

Forage fish dispersal, concentration, and stranding on ridge-and-slough habitats

Simeon Yurek¹, Donald L. DeAngelis^{1,2},
Joel C. Trexler³, Laurel G. Larsen⁴

¹University of Miami, Miami, FL

²Southeast Ecological Science Center, USGS,
Gainesville, FL

³Florida International University, Miami, FL

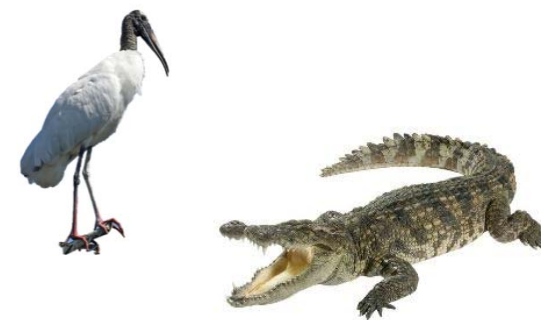
⁴University of California, Berkeley, Berkeley, CA

Primary research questions

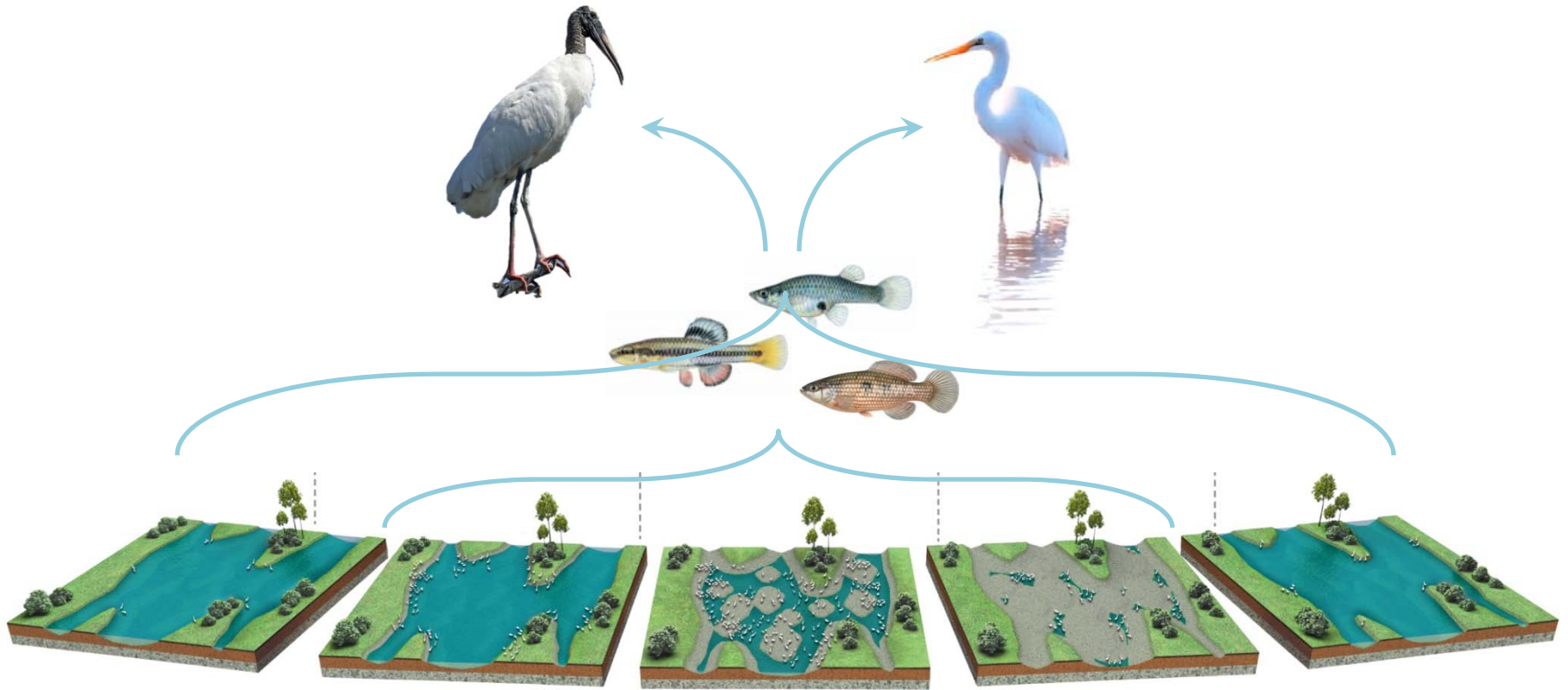
How is energy transmitted up the food chain from the aquatic system to top predators?



How do seasonal wetland dynamics, created by water flows interacting with topography, mediate this energy transfer?



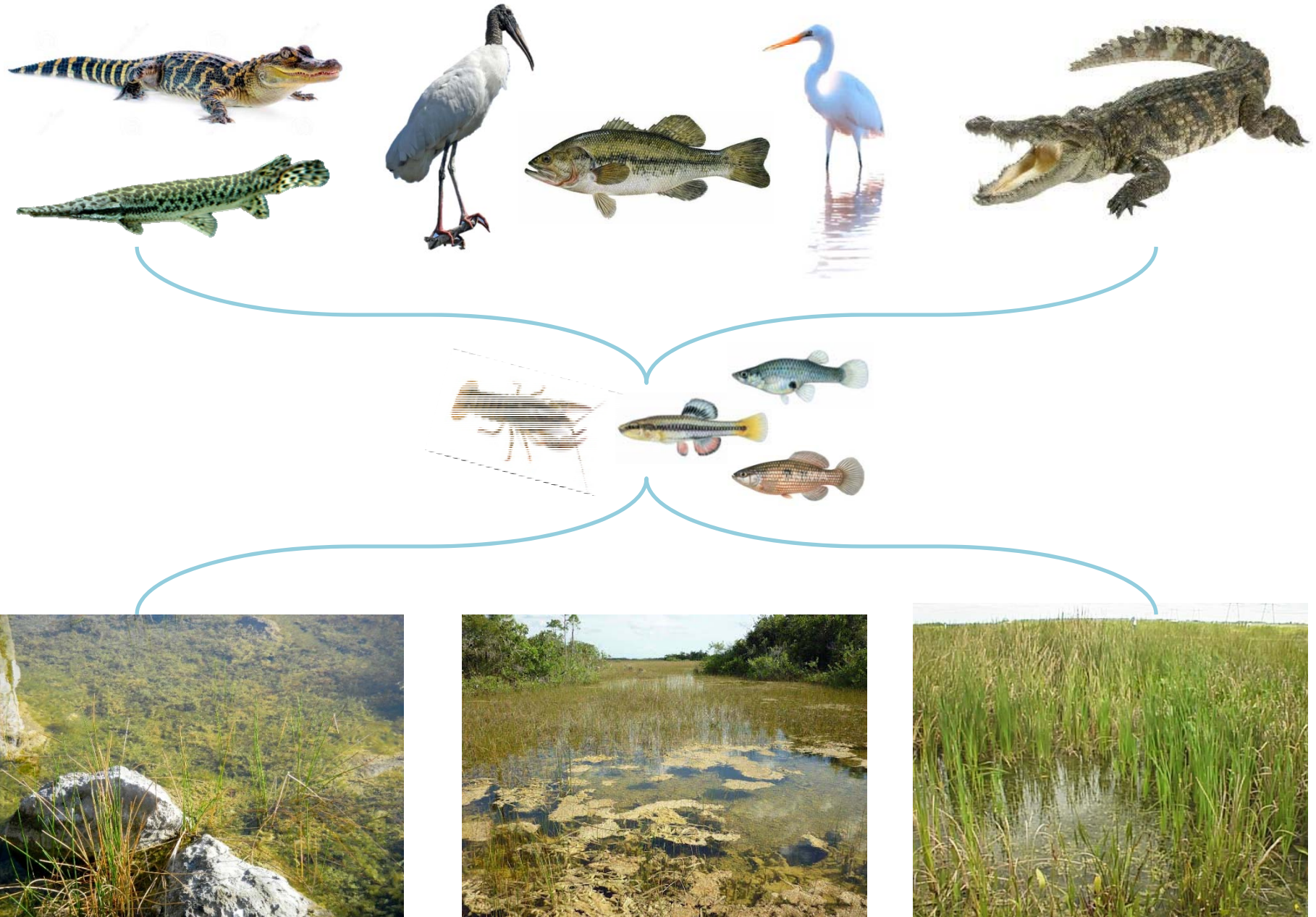
Expanding and contracting wetlands



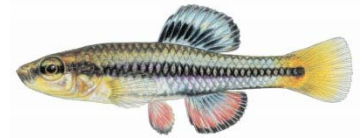
courtesy of Everglades Foundation

Wasp-waist food web

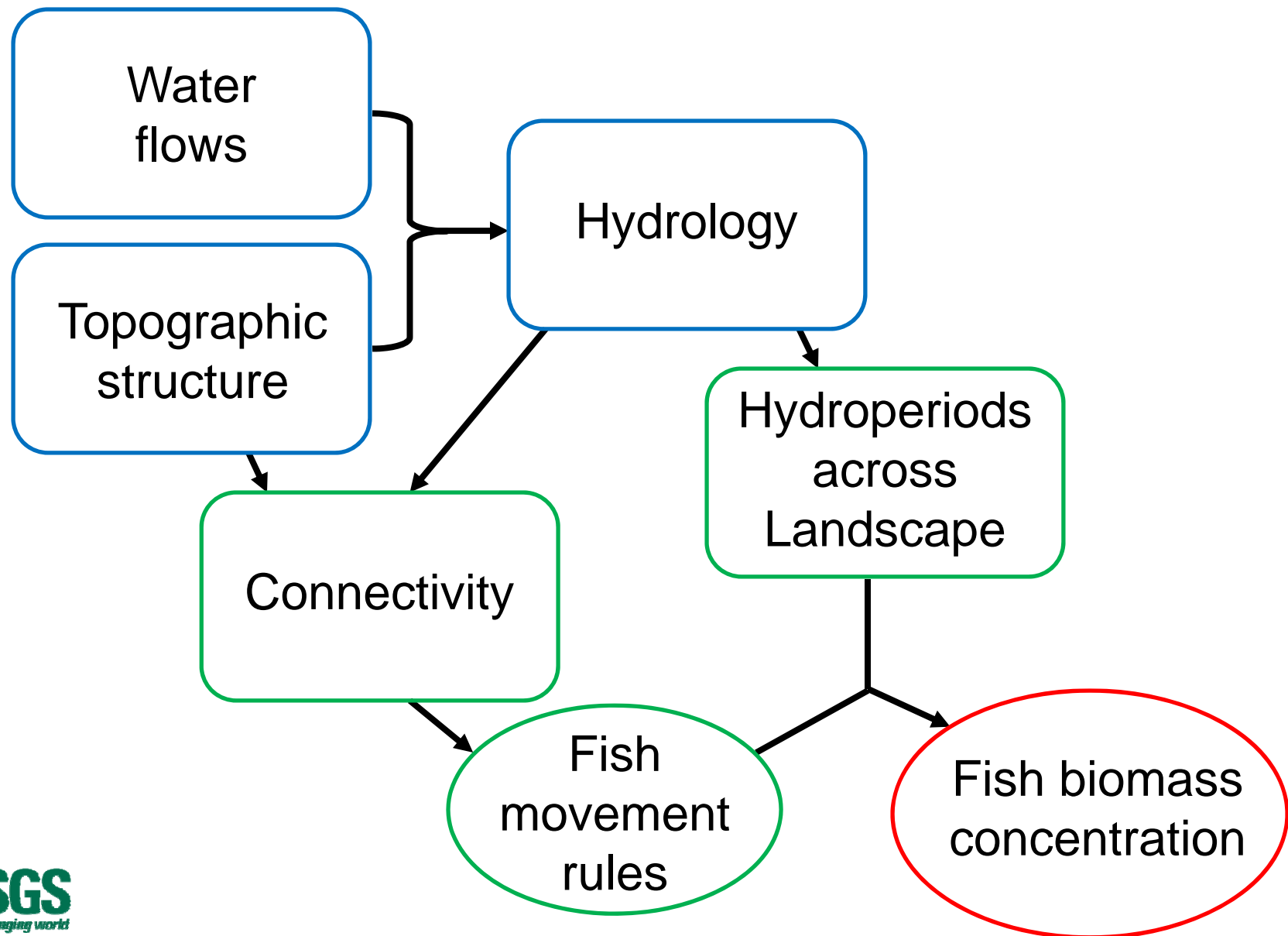
after Bakun (2006)



Spatiotemporal connectivity is critical



Conceptual model: Ecohydrology



Modeling Ecohydrology

Develop a numerical computer model that simulates:

- Energy transmission in an Everglades fish food web
- Biomass growth and dispersal of forage fish with different life history traits

