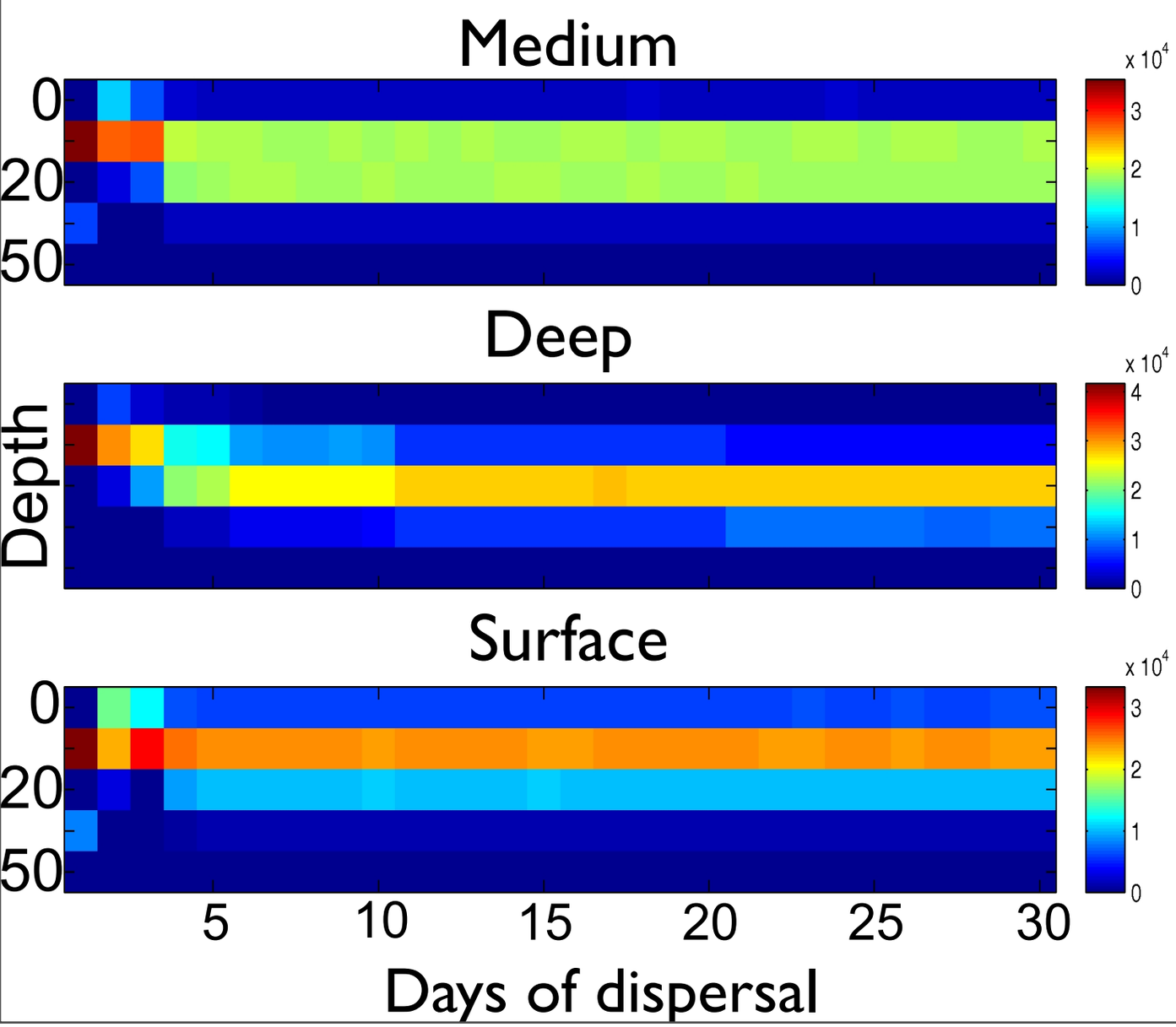

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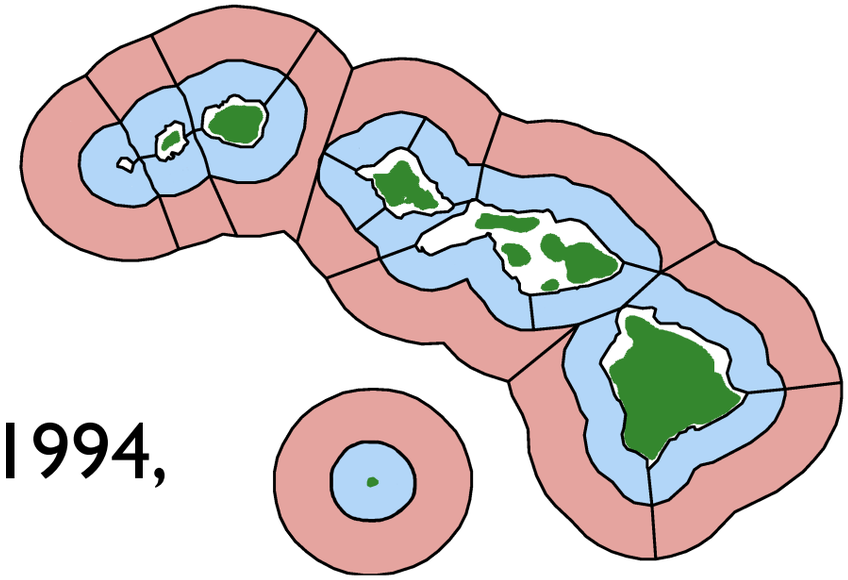

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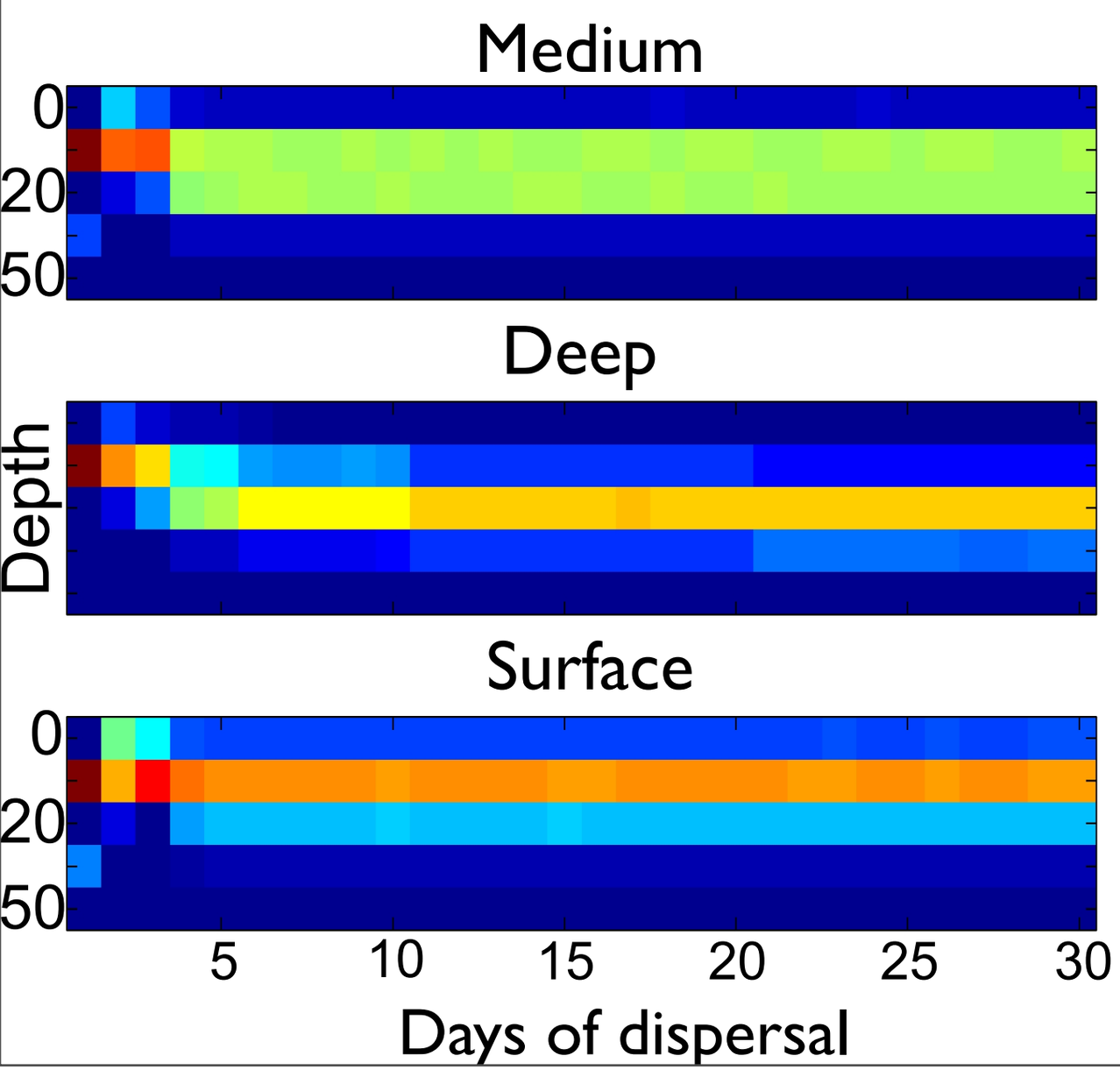

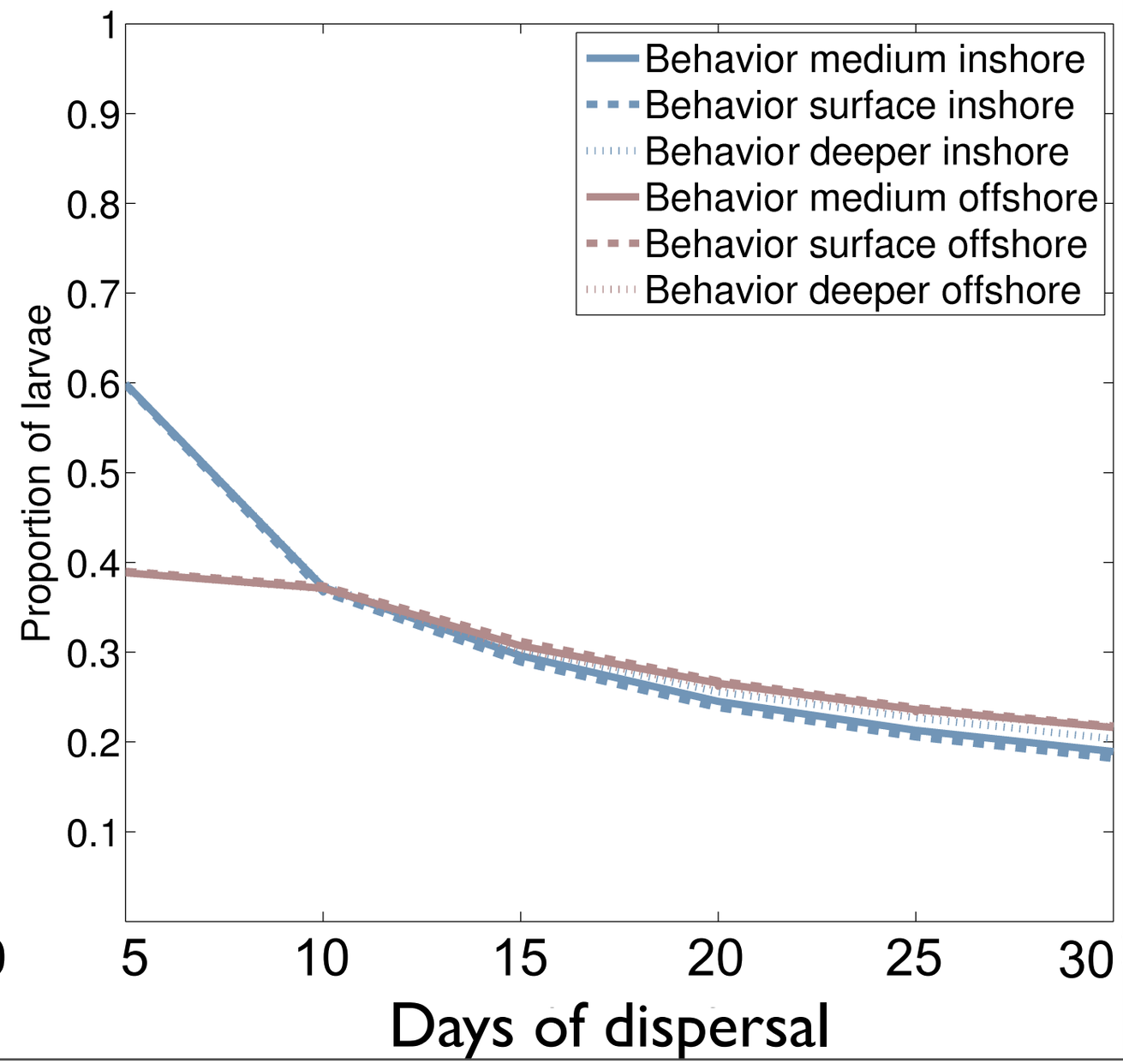

Mortality and Turbulence

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Optimal Turbulence

Margulies *et al.* 2001, Kimura *et al.* 2004, Margulis *et al.* 2007

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Survival of larvae at 10 m depth