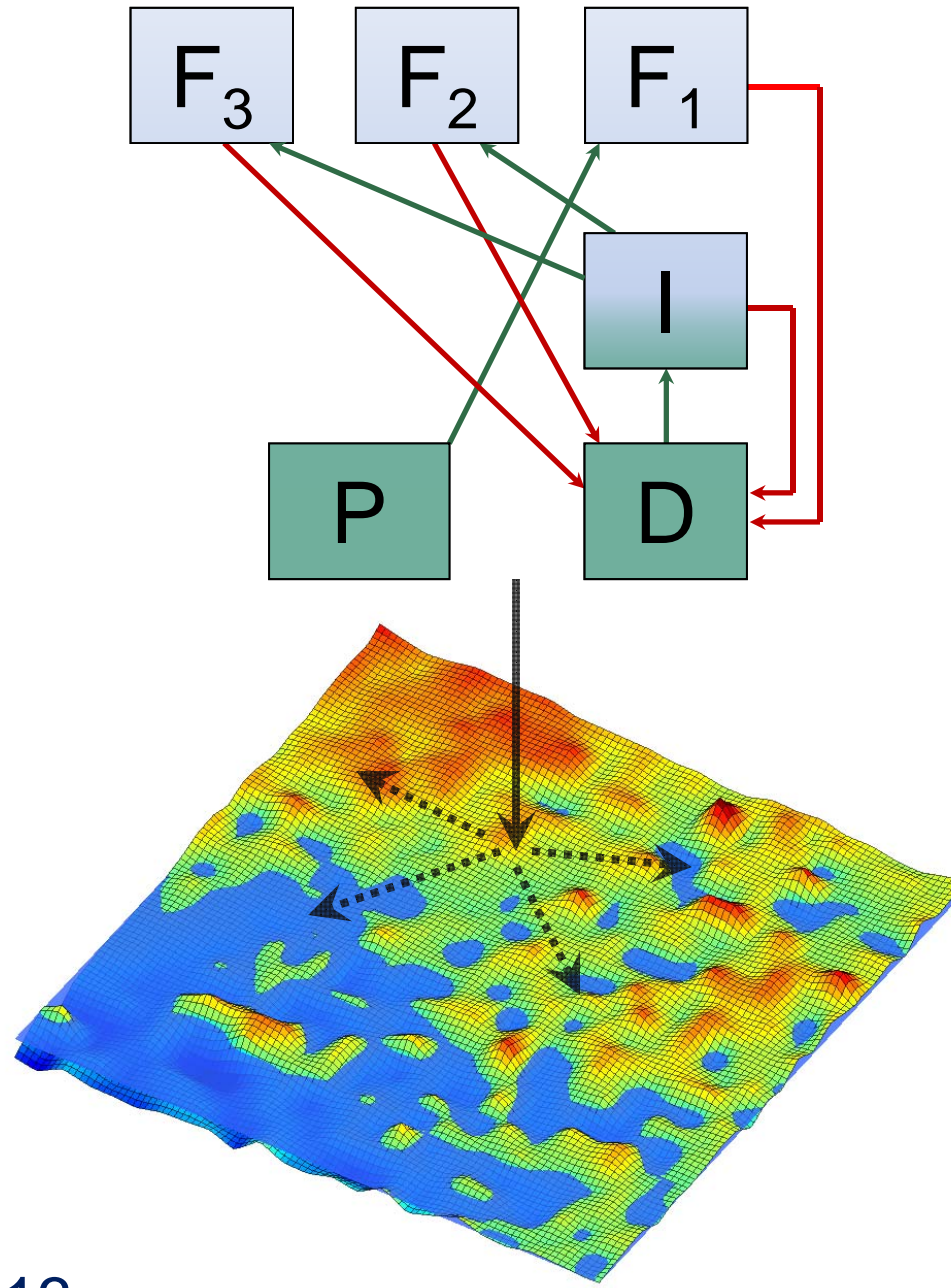
On landscapes with:

- Seasonally dynamic hydrology
- Structurally variable ridge-and-slough topography



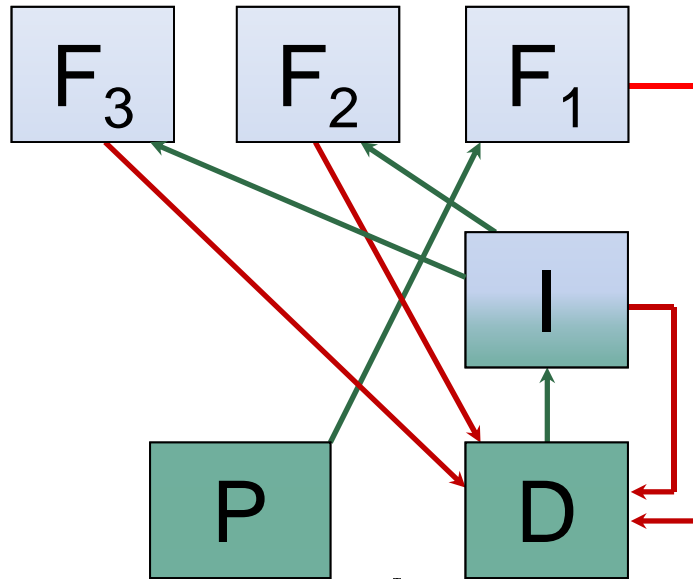
GEFISH

Greater
Everglades
Fish Model



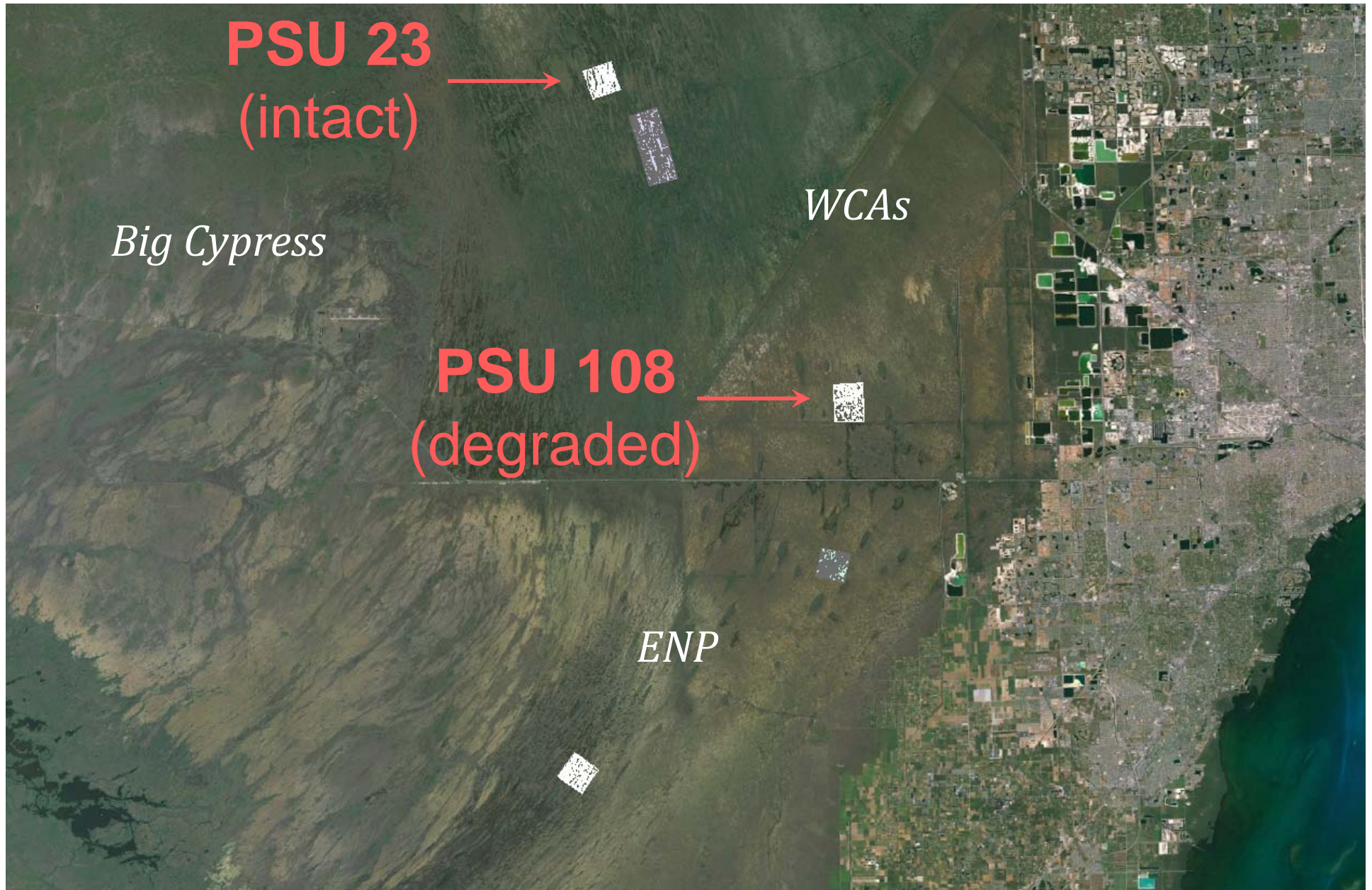
GEFISH

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Fish Model

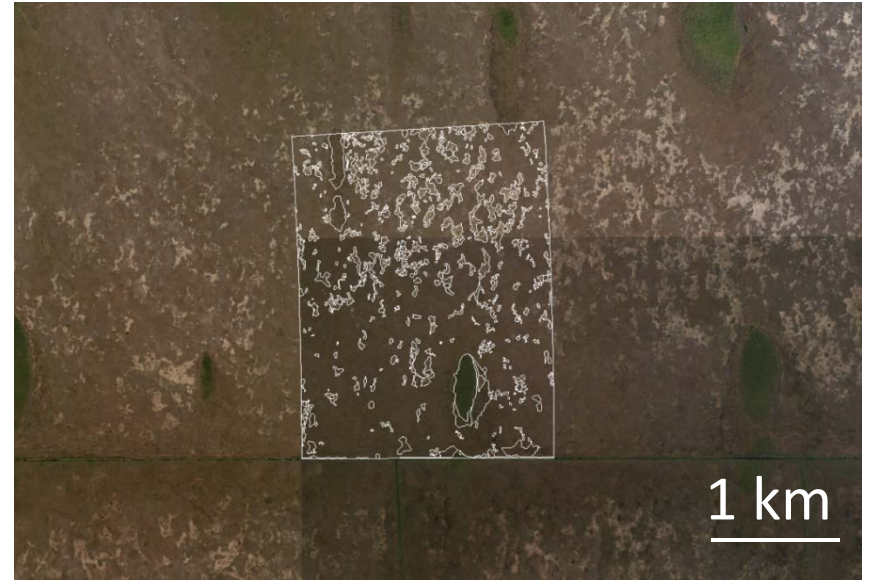
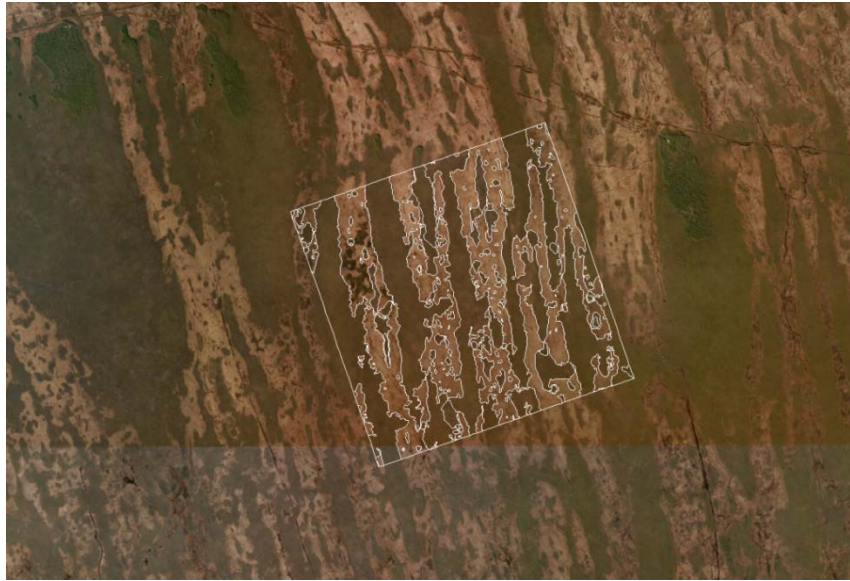




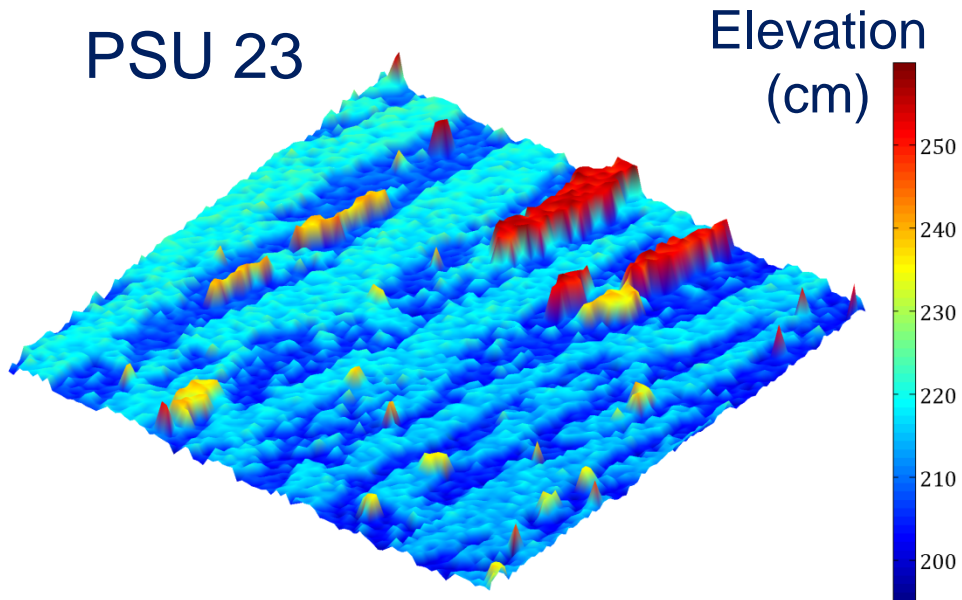
Primary Study Units (PSUs)



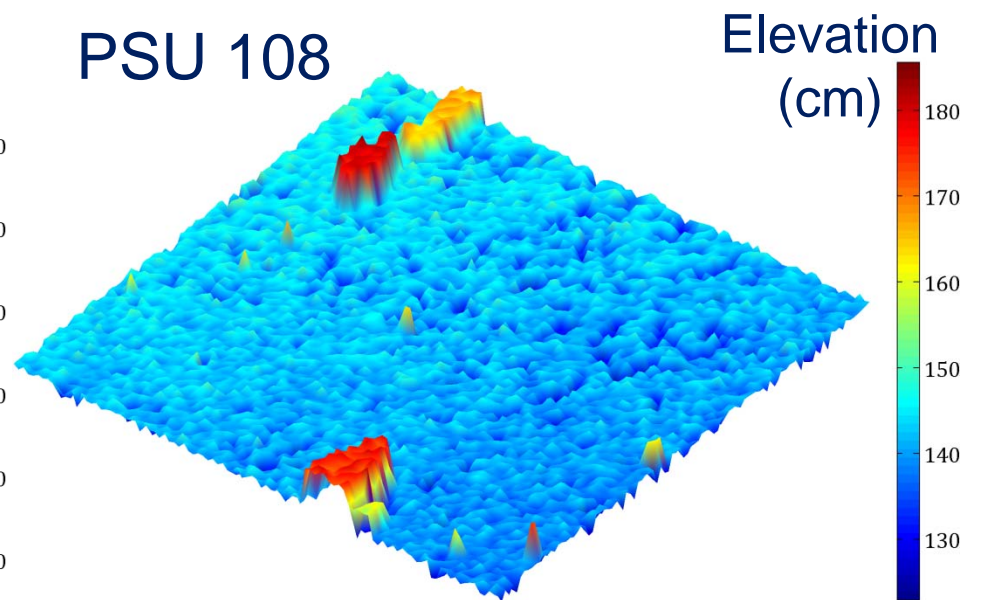
Intact and degraded habitat



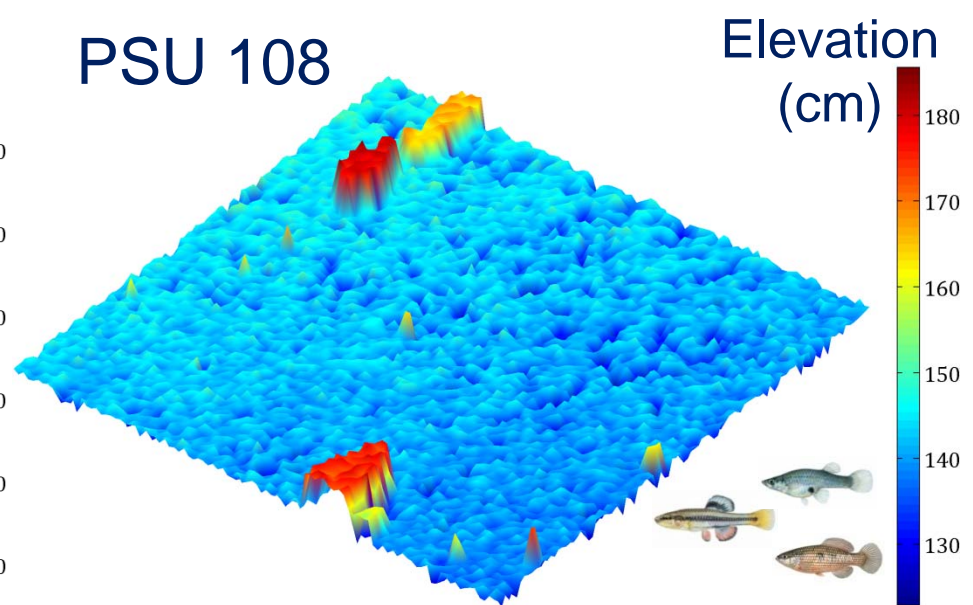
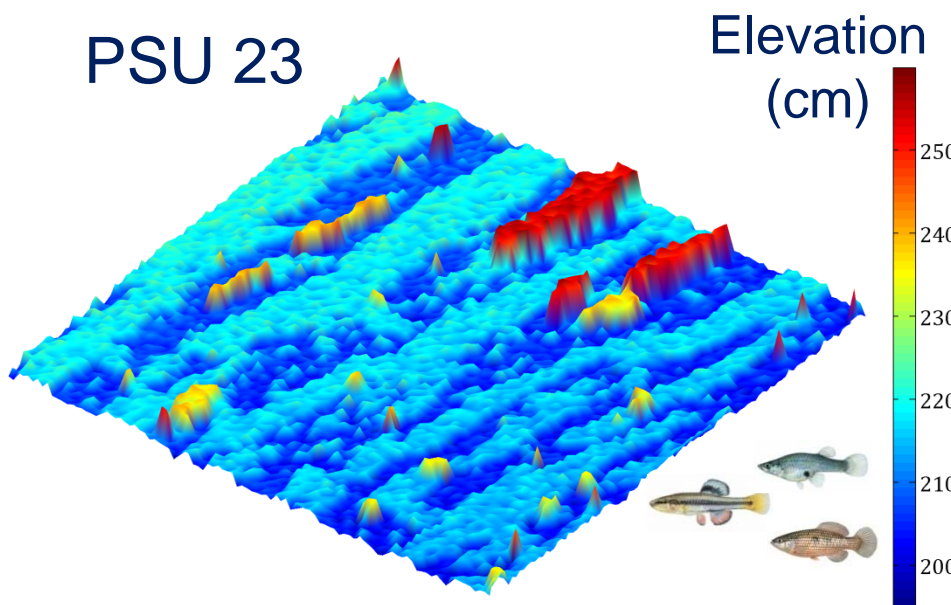
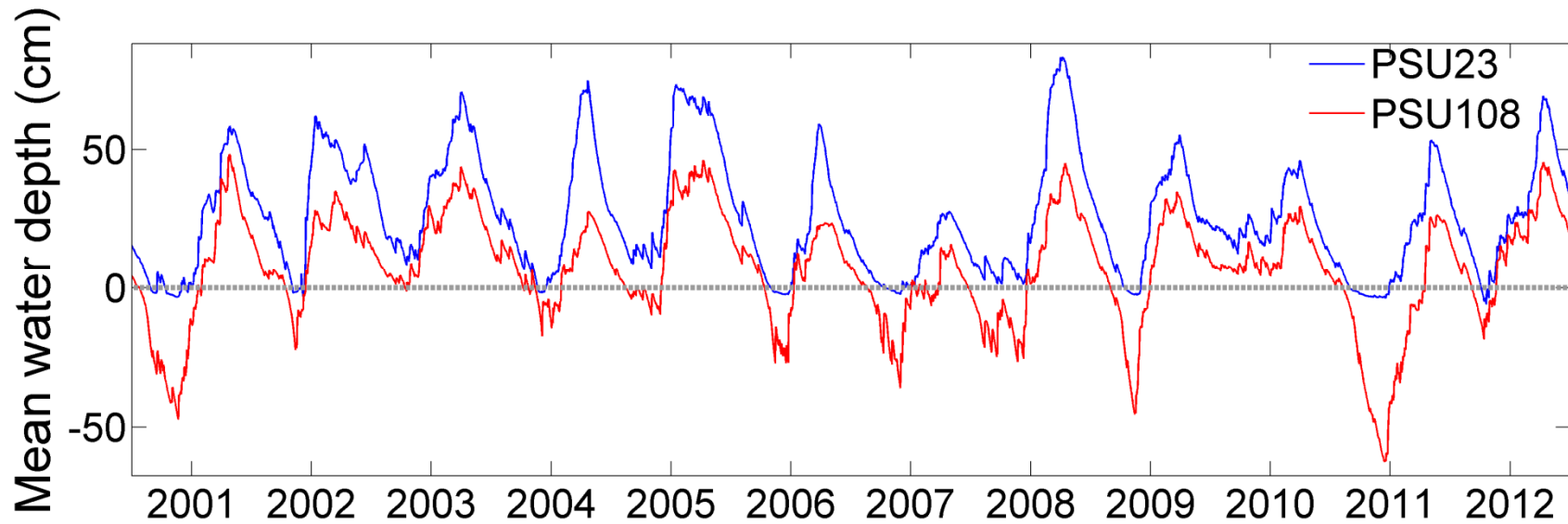
PSU 23



PSU 108



Intact and degraded habitat



Fish functional groups

Fish 1



Gambusia holbrooki
Eastern mosquitofish

Fish 2



Jordanella floridae
Flagfish

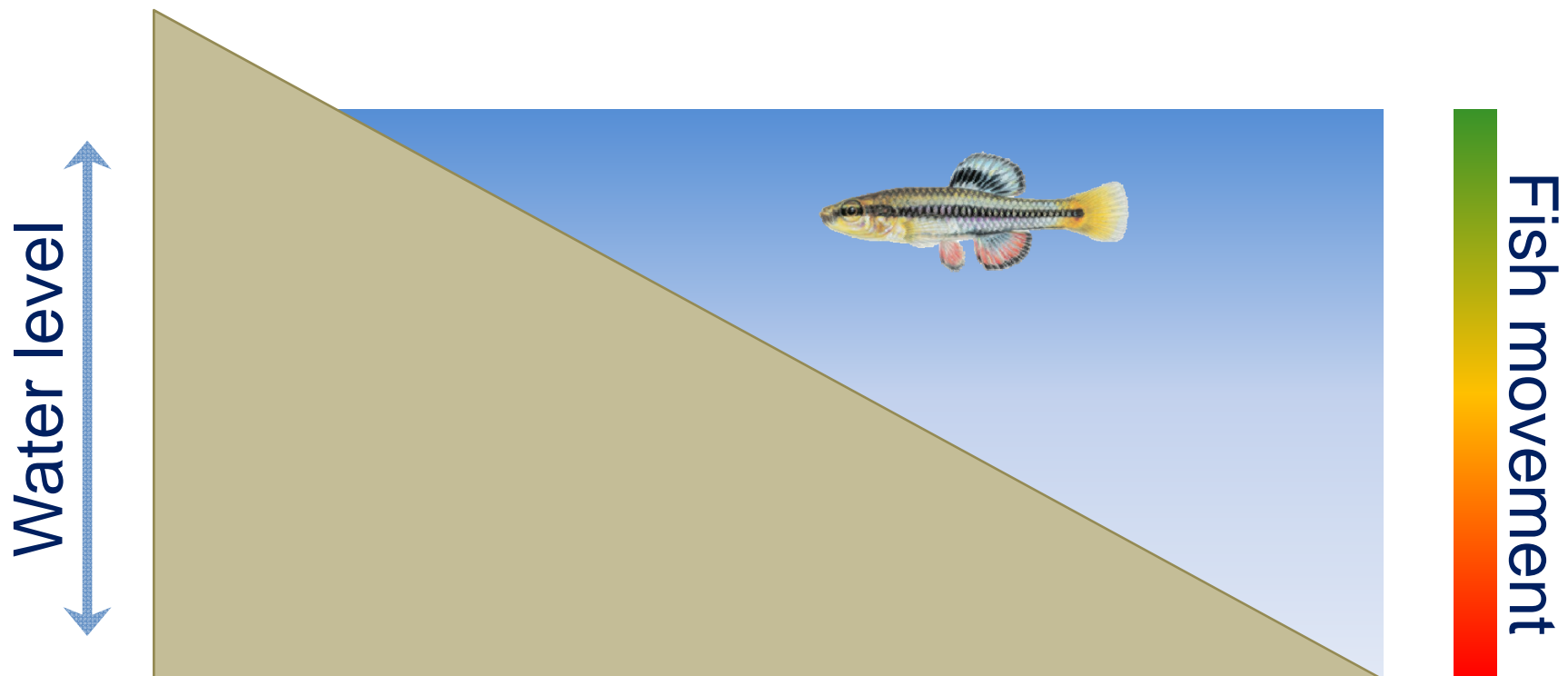
Fish 3



Lucania goodei
Bluefin killifish

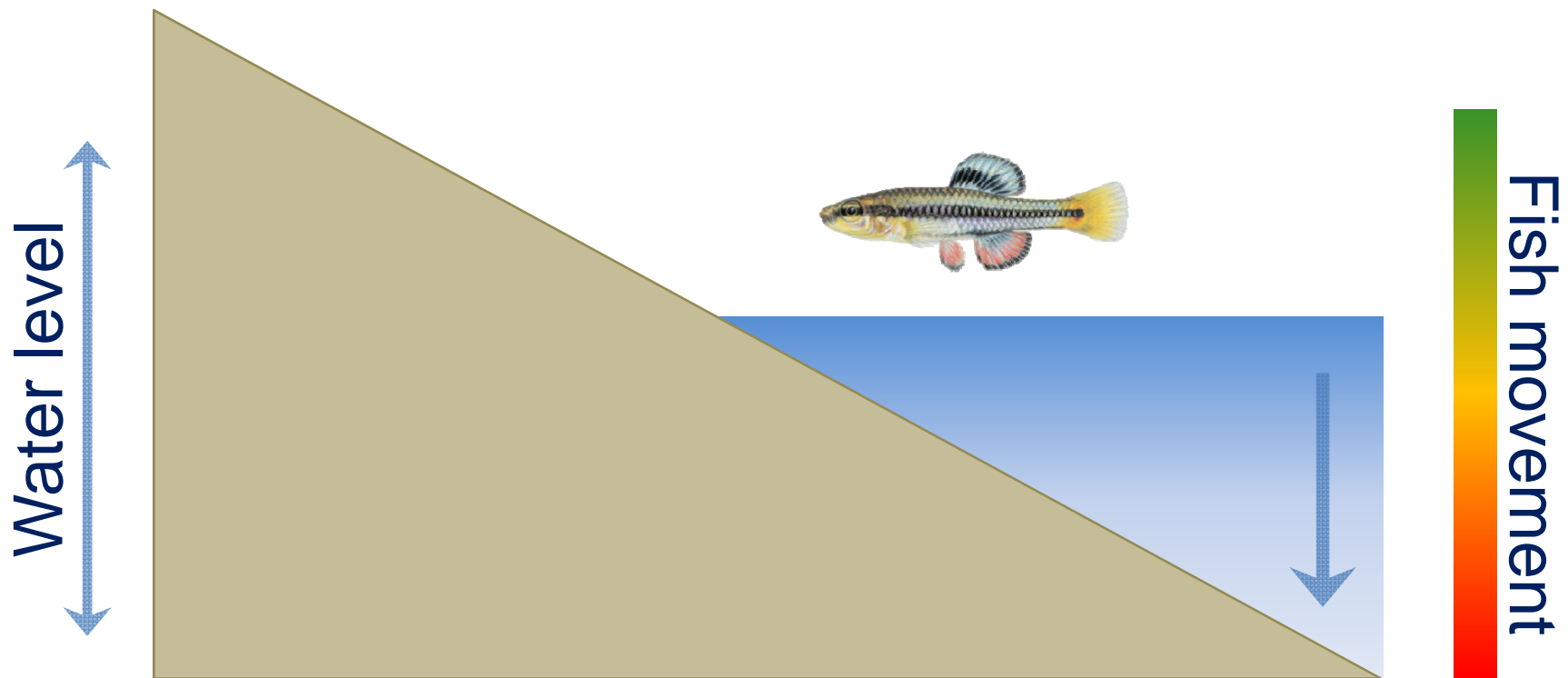
Fish movement

- Changing water levels drive fish movement
- Increased movement in shallower depths