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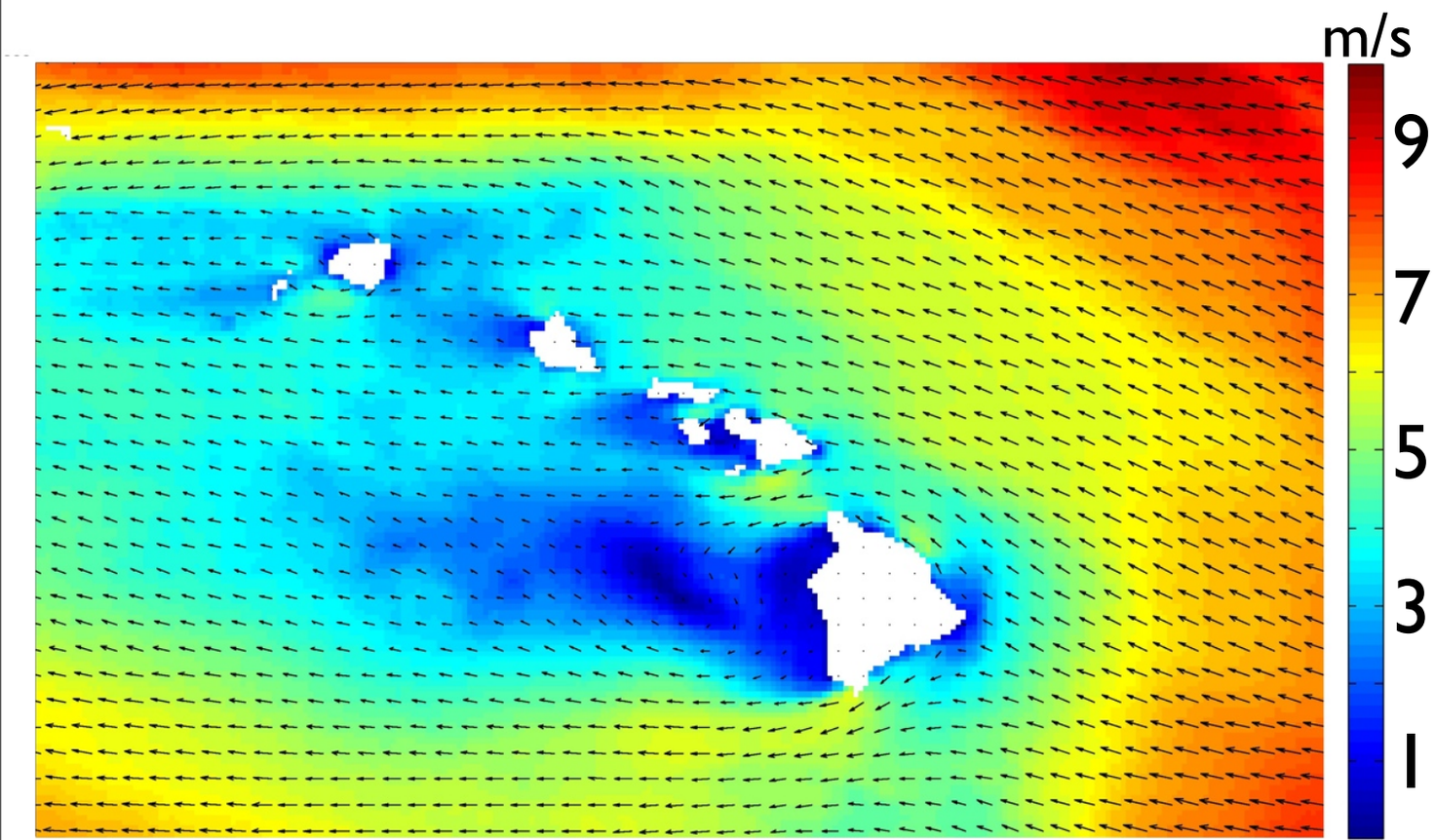

Regional wind

Tu and Chen 2011

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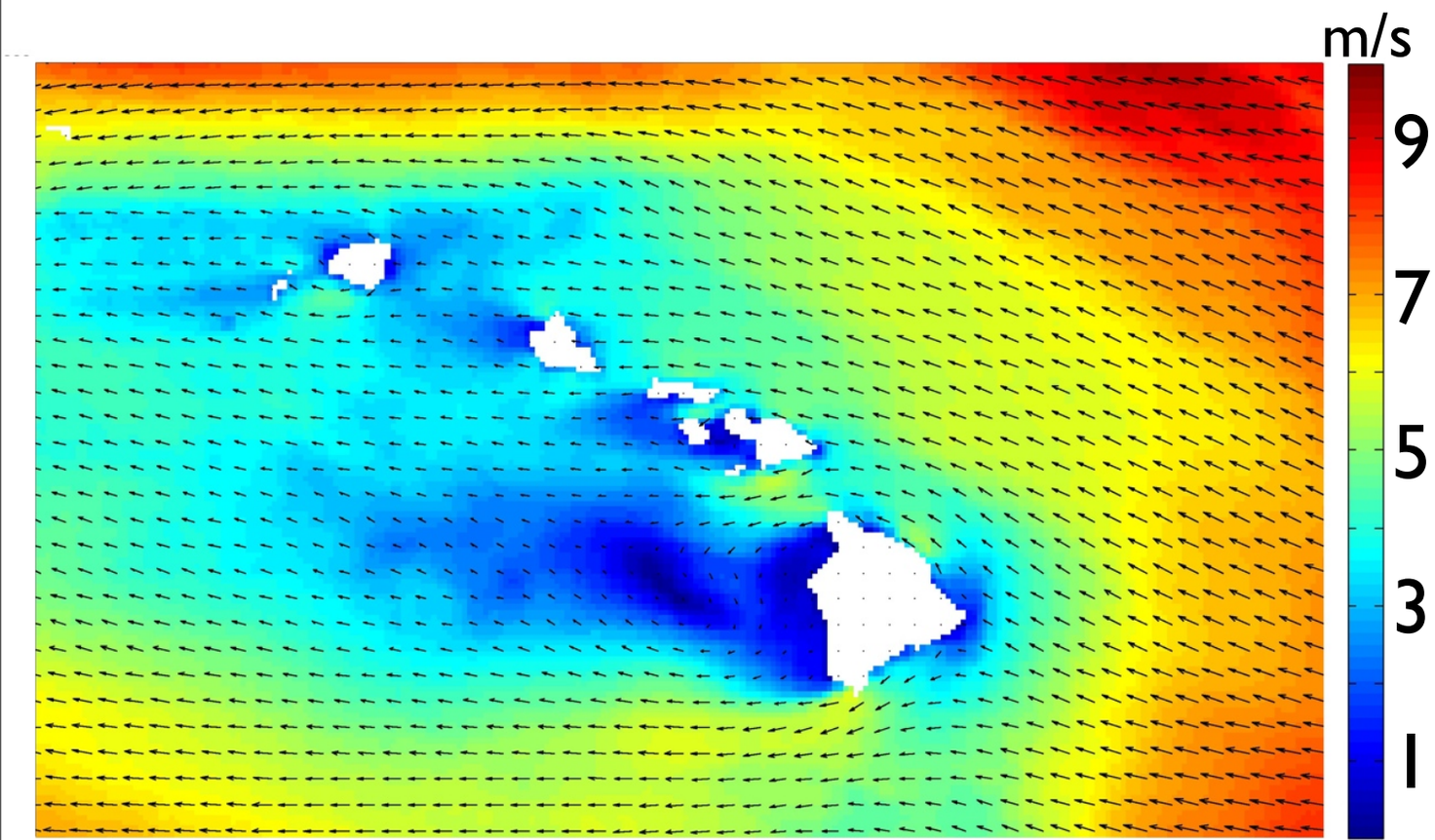

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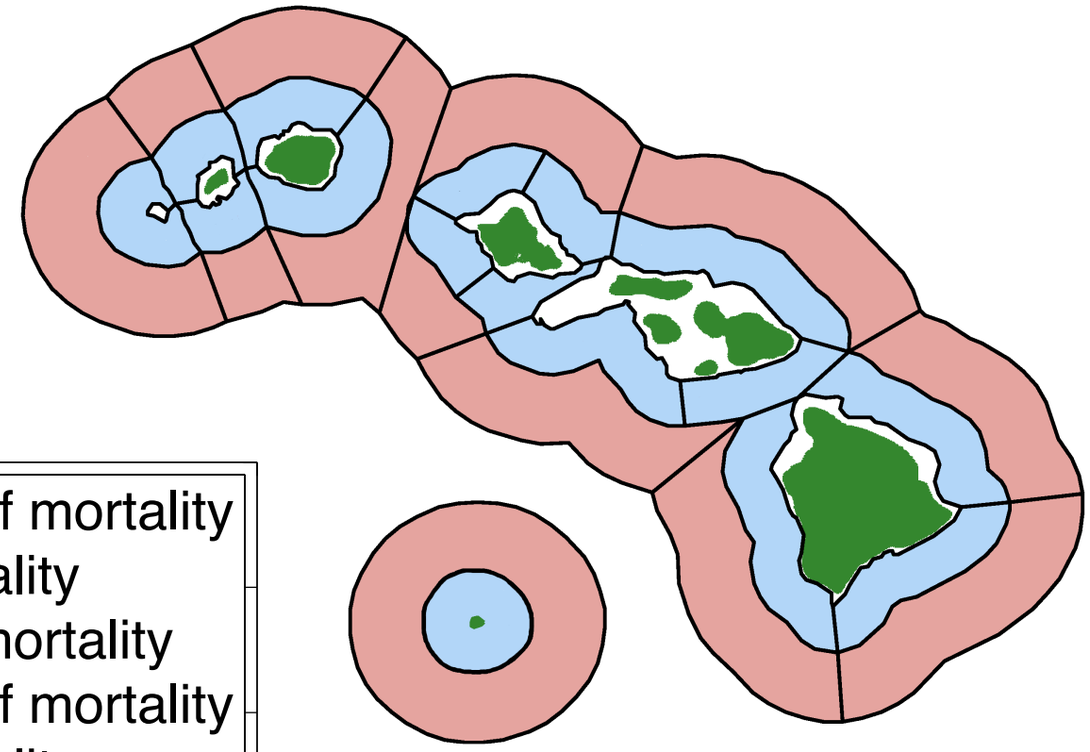
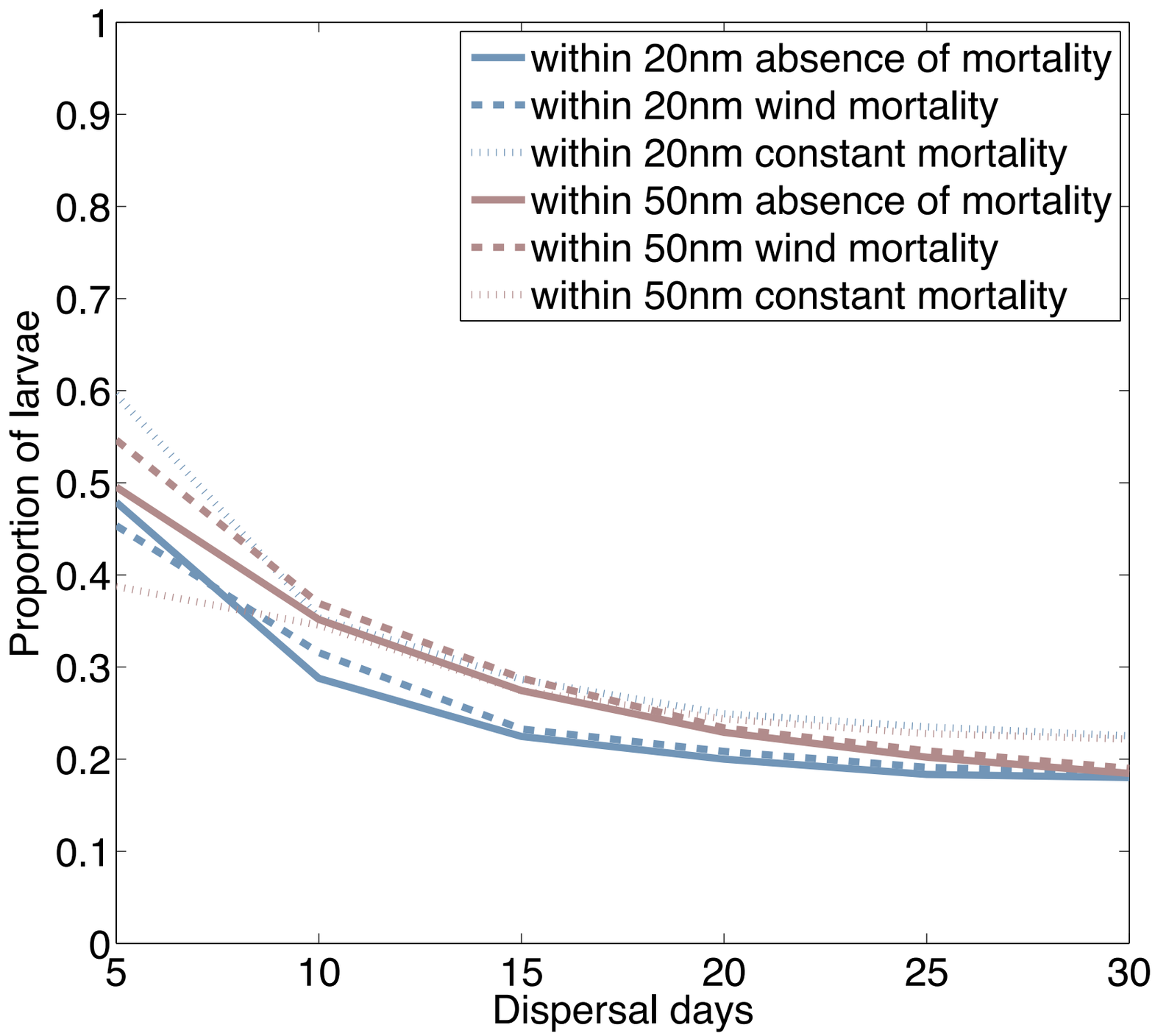
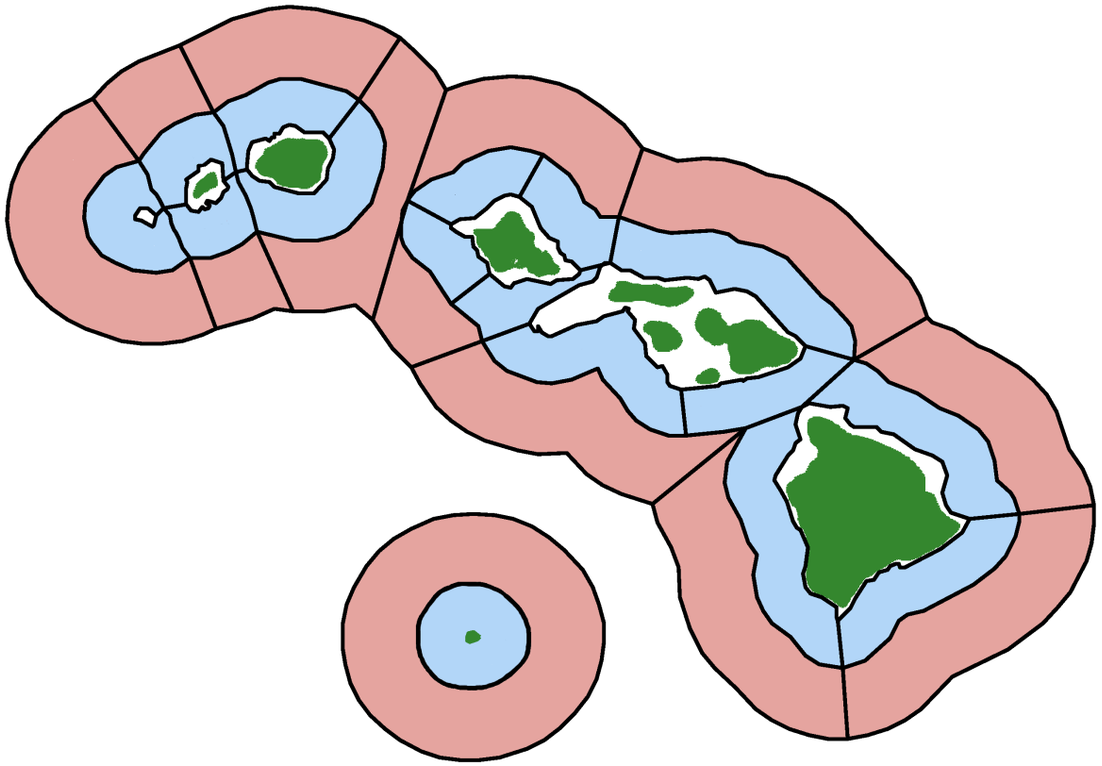
Mortality Index