Fish stranding

- Water levels fall, marsh dries
- Fish trapped and don't move

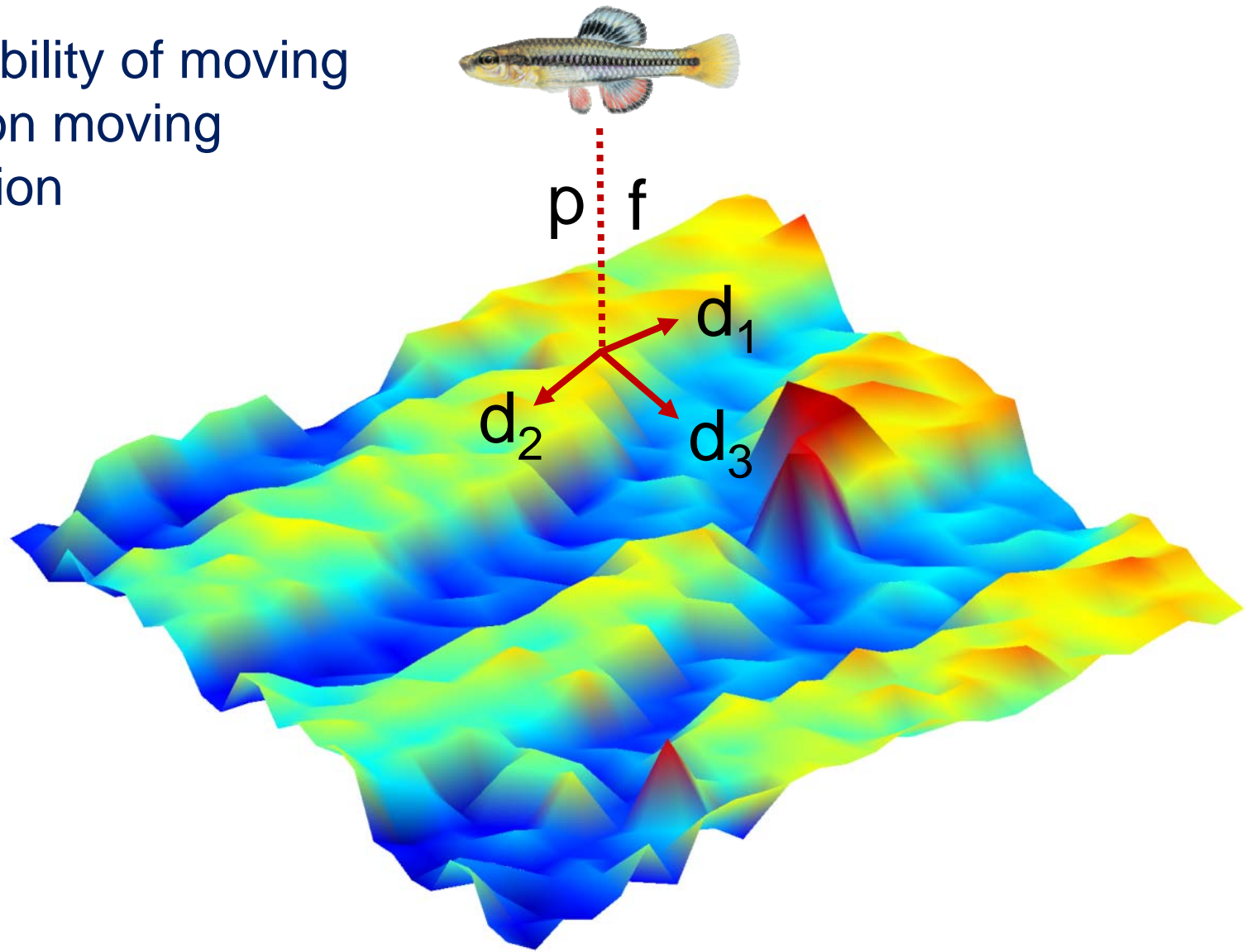


Modeling movement:

p = probability of moving

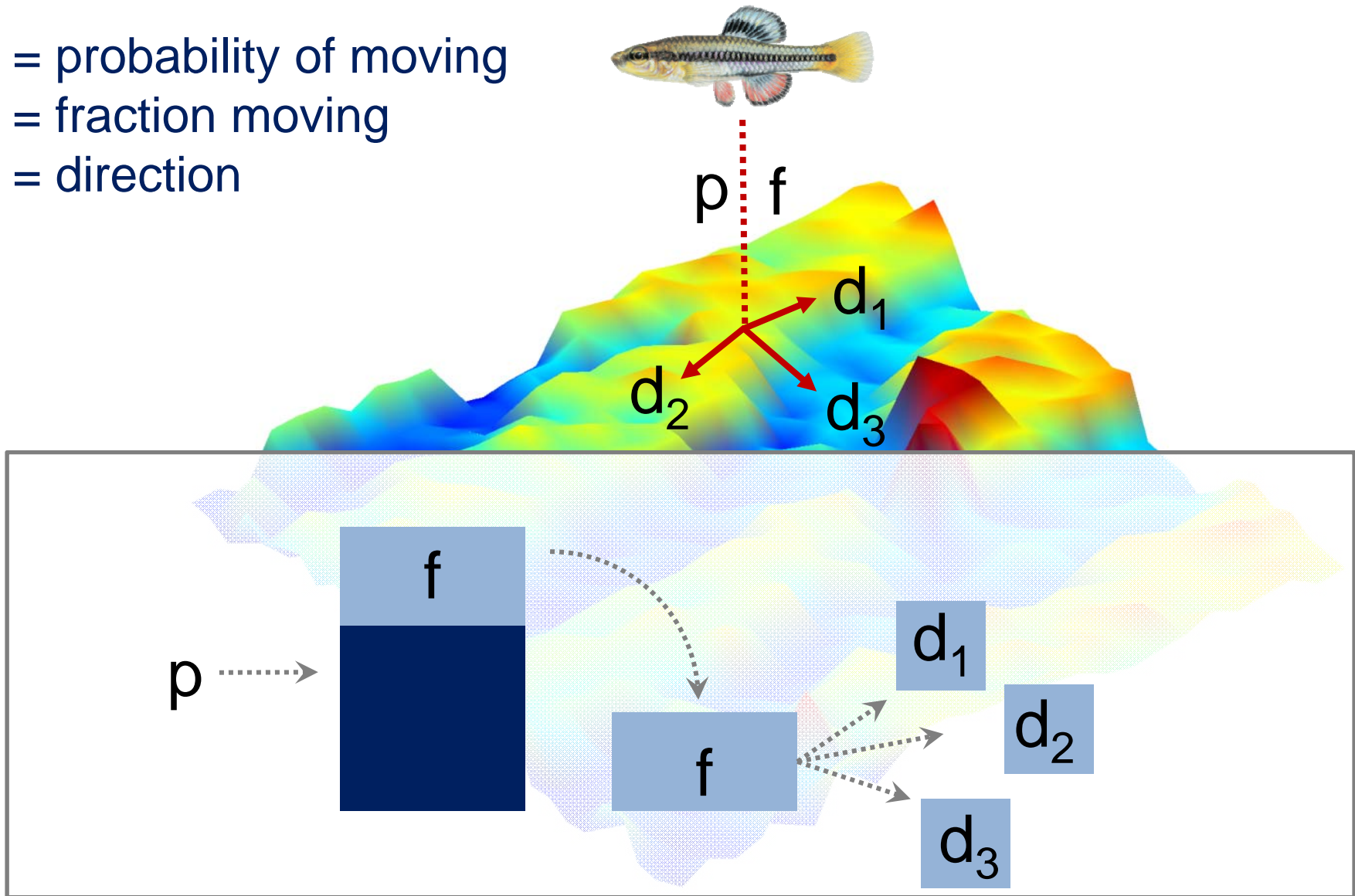
f = fraction moving

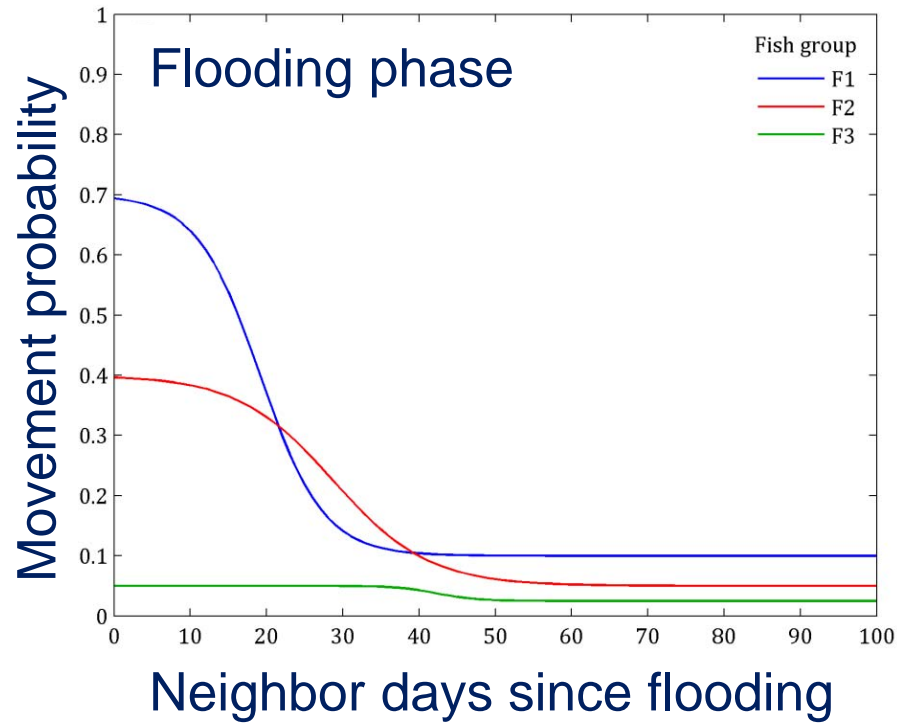
d = direction



Modeling movement:

p = probability of moving
 f = fraction moving
 d = direction





Fish species:



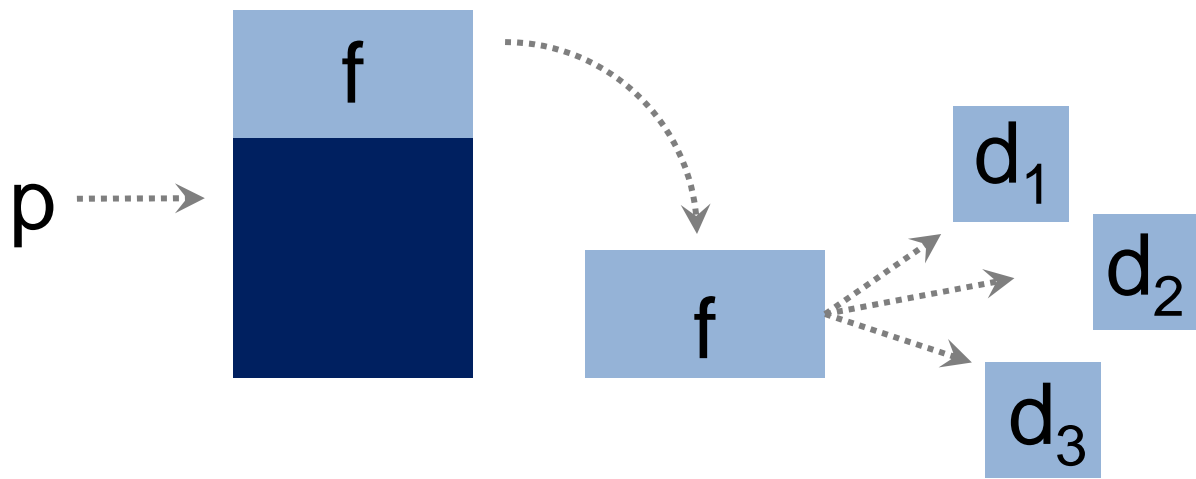
Gambusia holbrooki
Eastern mosquitofish



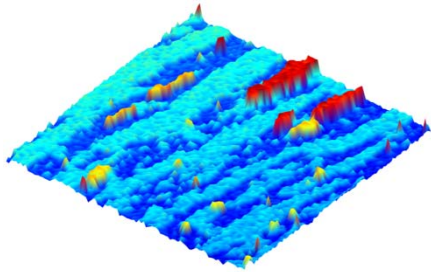
Jordanella floridae
Flagfish



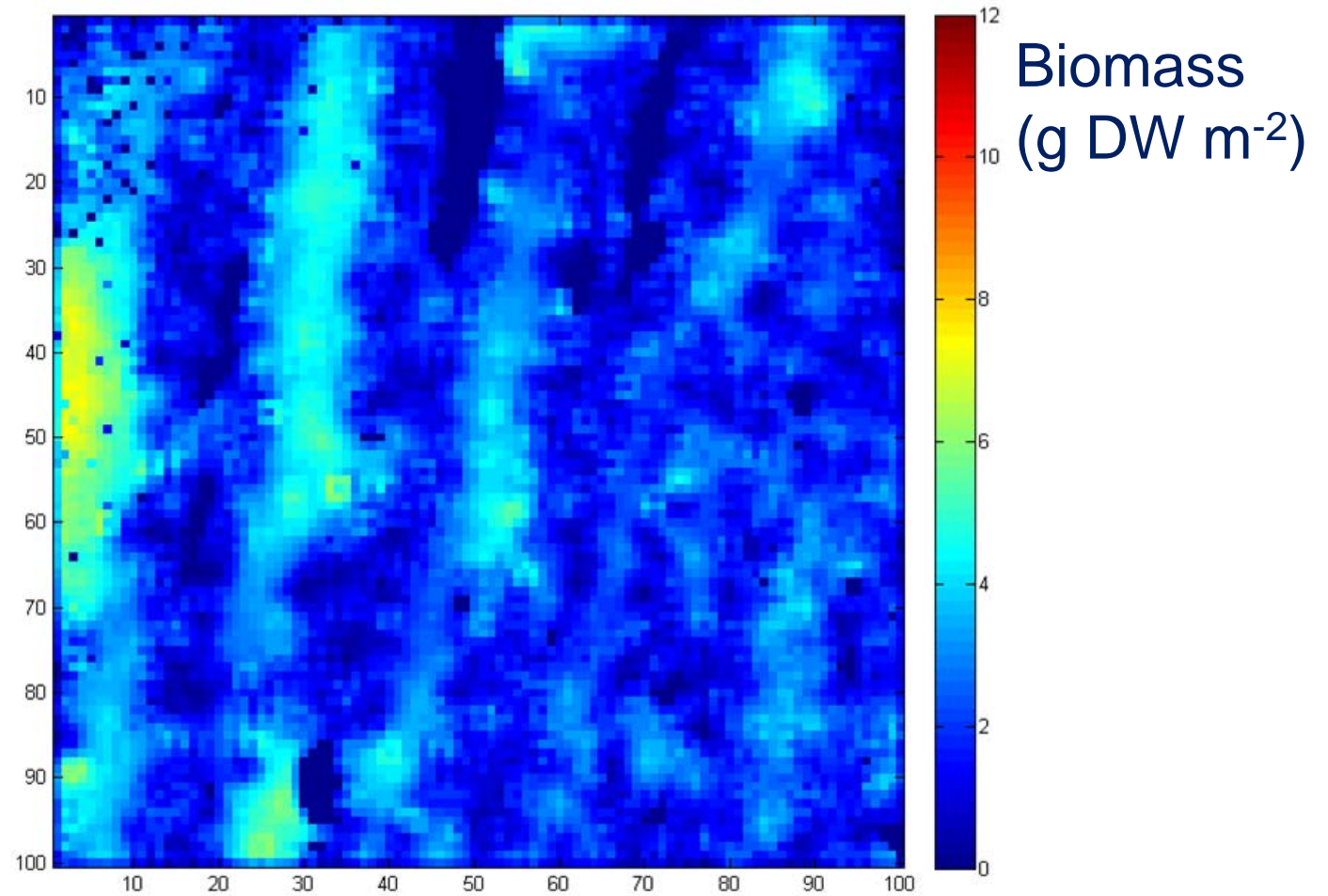
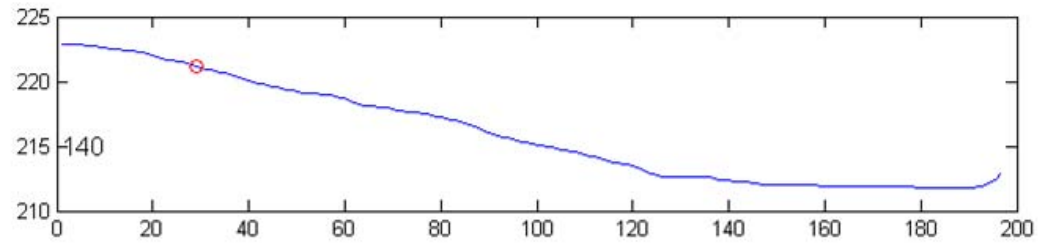
Lucania goodei
Bluefin killifish



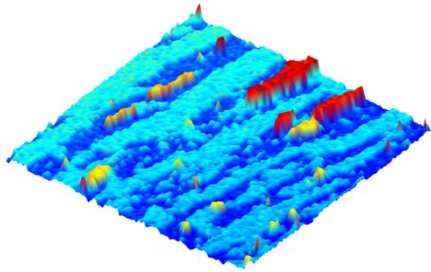
PSU 23



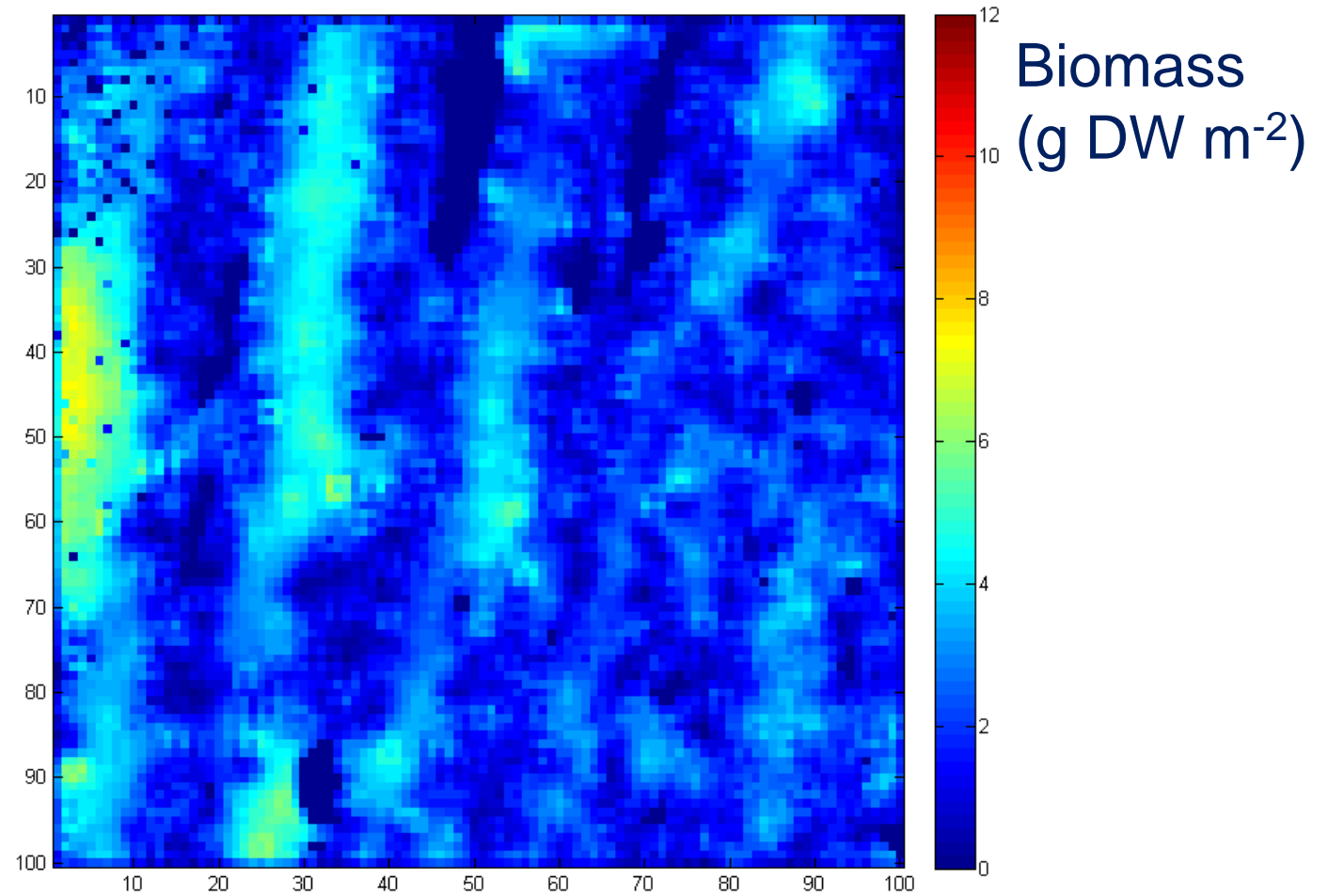
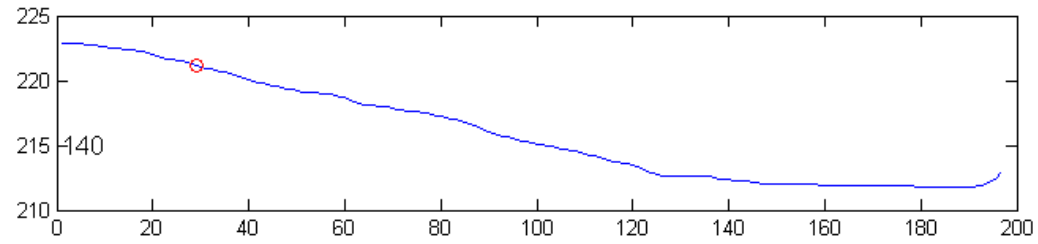
Pulsed movement



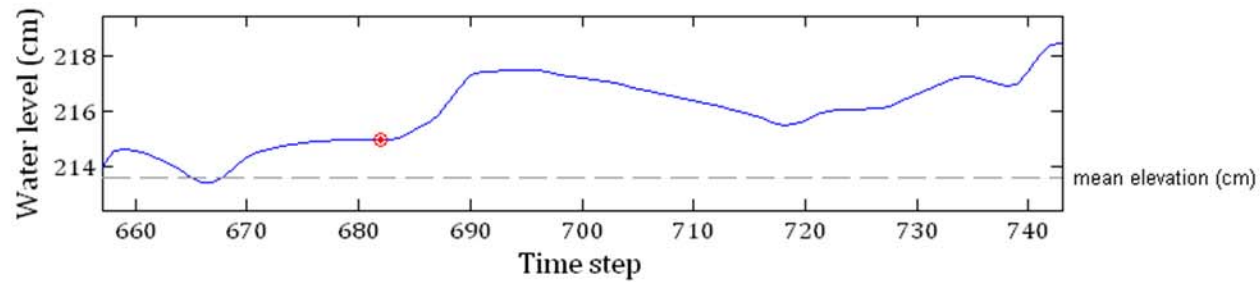
PSU 23



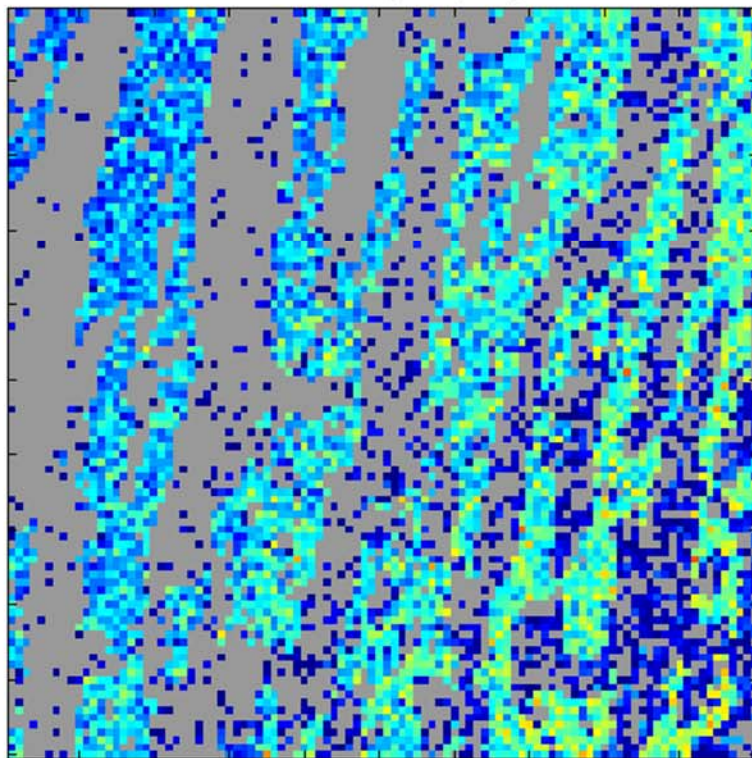
Pulsed movement



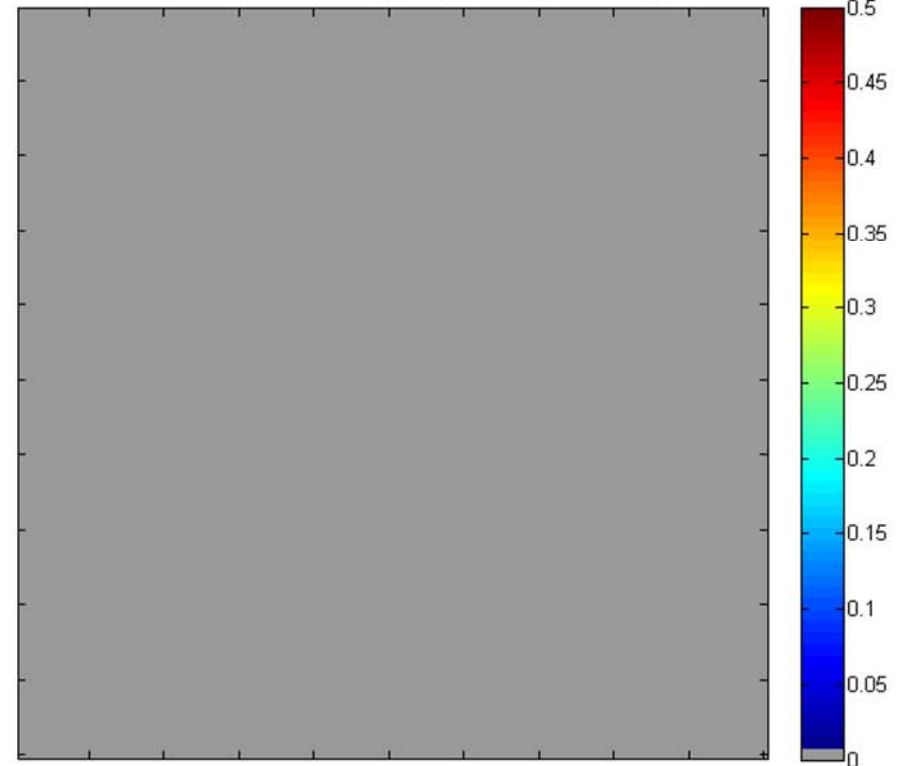
Model output: Stranded biomass



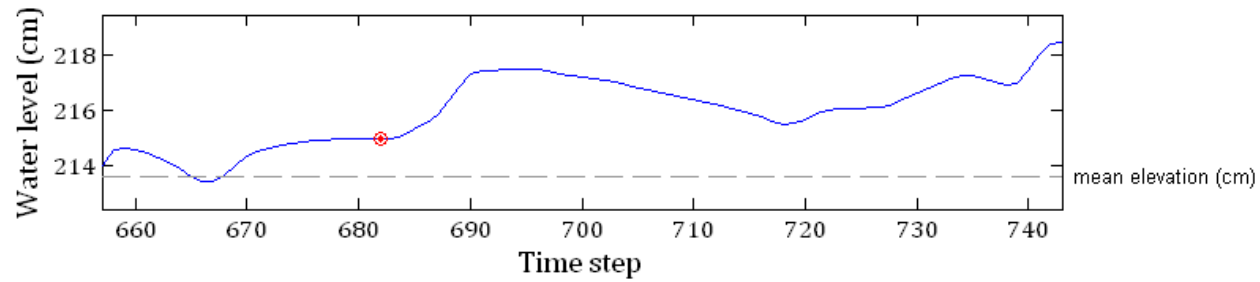
Water depth (cm)