Mortality Schemes





Monthly variability



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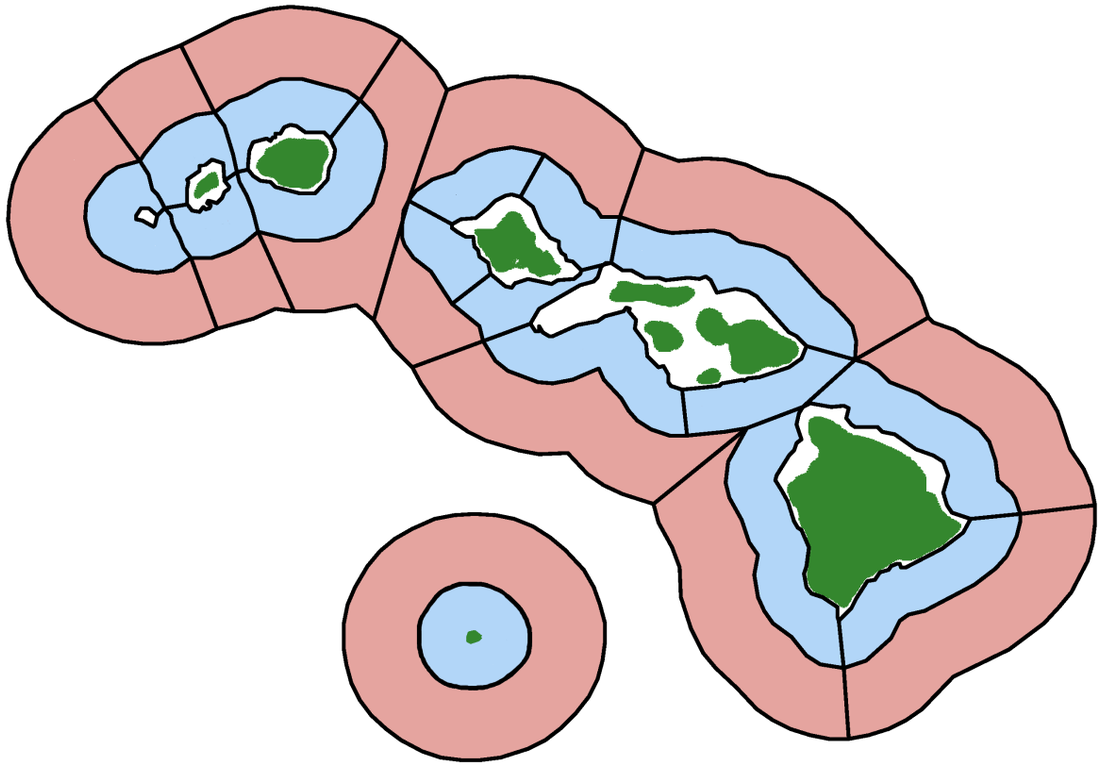
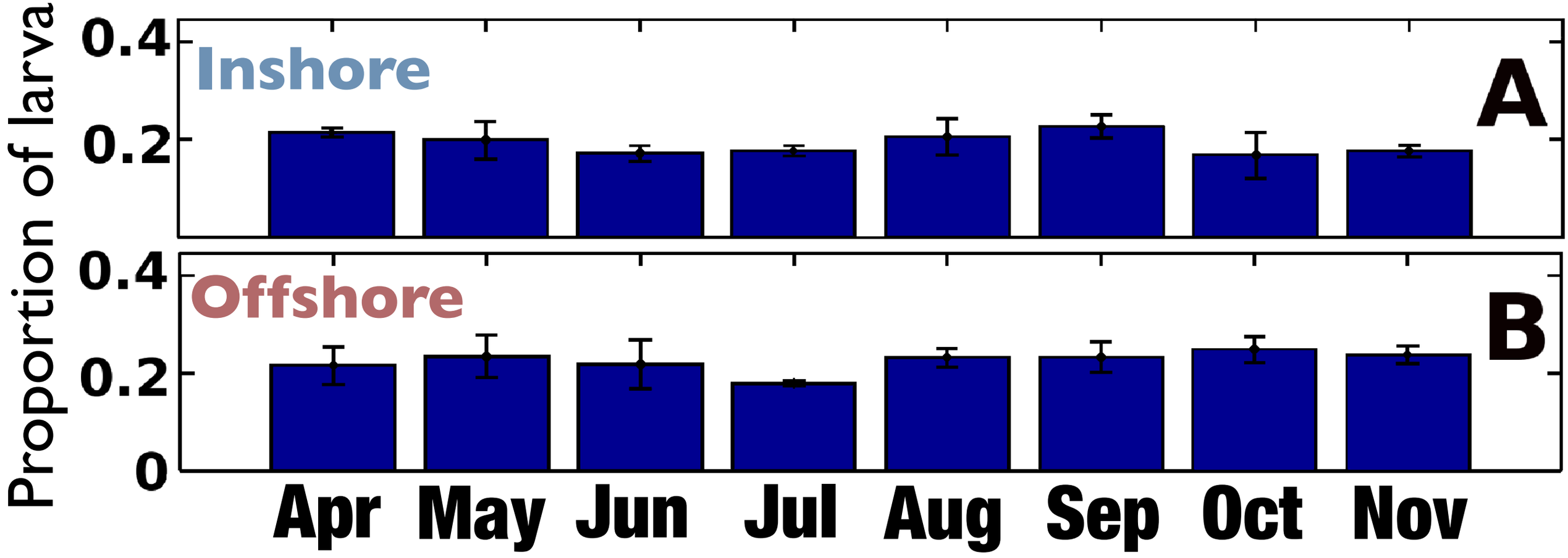
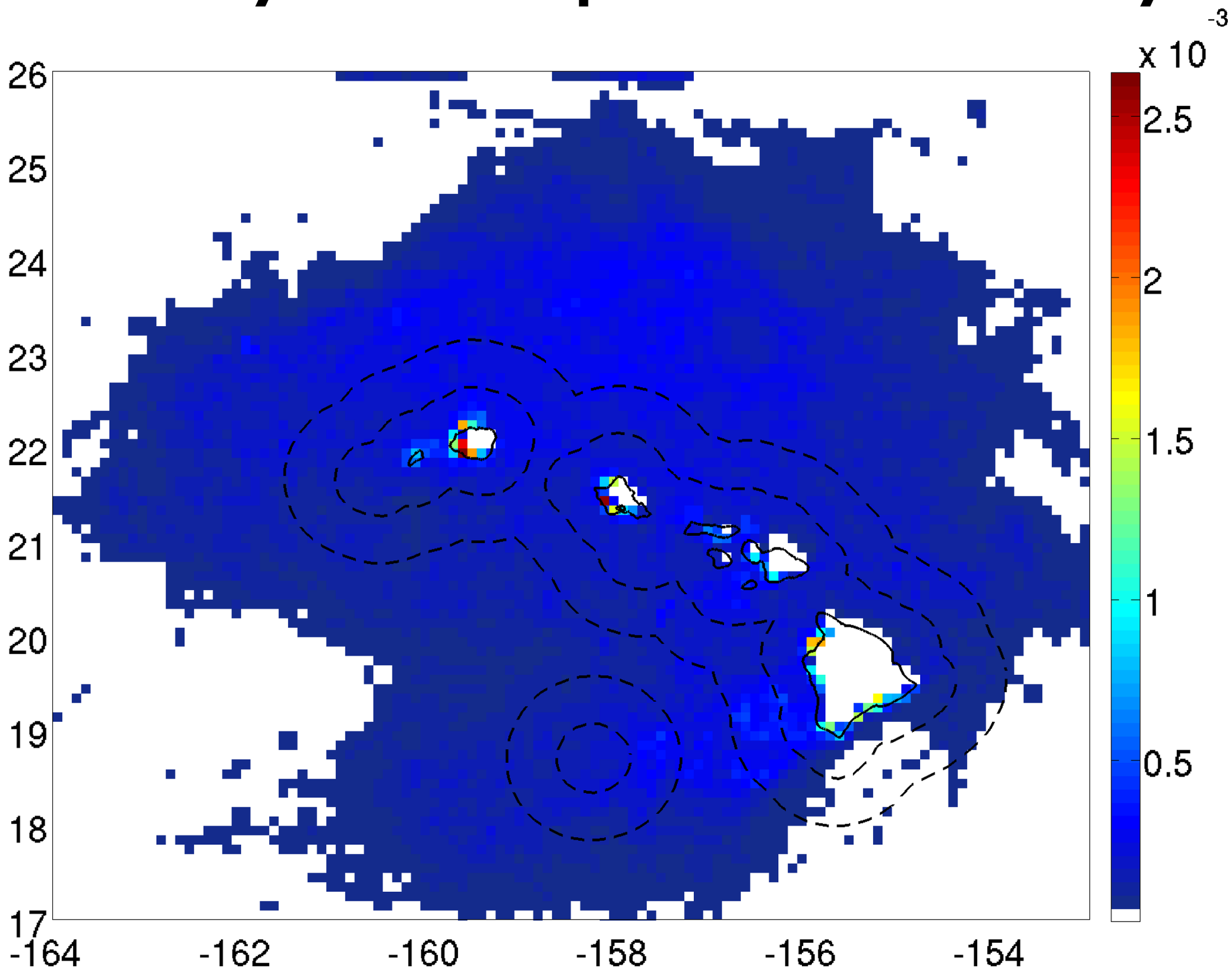
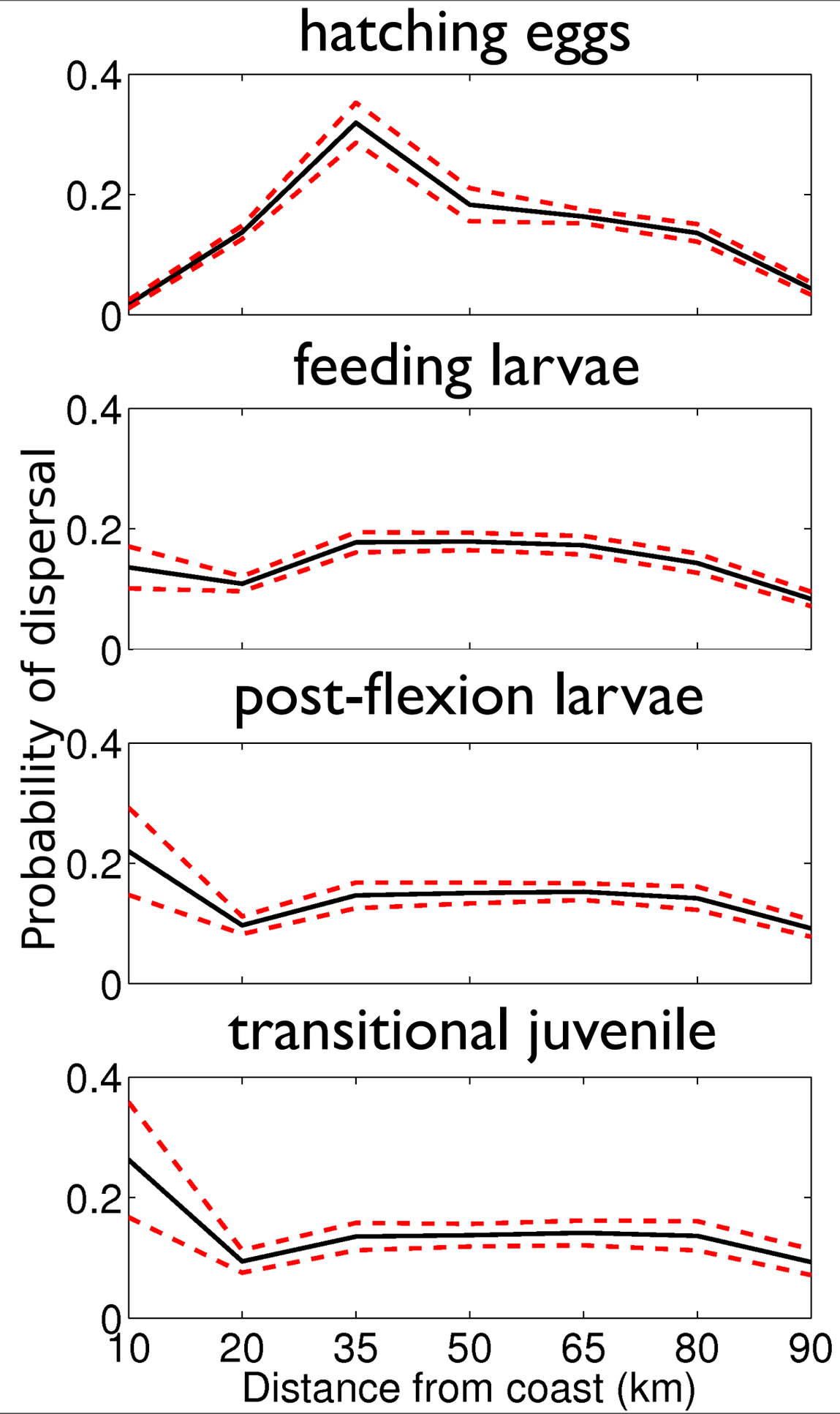




Variability of Dispersal Pathways



Cross-shore distribution



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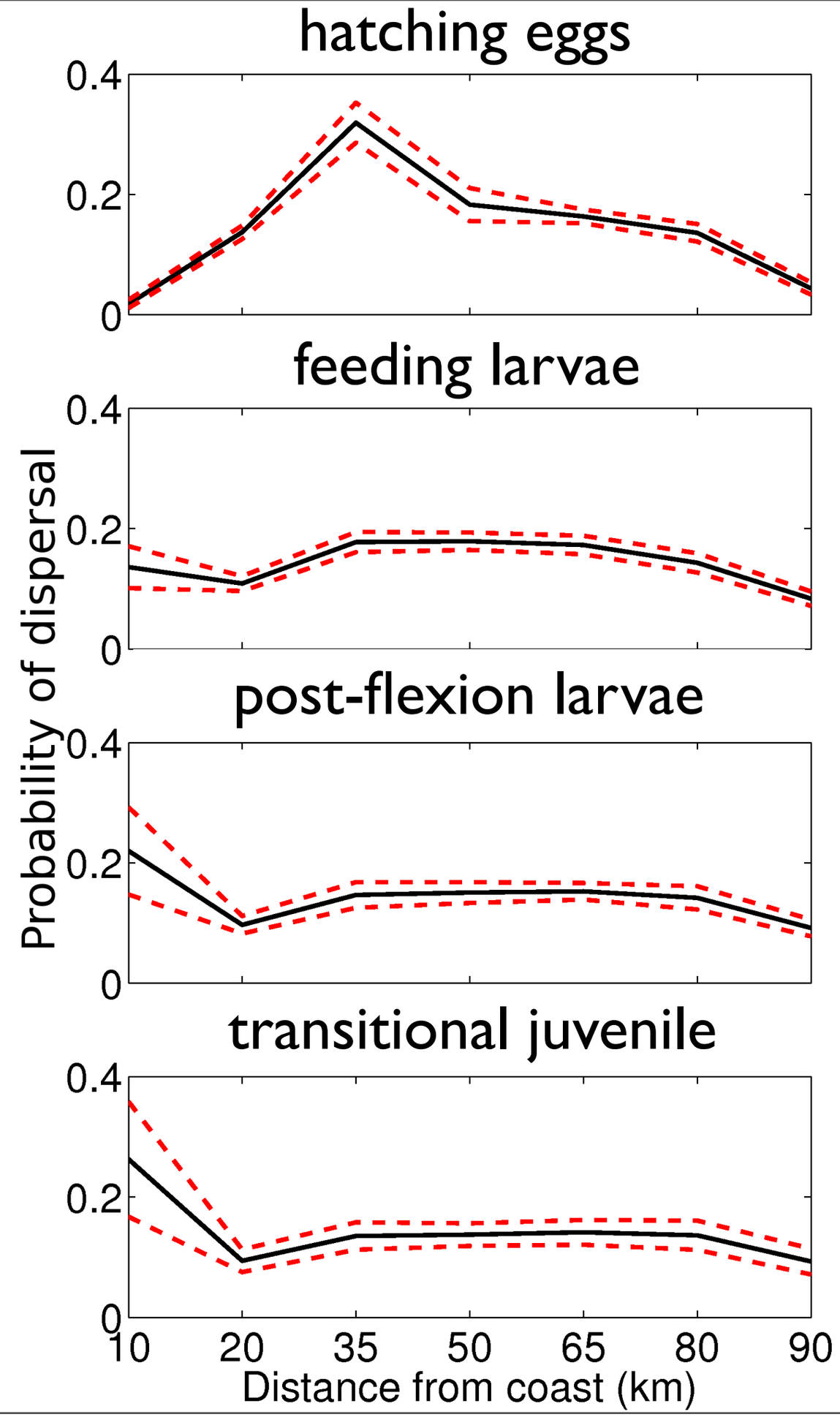
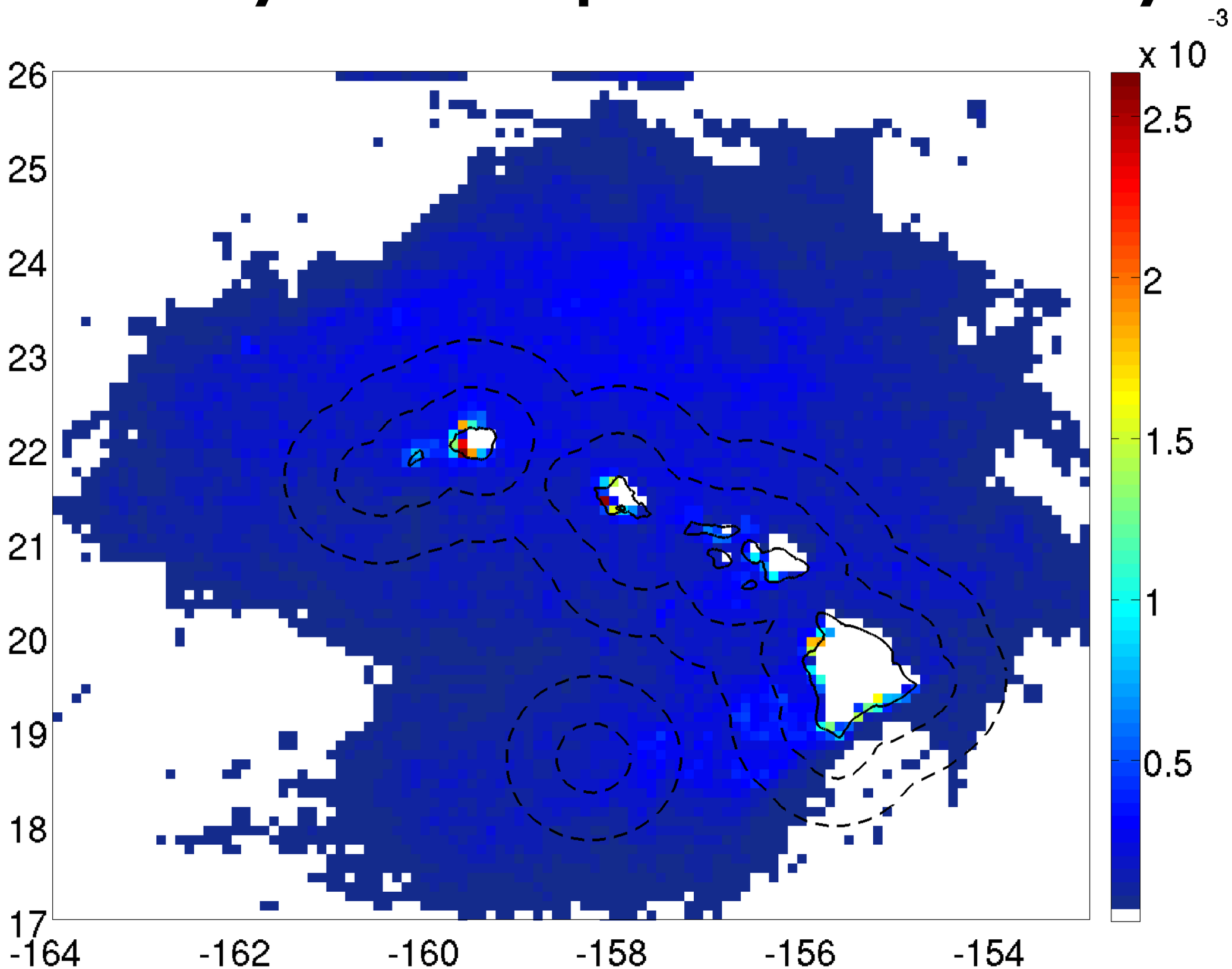


Field studies: higher abundances of *Thunnus sp*. larvae in nearshore areas

Miller 1979, Leis 1991, Boherlet and Mundy 1994, Boehlert and Mundy 1996, Fowler *et al.* 2008

Variability of Dispersal Pathways



Average Dispersal Pathways

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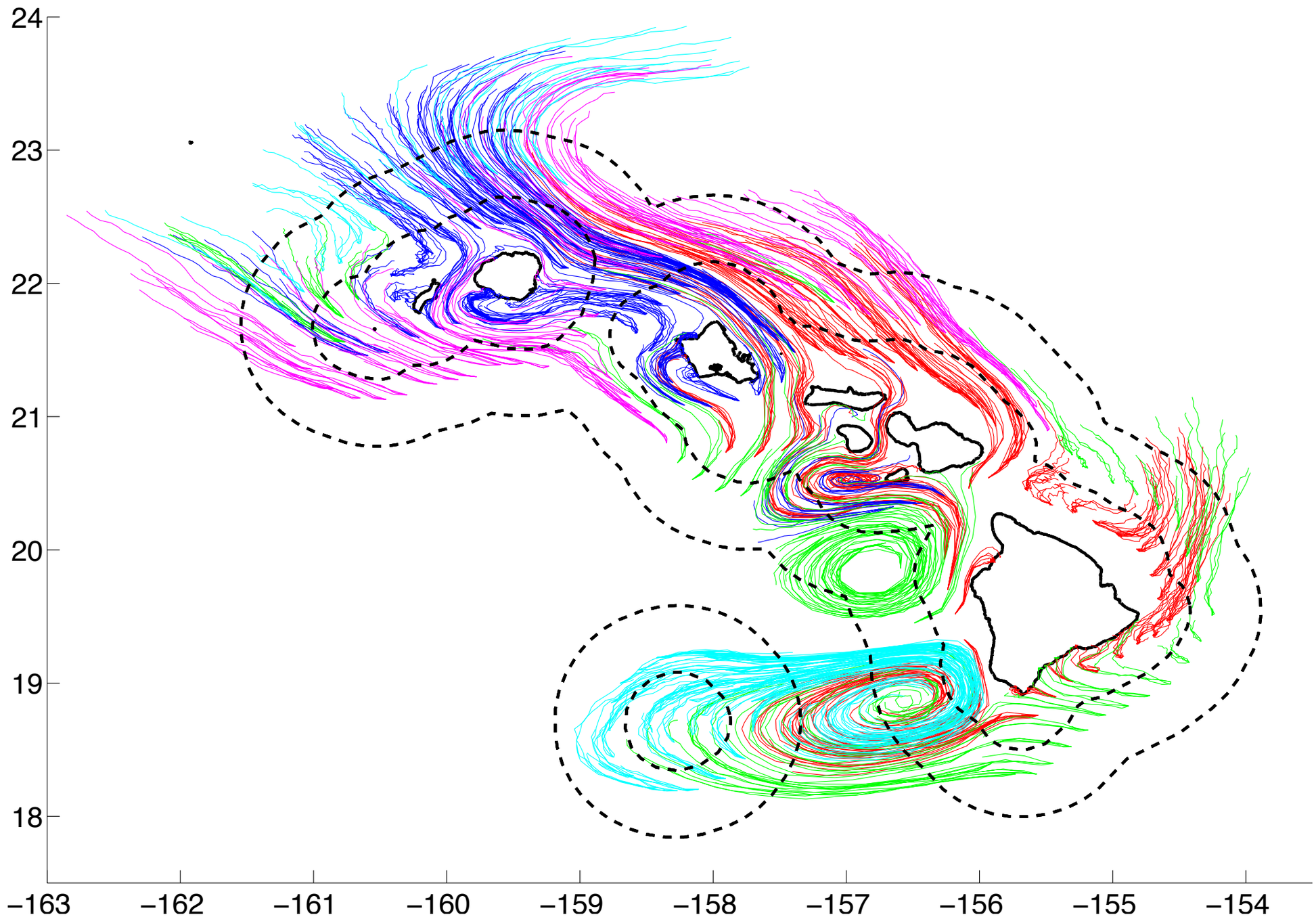

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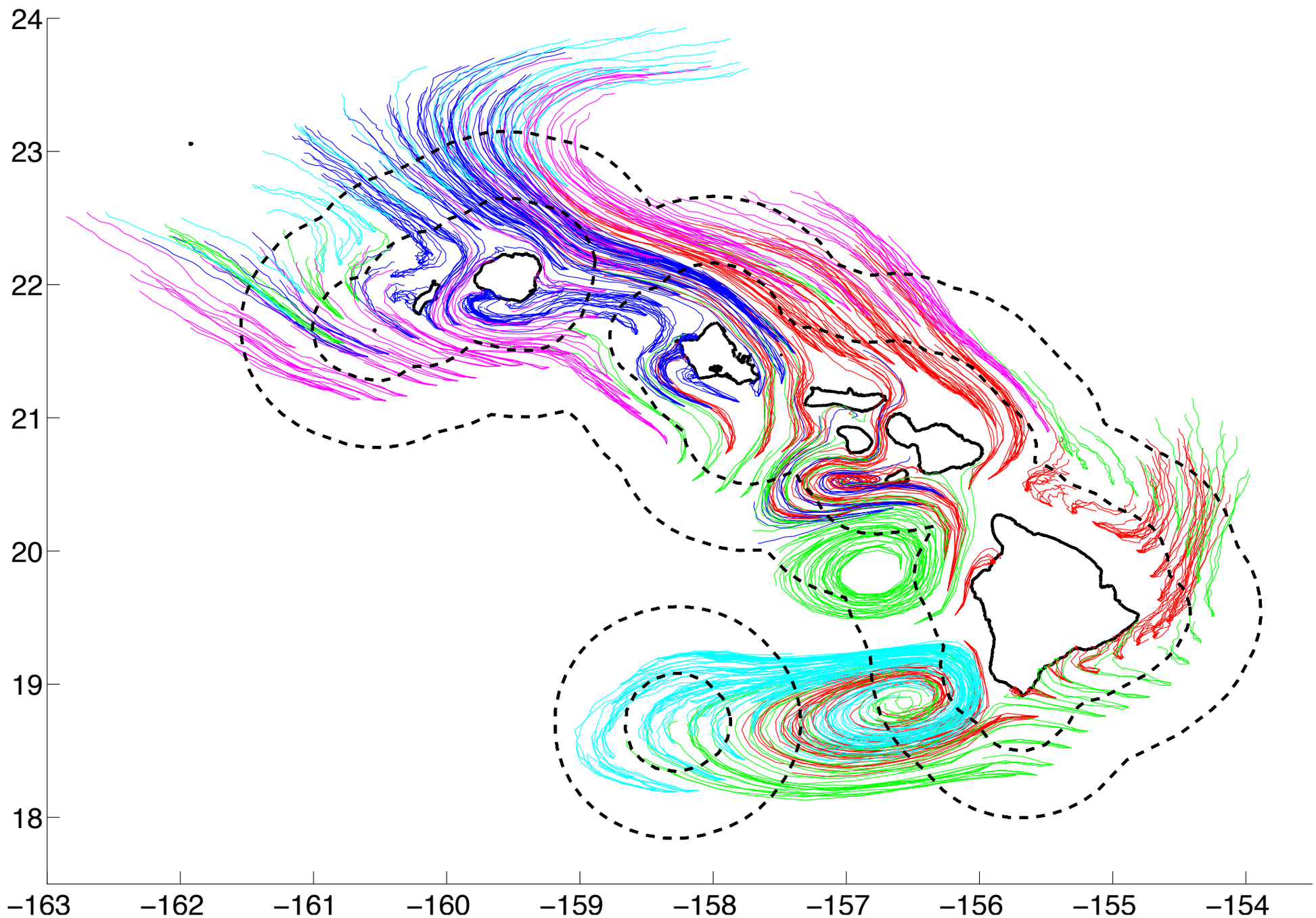