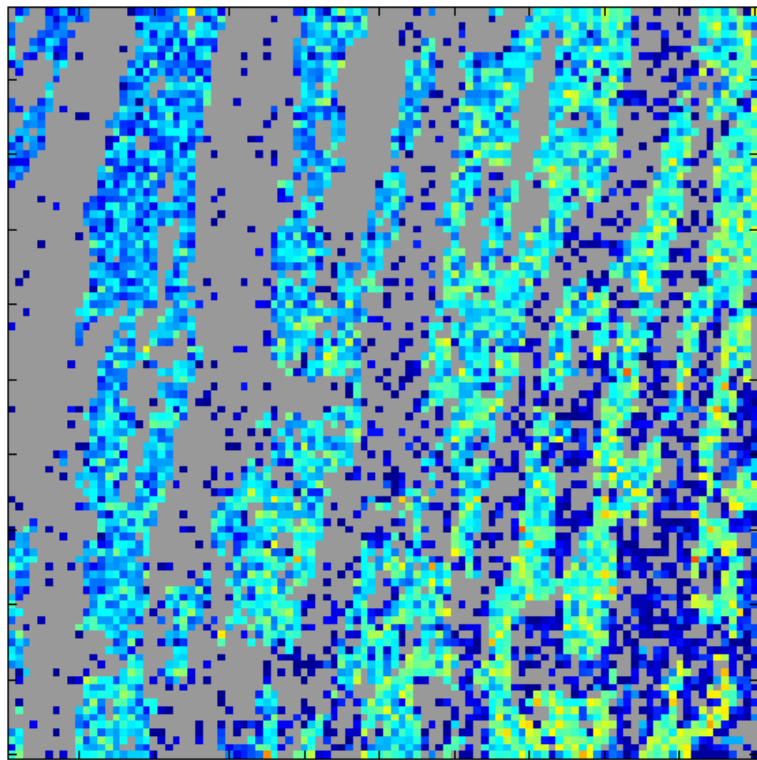
Fish 1 Biomass (g dry weight m⁻²)



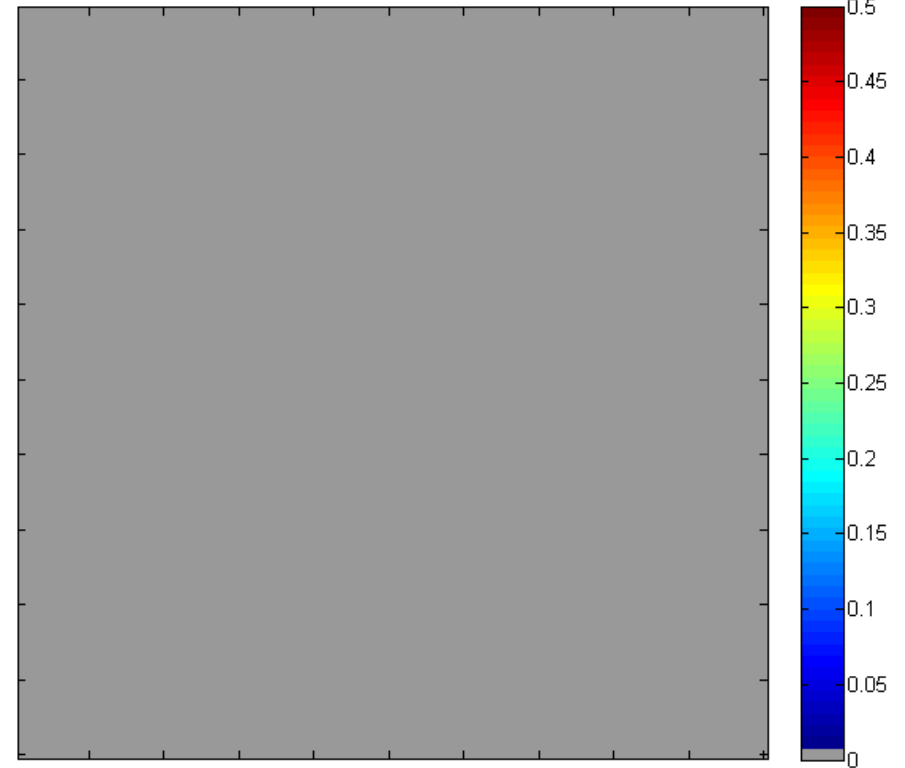
Model output: Stranded biomass



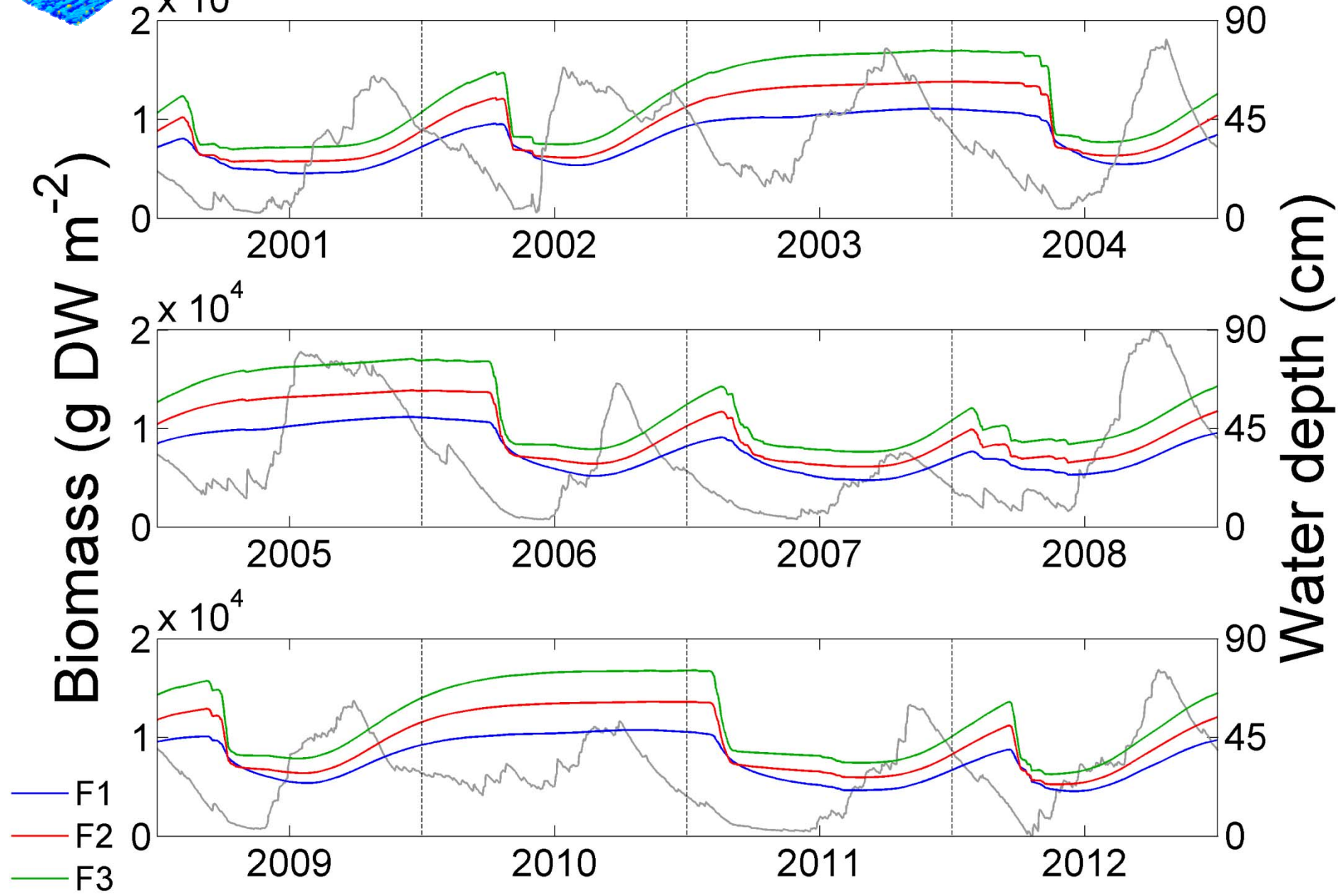
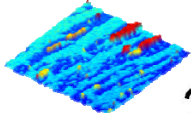
Water depth (cm)



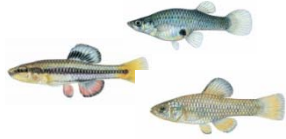
Fish 1 Biomass (g dry weight m⁻²)