70% of retention

Directional Behavior

Staaterman et al. 2012 JTB

Directional Behavior

Staaterman et al. 2012 JTB

Larvae 200 km around the islands:
detect nearshore environment

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Swimming capabilities:
increase with time

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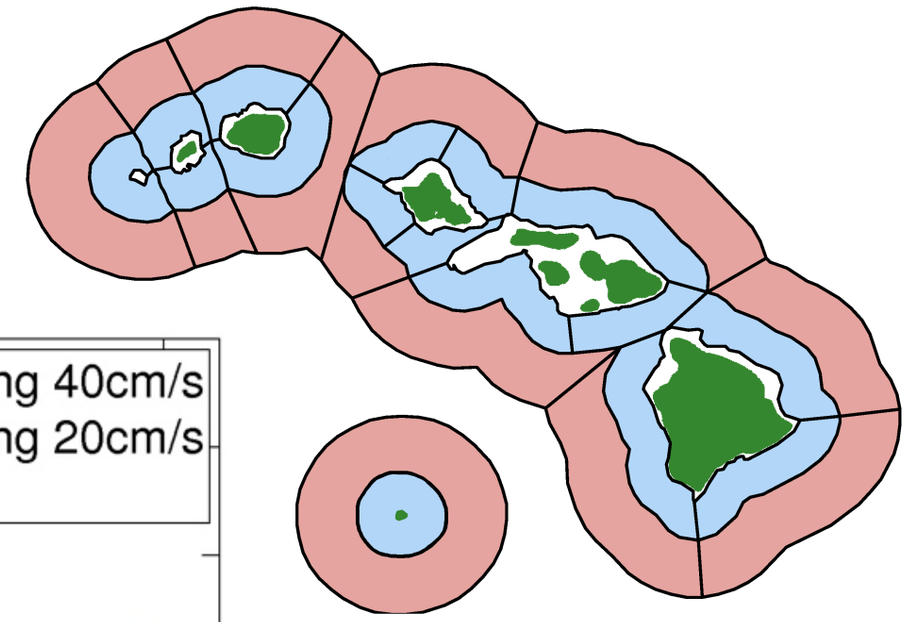
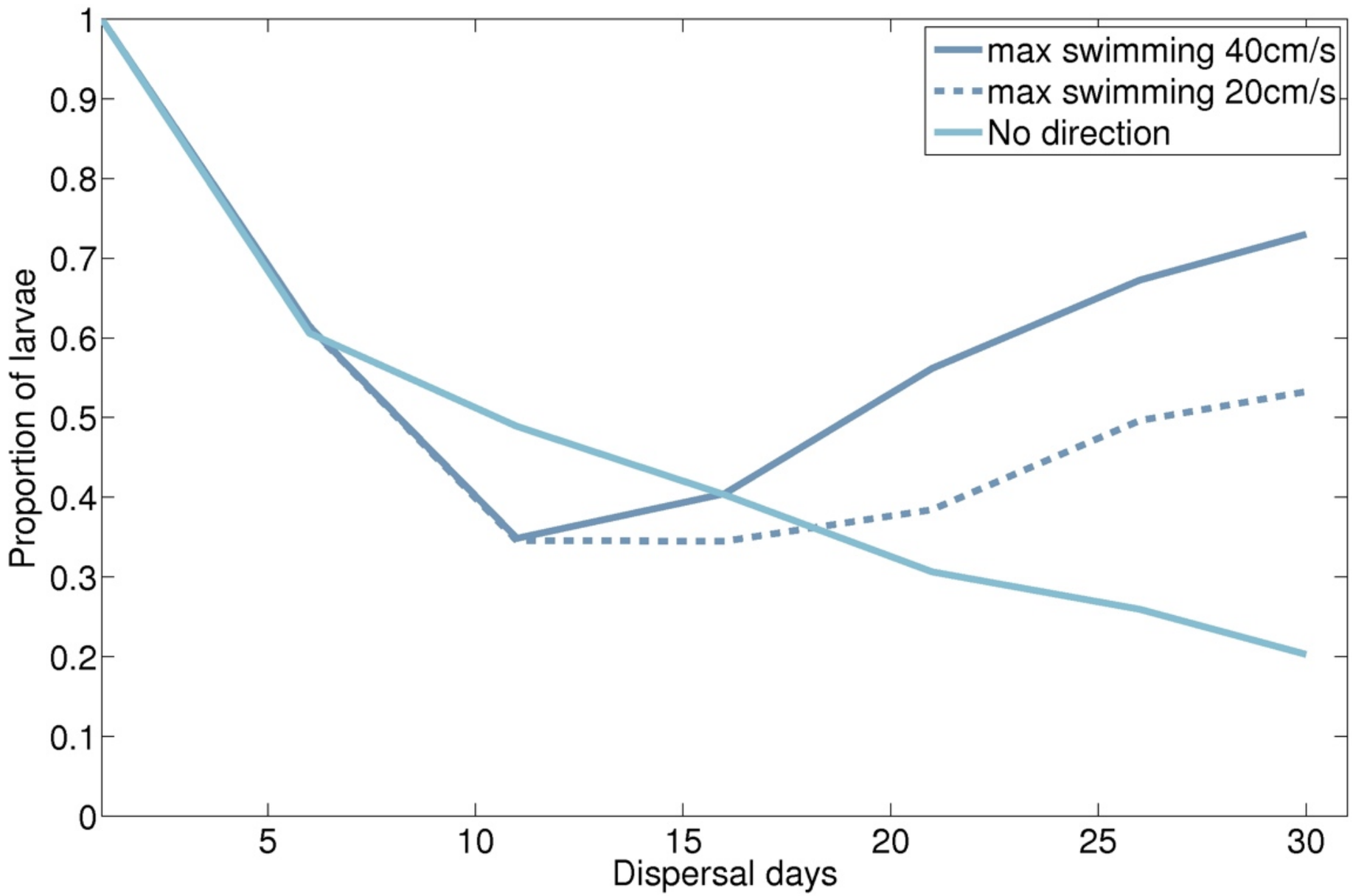
Preliminary simulations:
Spawning on leeward Hawai'i
May/2009

Directional Behavior





Conclusions

Ontogenic vertical migration and mortality schemes:

did not significantly affected the number of retained larvae

No seasonality of retention:

other factors shaping spawning

High variability of dispersal pathways:

however, environment around Hawai'i is conducive for retention

Directional swimming behavior

can increase the retention around the islands

will be further investigated

Thanks! Mahalo! Questions?

Acknowledgments:

Funding:

Pelagic Fisheries Research Program

CAPES and Fulbright

Collaboration:

Jeanne Wexler (IATTC)

Bruce Mundy (NMFS)

Christopher Kelley (UH)

Brian Bowen (HIMB)

Brian Powell (UH)

Erica Staaterman (UMiami)

Ana Vaz

vaz@hawaii.edu

Photo by D. Benetti

Directional Behavior

Correlated random walk (Codling et al., 2004)

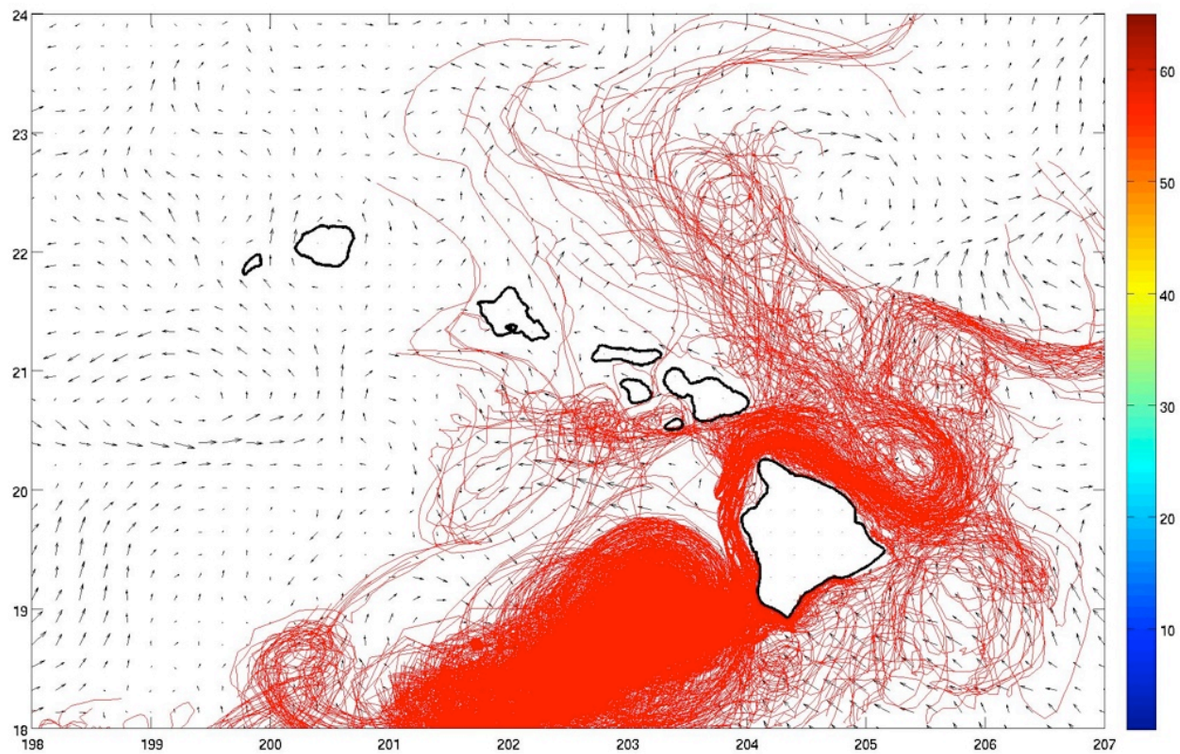
Larvae seeks "target destination"
Success depends on:
1) strenght of the cue
2) maximum detection distance, Beta
3) swimming speed S
4) ability to navigate in a turbulent flow

Based on:
1) current larval direction (based on travel from previous time step to current, angle)
2) distance from target (must be smaller than Beta)
3) preferred direction (angle between current position and the target destination)
4) cue strength

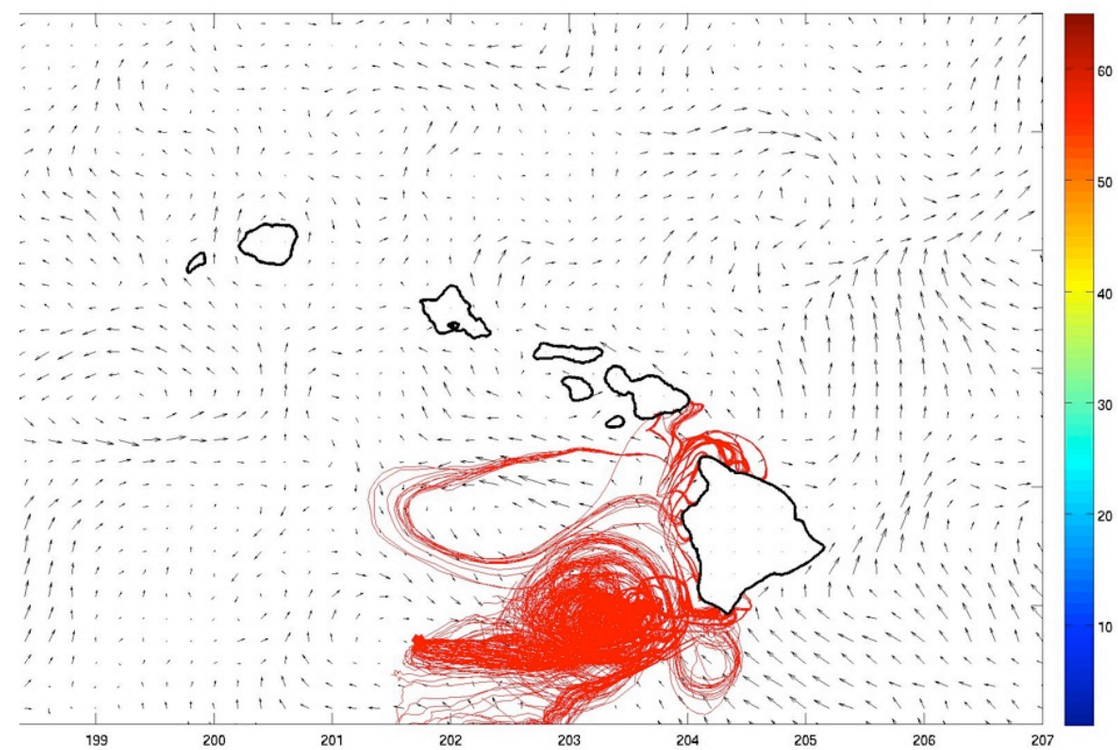
Larvae will receive a bearing from a von Mises distribution (theta)

uorient=S*cos(theta)
vorient=S*sin(theta)

Trajectories

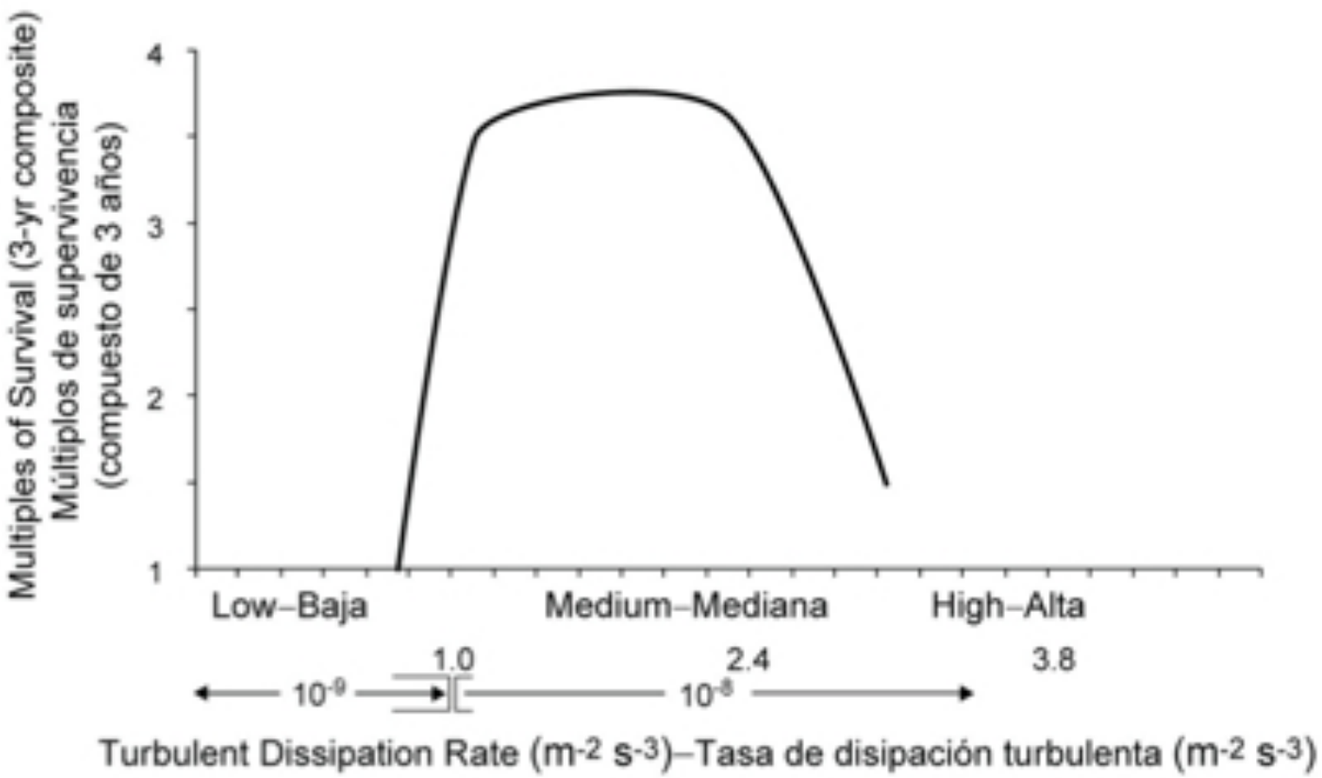


No directional behavior



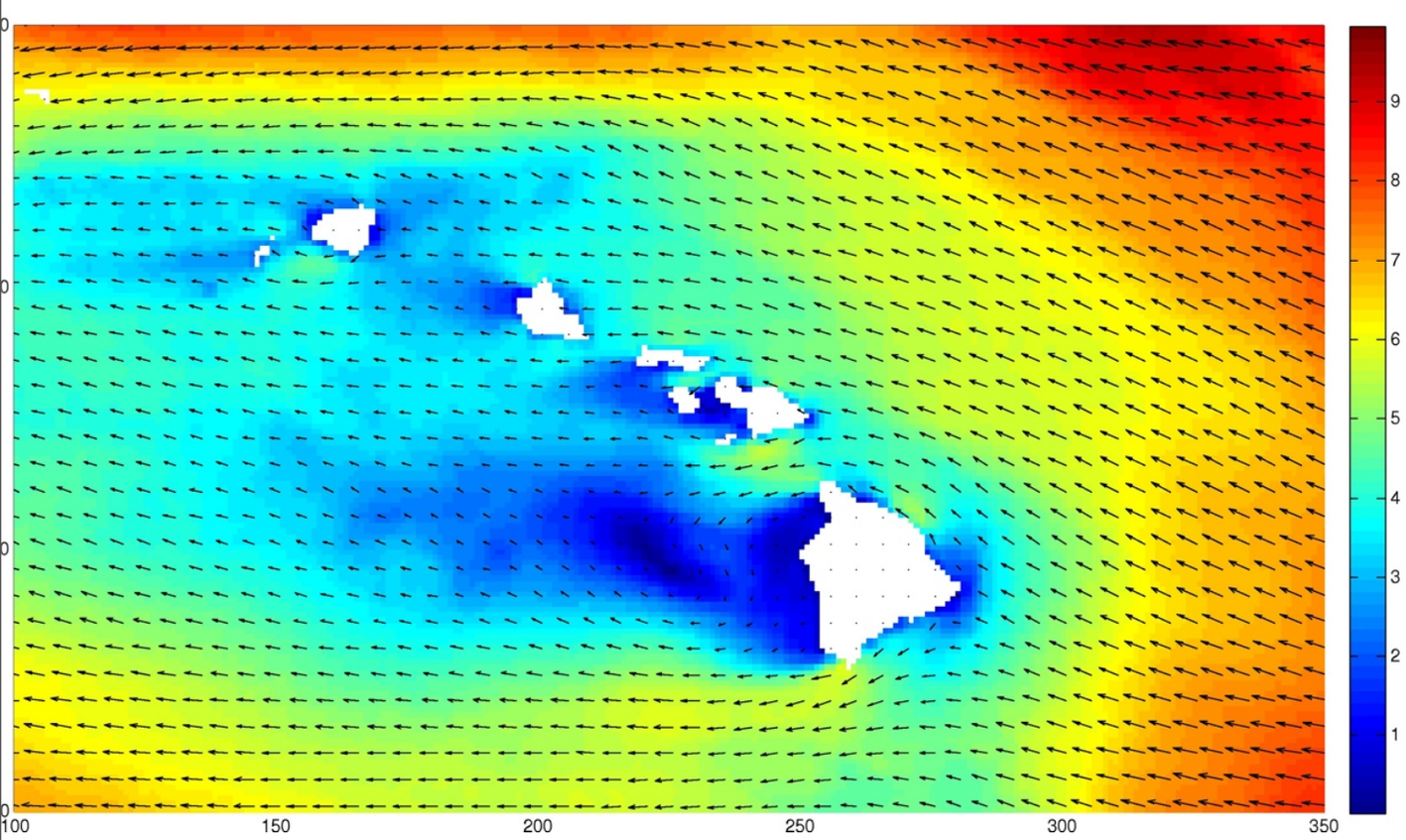
Directional behavior swimming velocities of 20cm/s

Mortality and Turbulence



Optimal Turbulence

Margulies *et al.* 2001, Kimura *et al.*2004, Margulis *et al.* 2007



Boundary Layer Model

McKenzie and Legget 1993, McKenzie, 1995

Mortality and Turbulence

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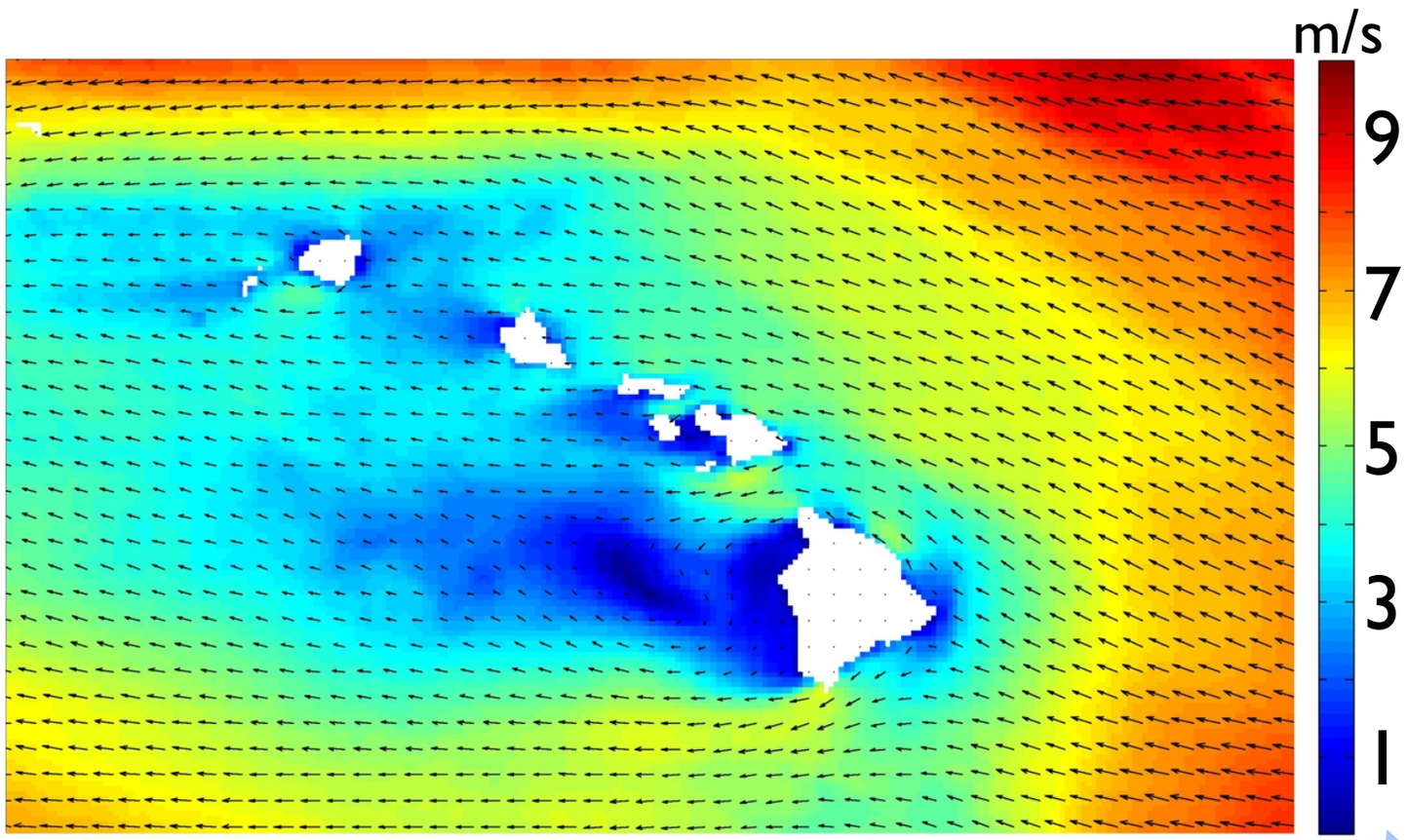

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Regional wind: create a mortality index

Tu and Chen 2011

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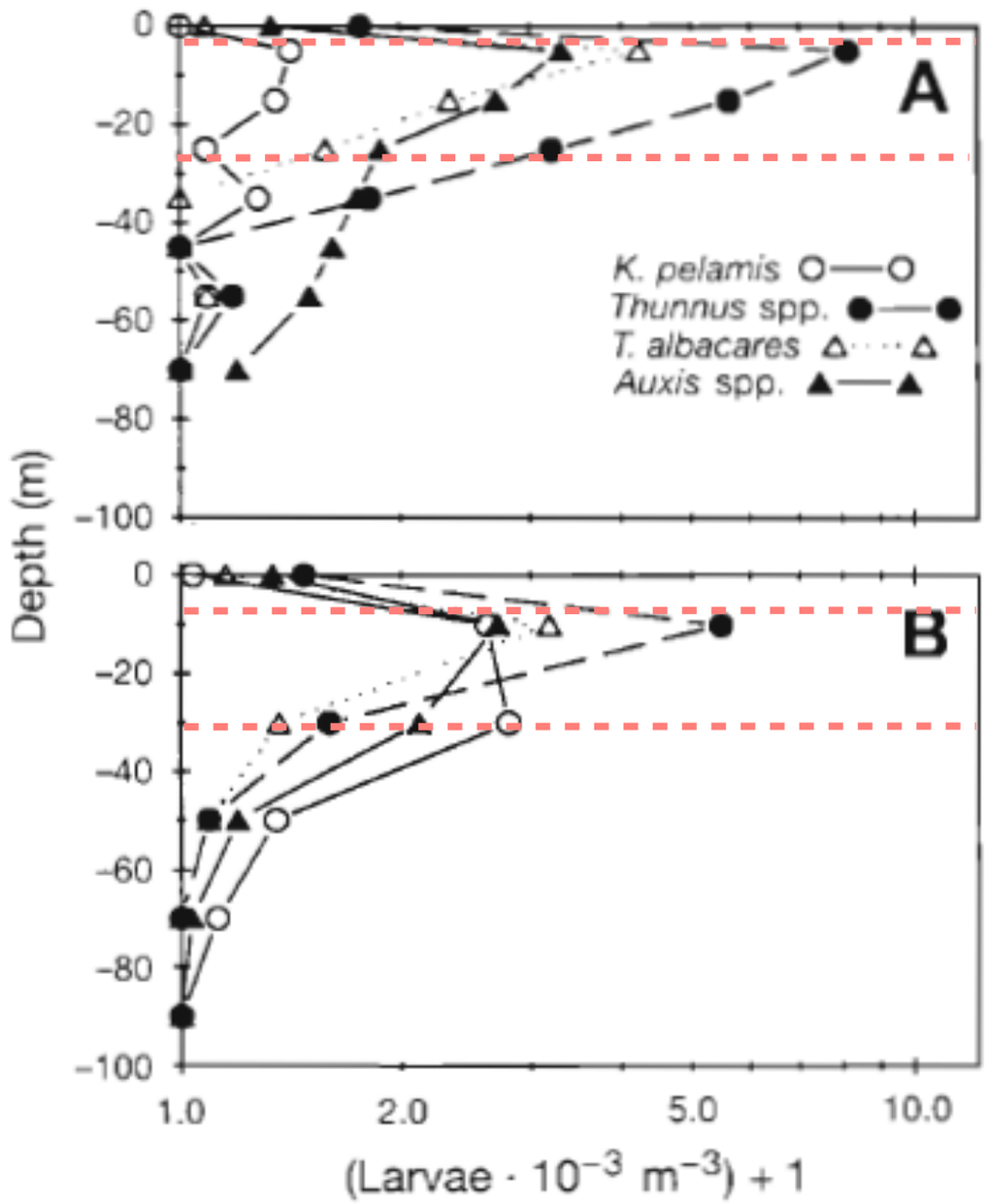