PSU 23: Total Biomass

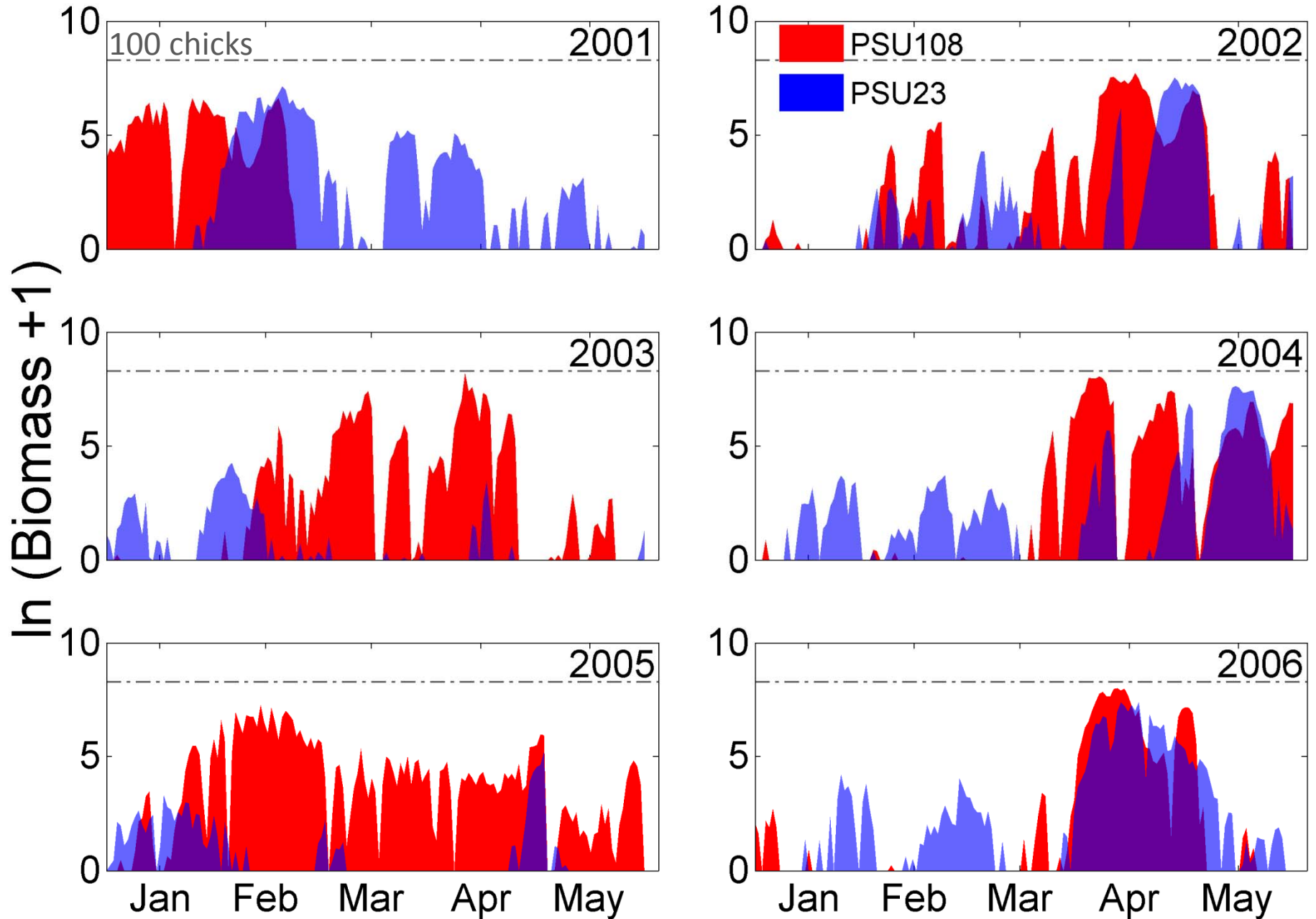


Fish Stranding



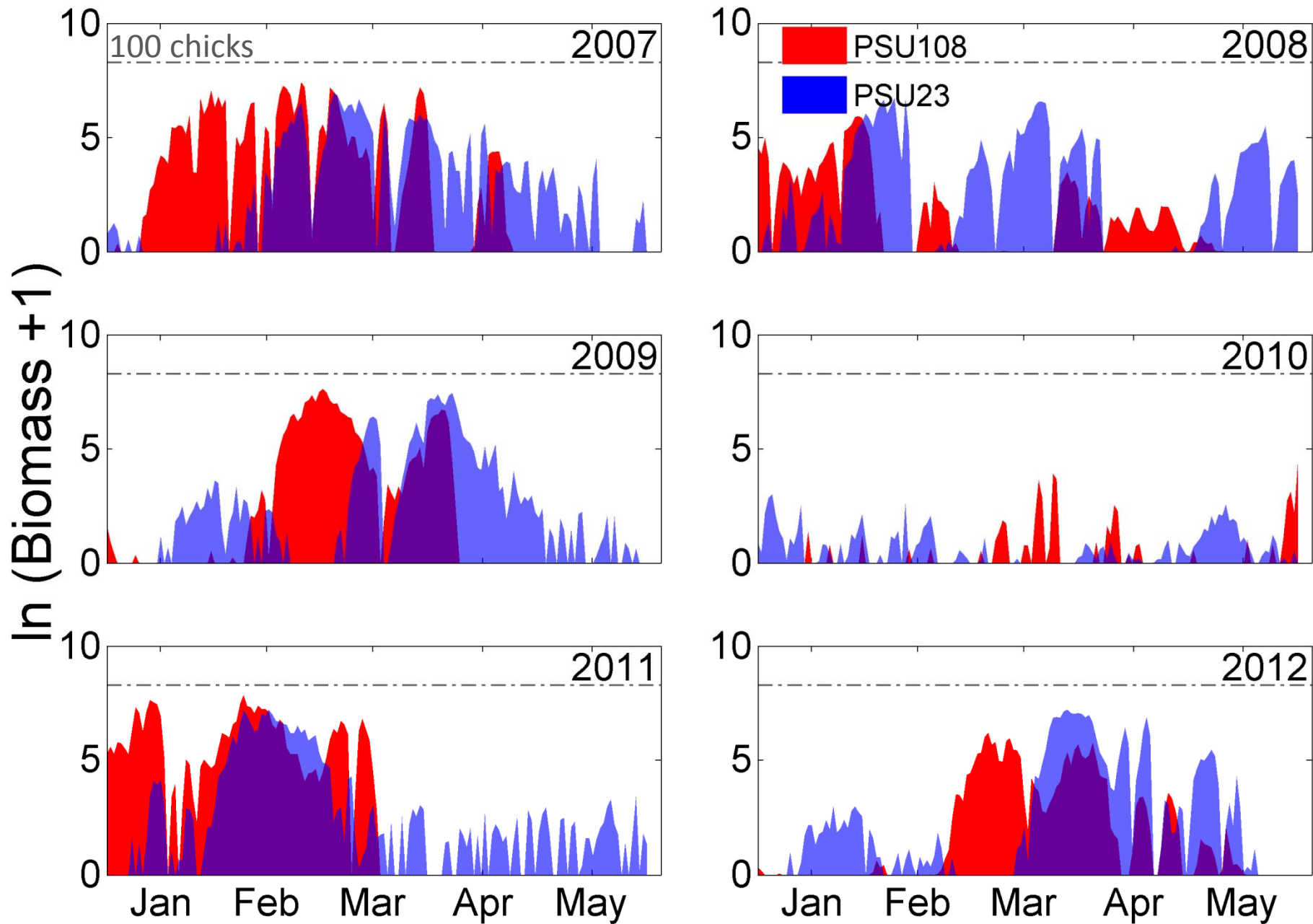


Fish Stranding (2001-2006)



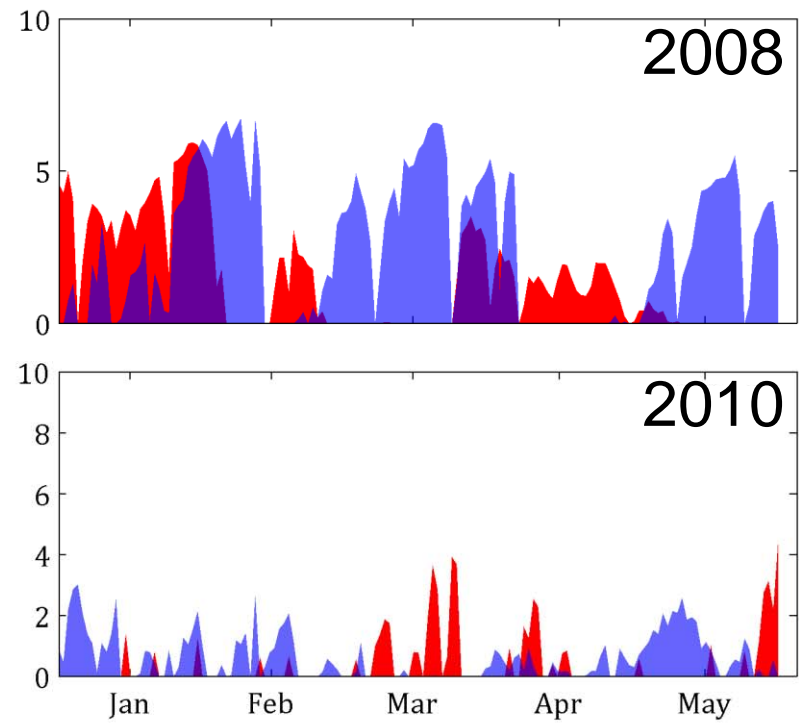
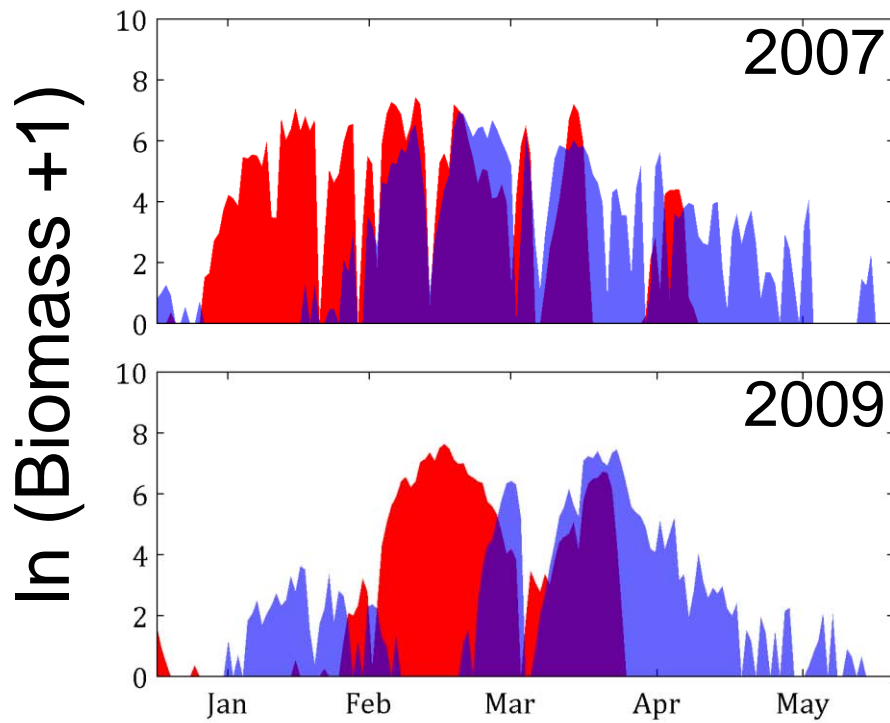
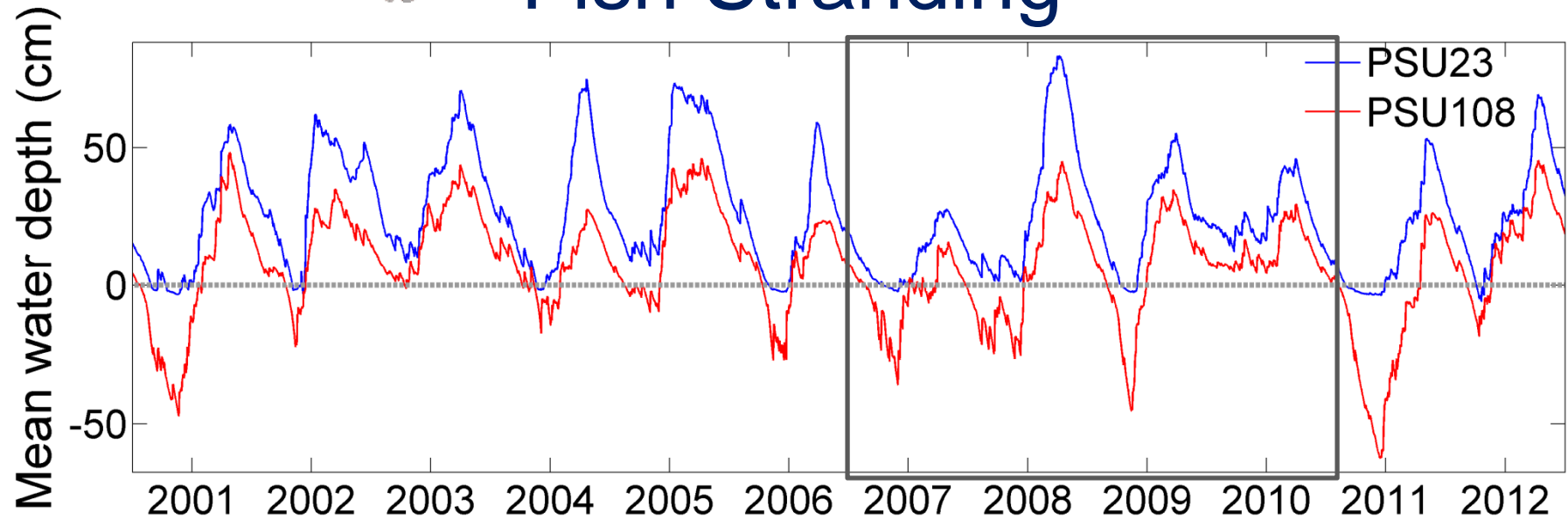


Fish Stranding (2007-2012)



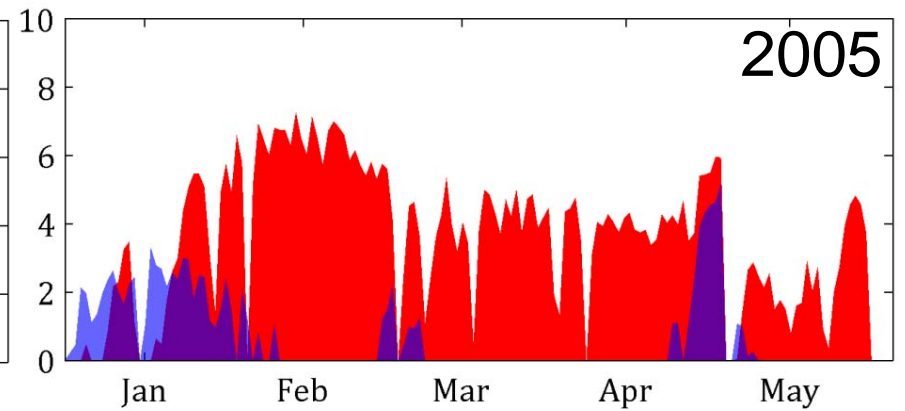
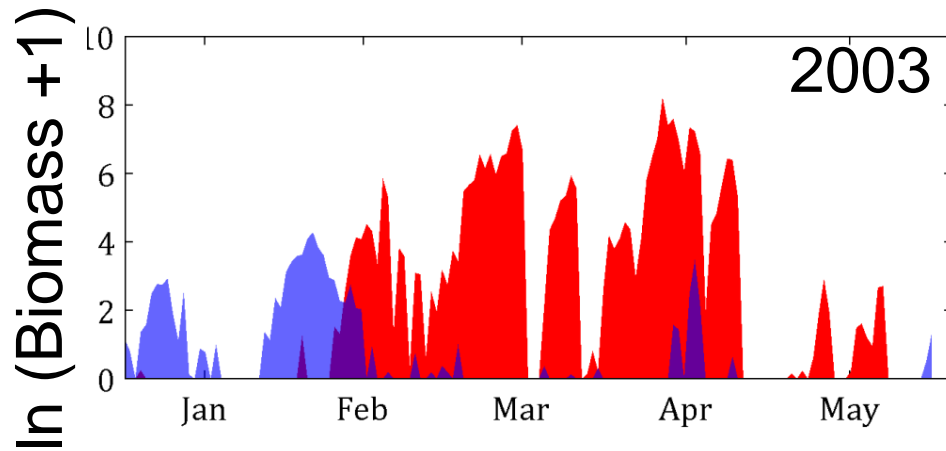
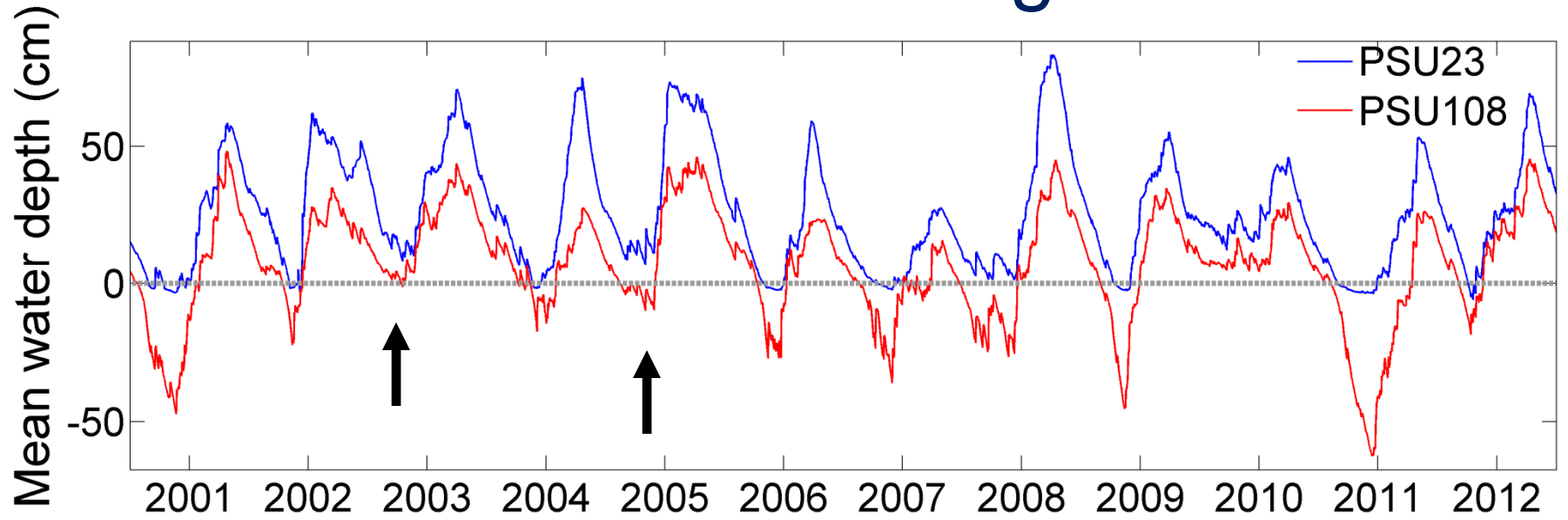