Boherlet and Mundy, 1994

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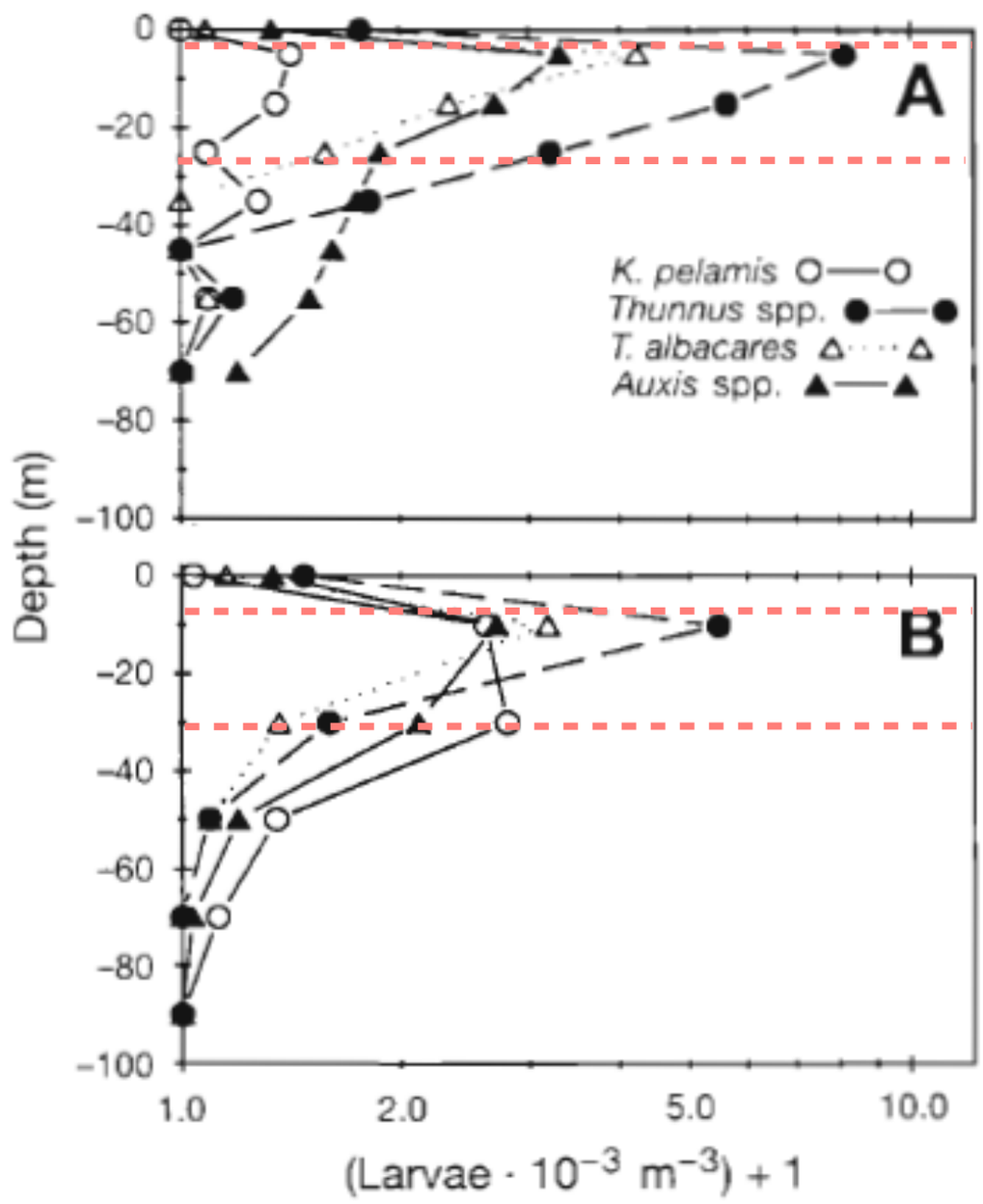

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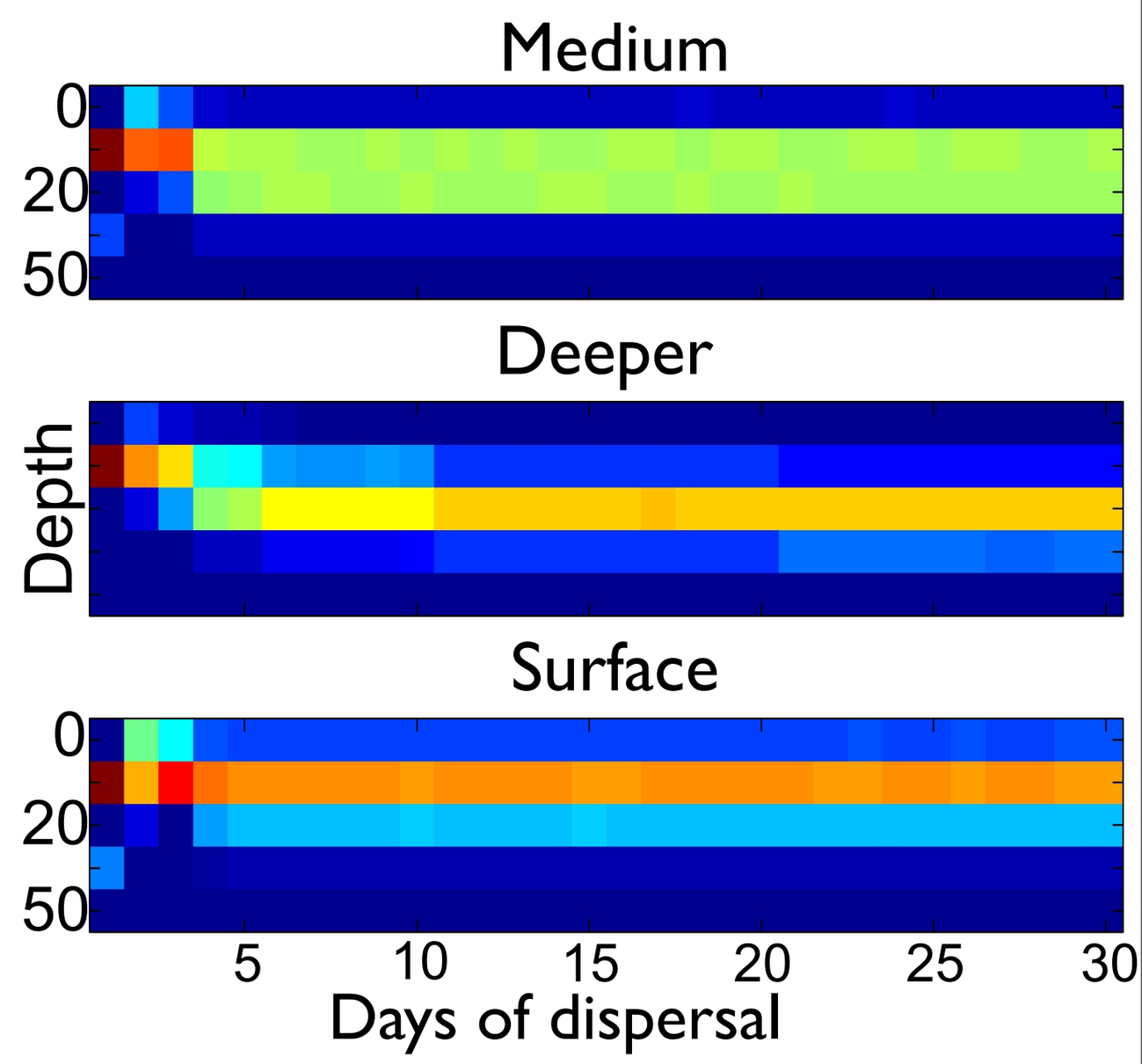
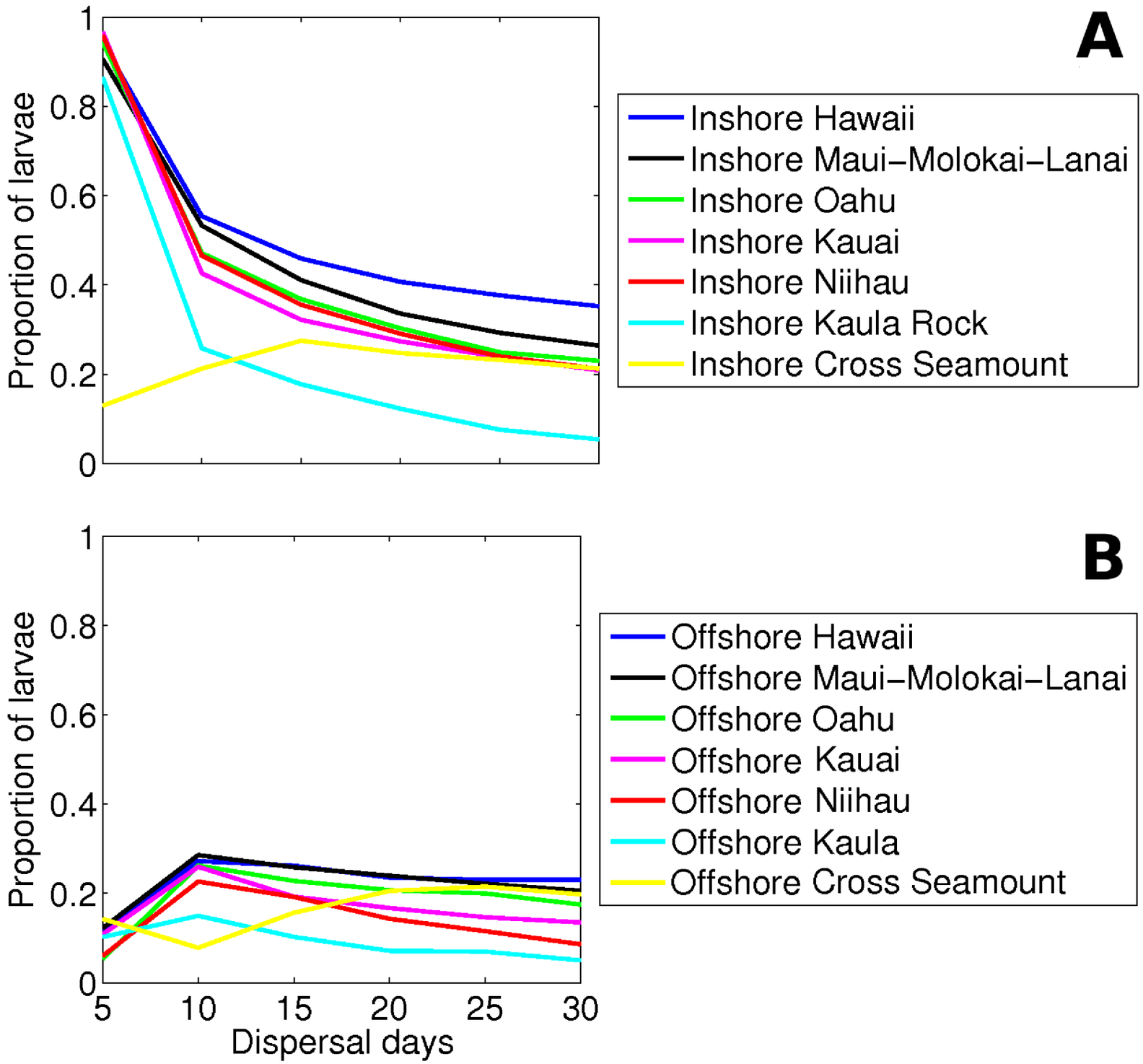
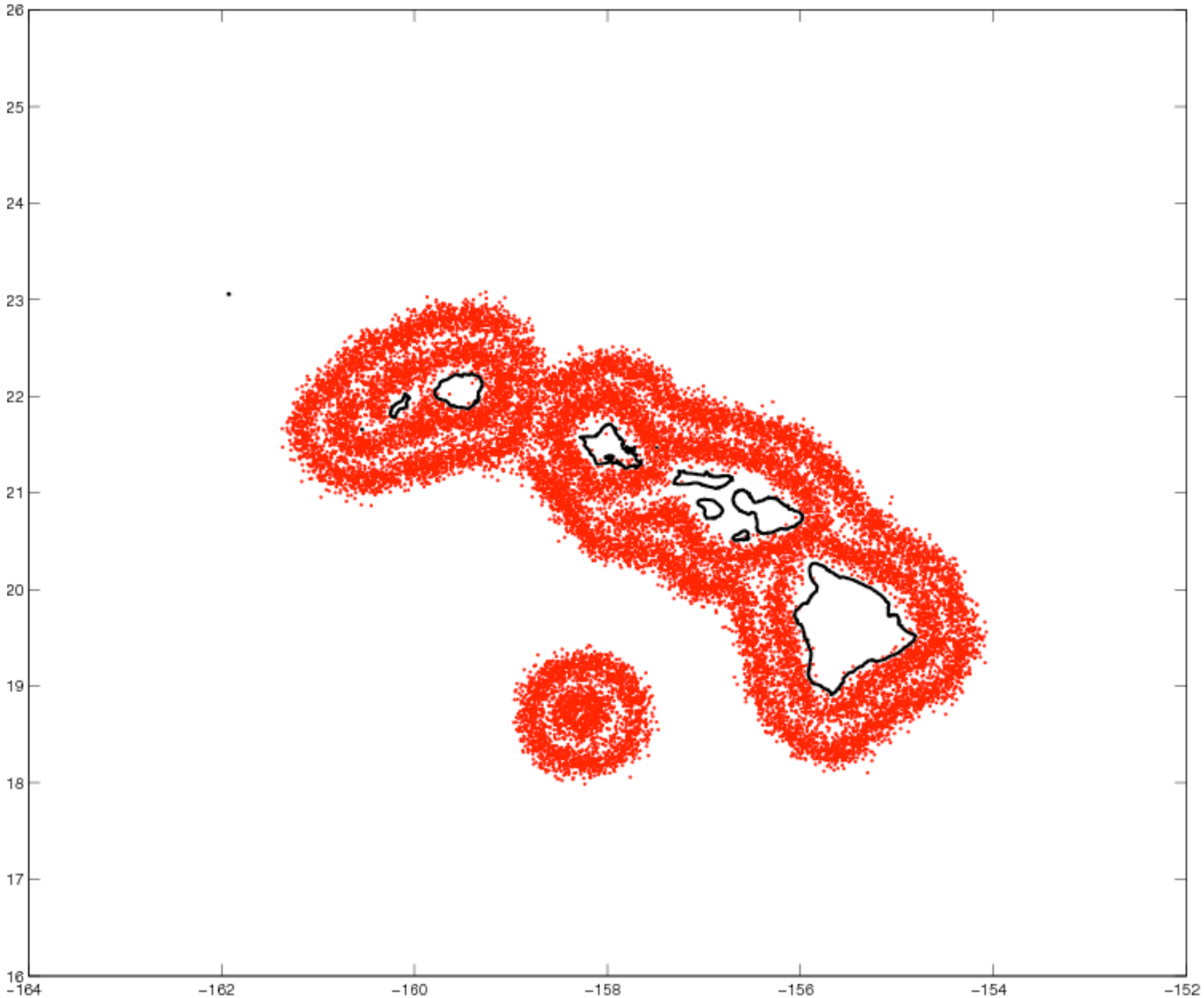


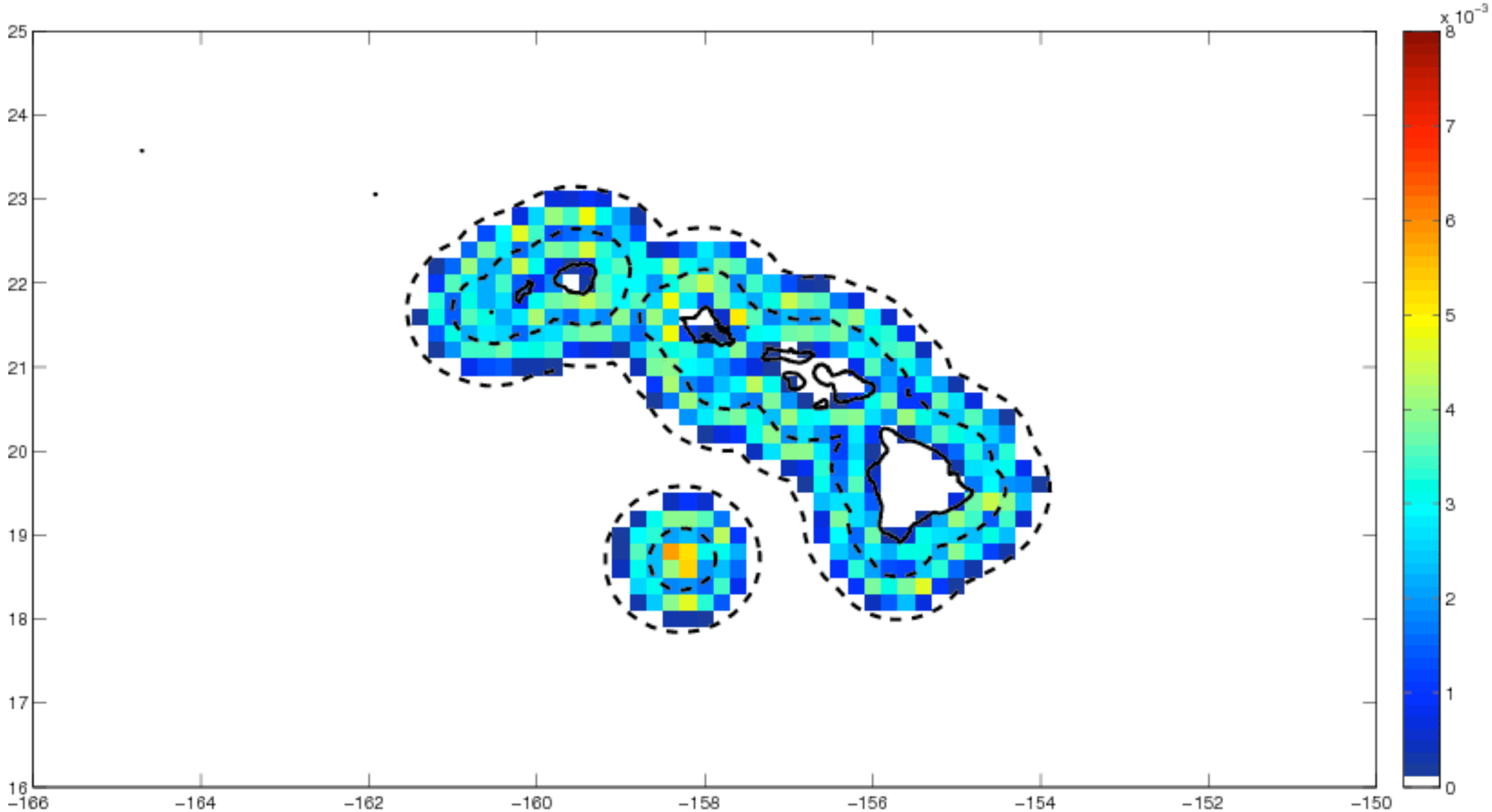
Island Variation



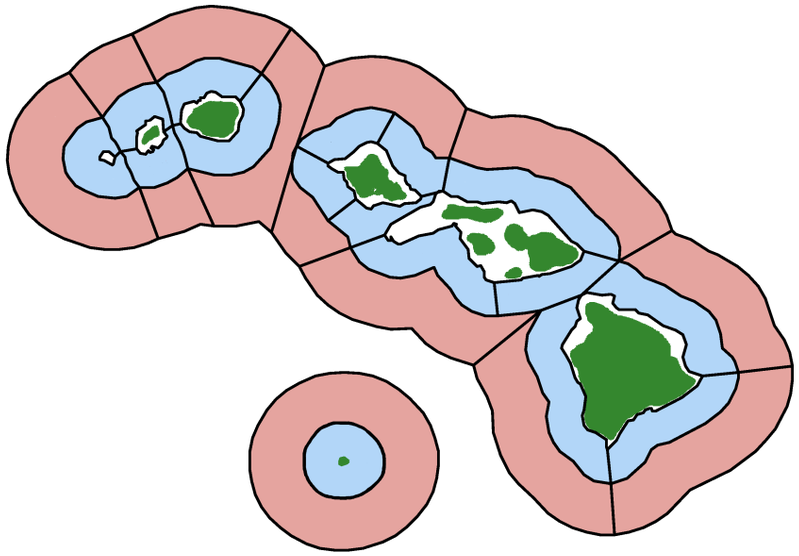
Random dispersion - diffusivity of 500m2/s



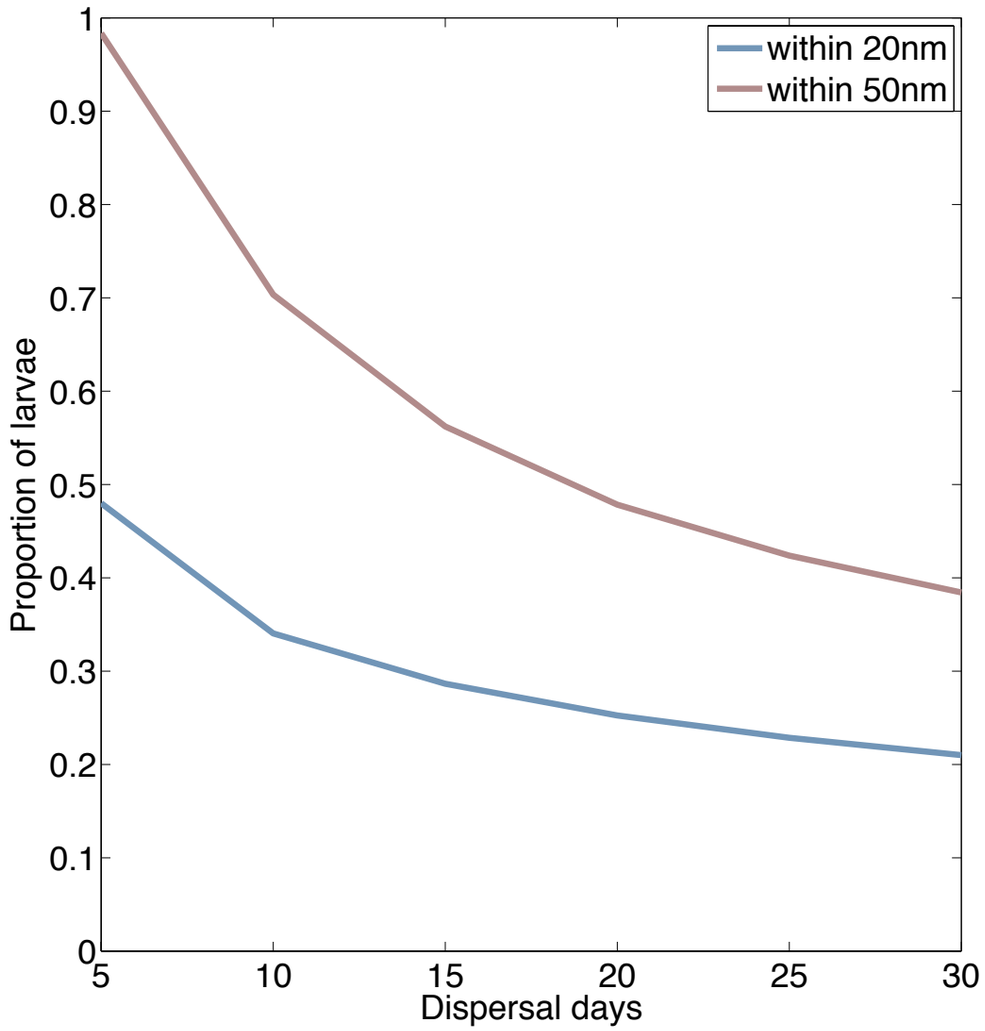
Random dispersion - diffusivity of 500m2/s



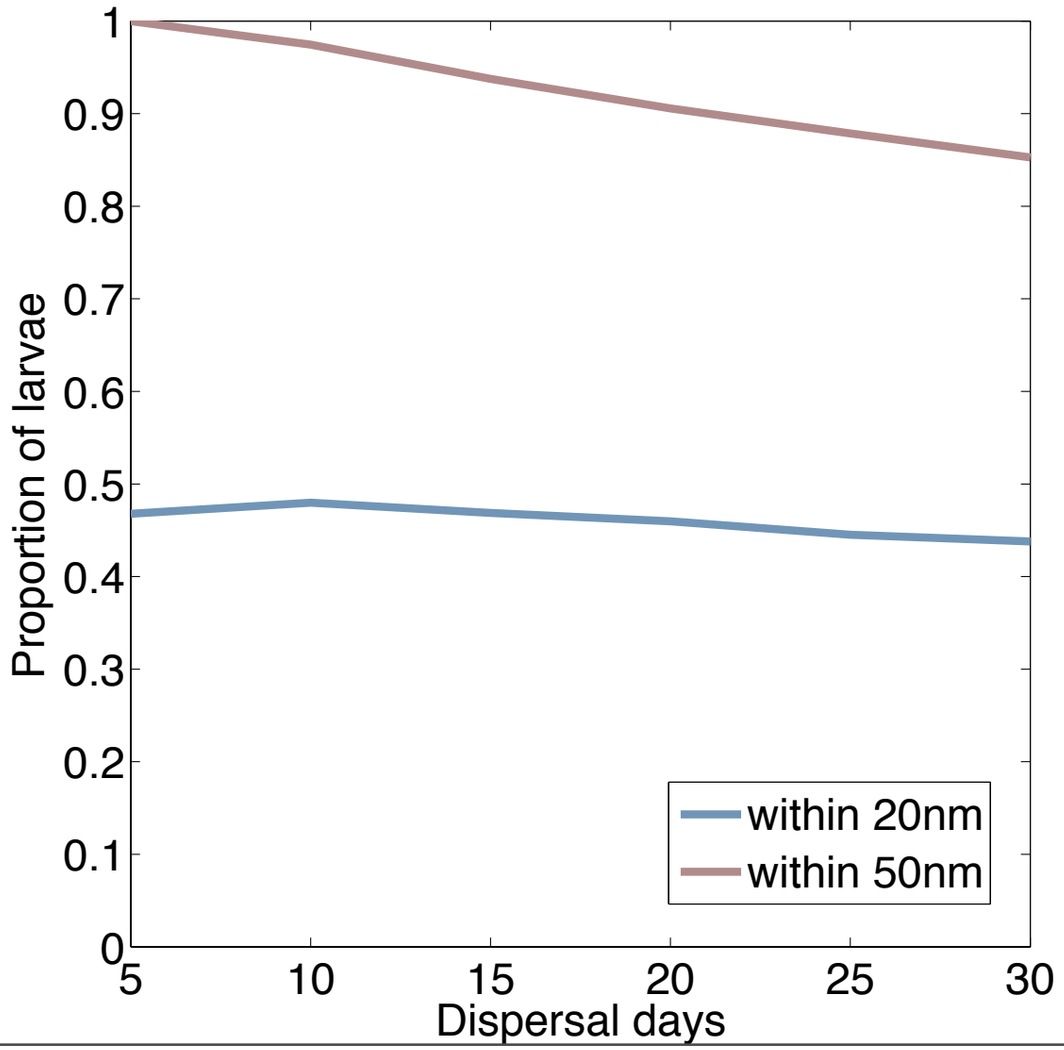
Evolution of dispersal



Time evolving flow



Random dispersion



Notes to myself:

What is the size of a 30 day YFT larvae?
(16 cm tagged animal)