Fish Stranding





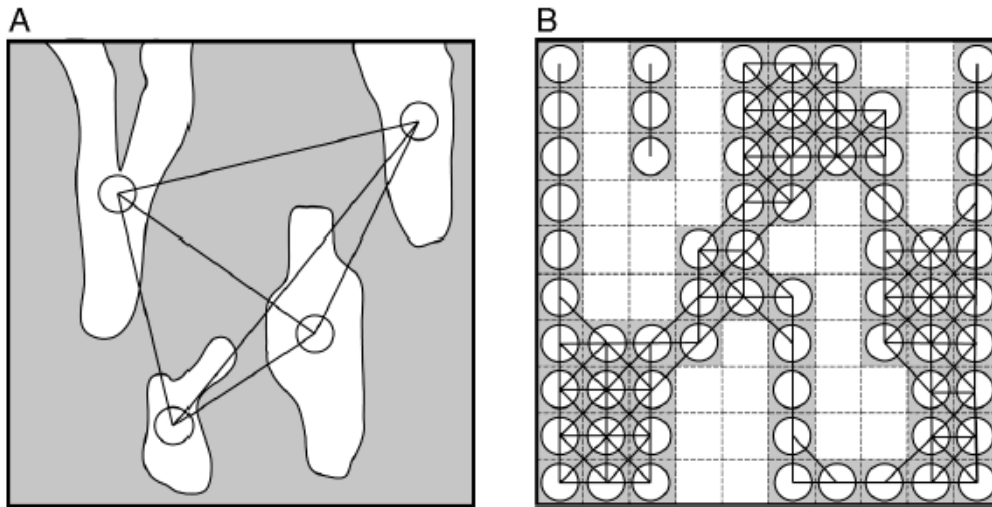
Fish Stranding



Directional Connectivity Index (DCI)

(Larsen et al., 2012)

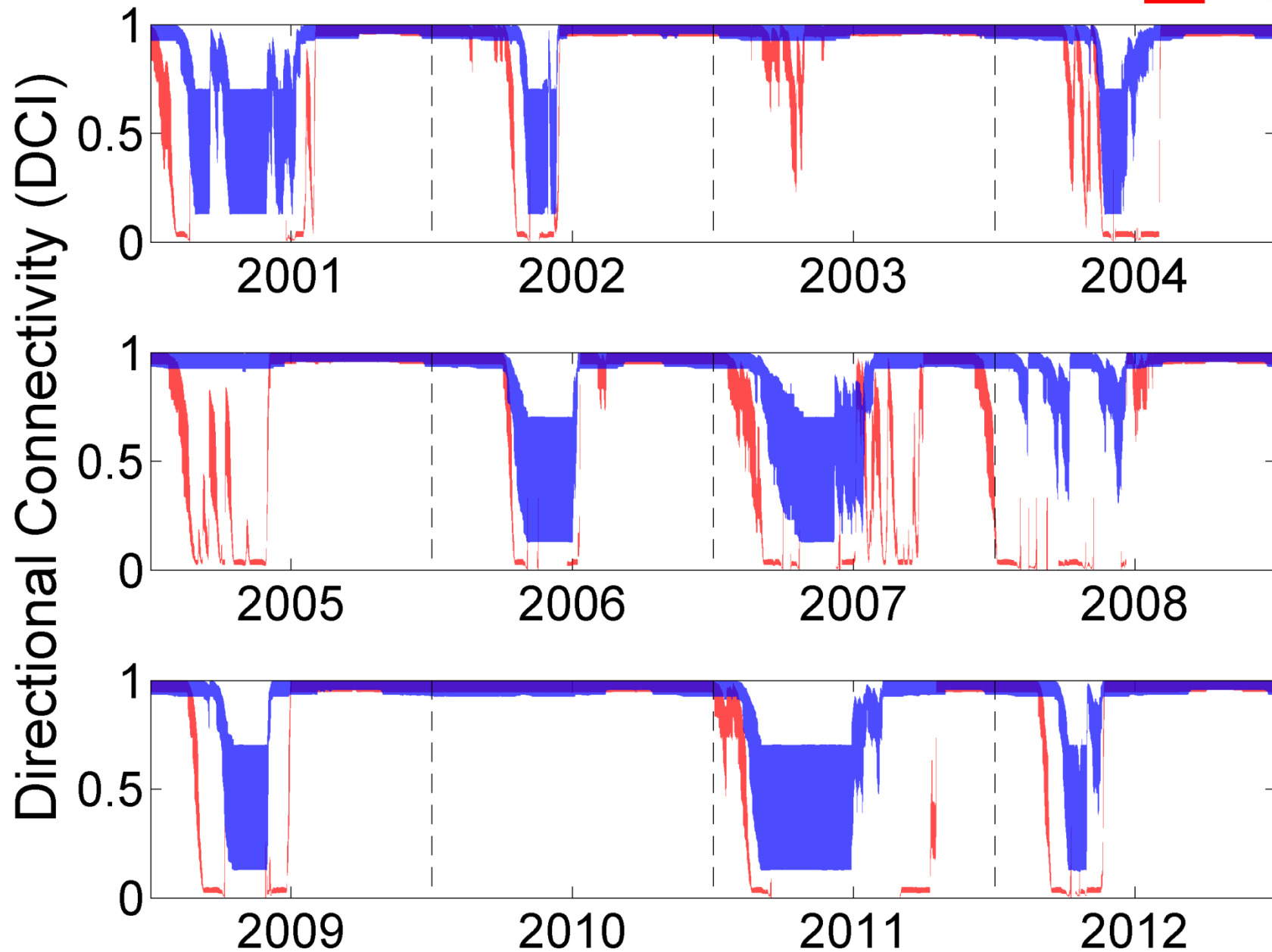
Structural connectivity → Fish movement → Biomass availability



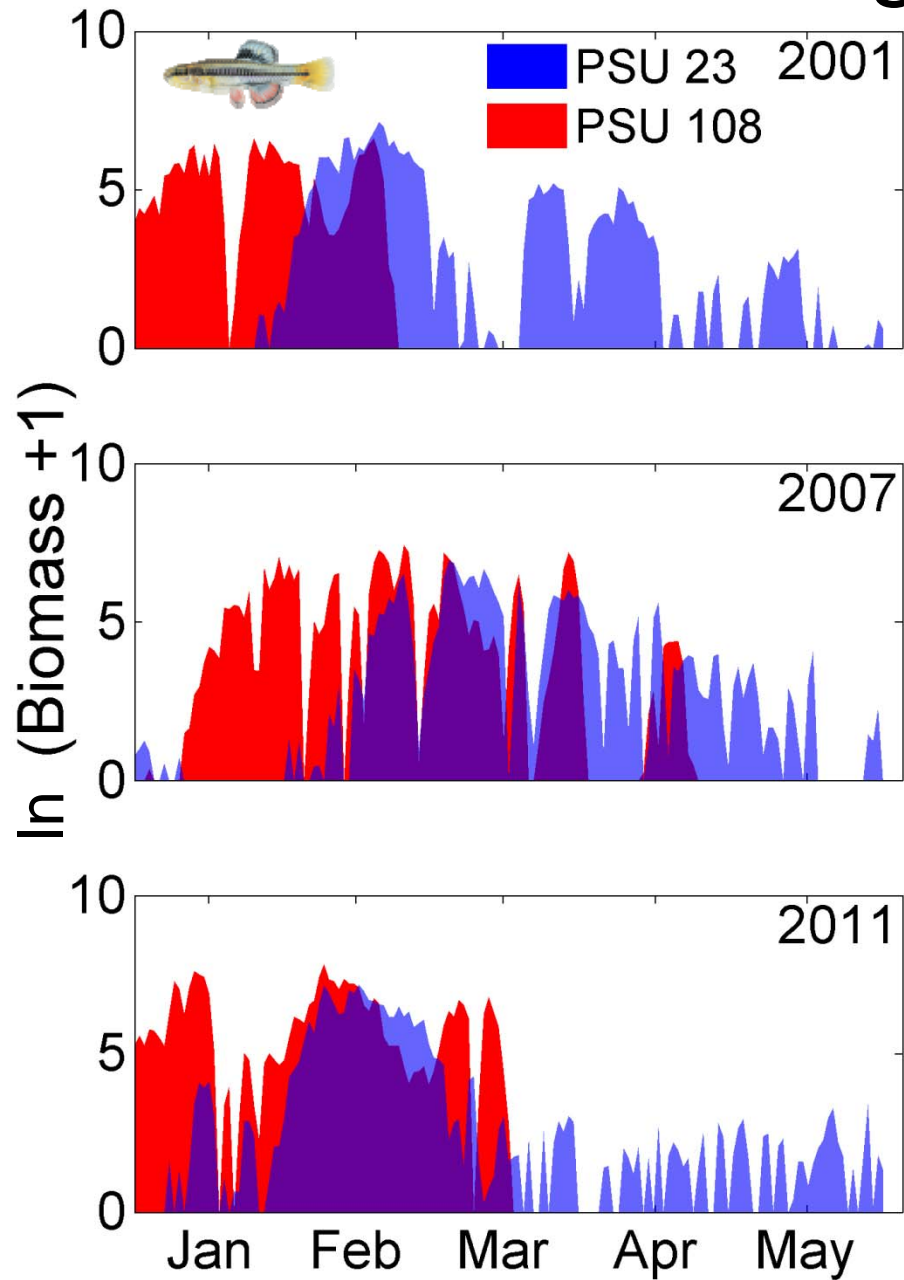
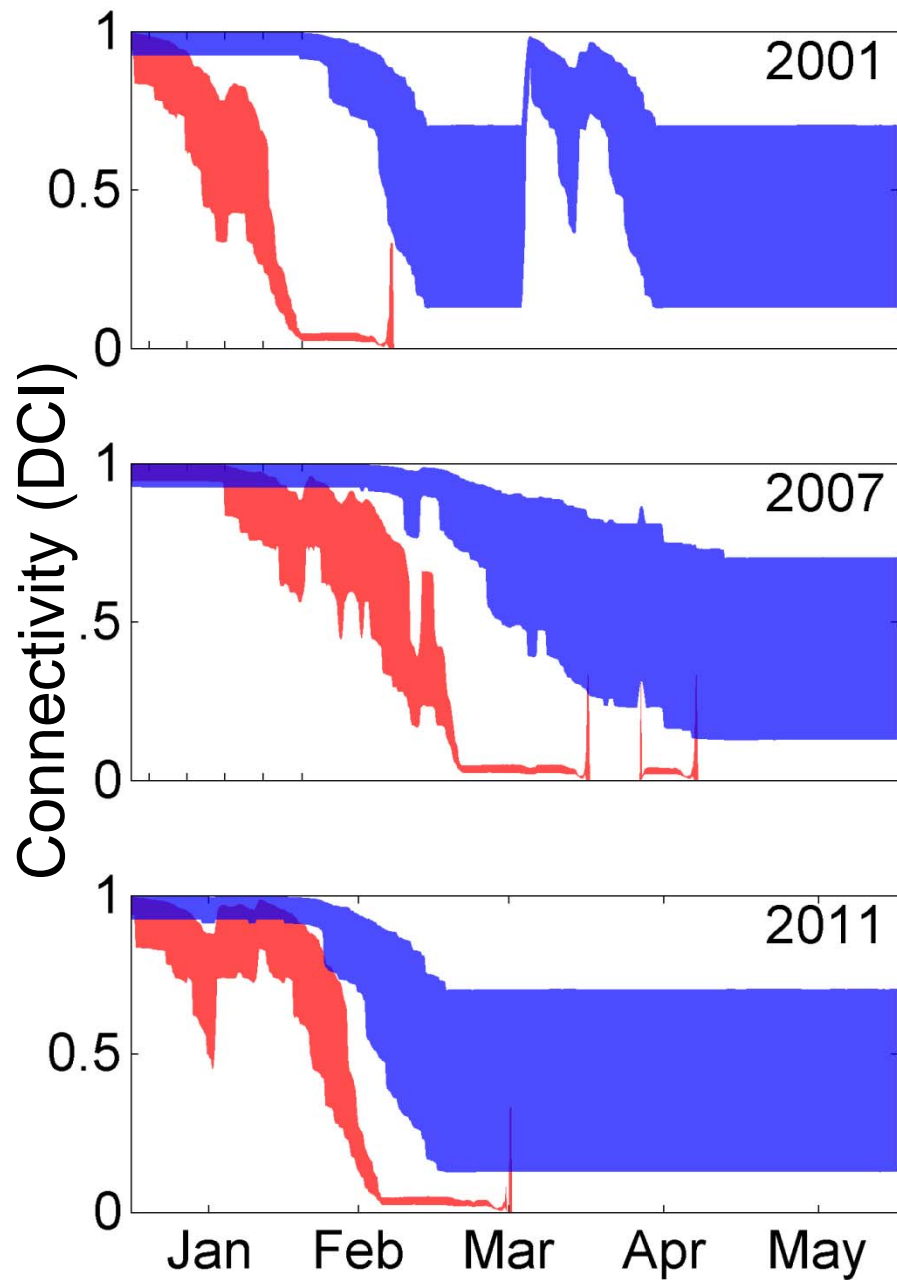
$$DCI = \frac{\sum_{i=1}^v \sum_{j=r+1}^R w_{ij} \frac{dx(j-r)}{d_{ij}}}{\sum_{i=1}^v \sum_{j=r+1}^R w_{ij}}$$

Connectivity Band (Min:Max)

PSU 23
PSU 108

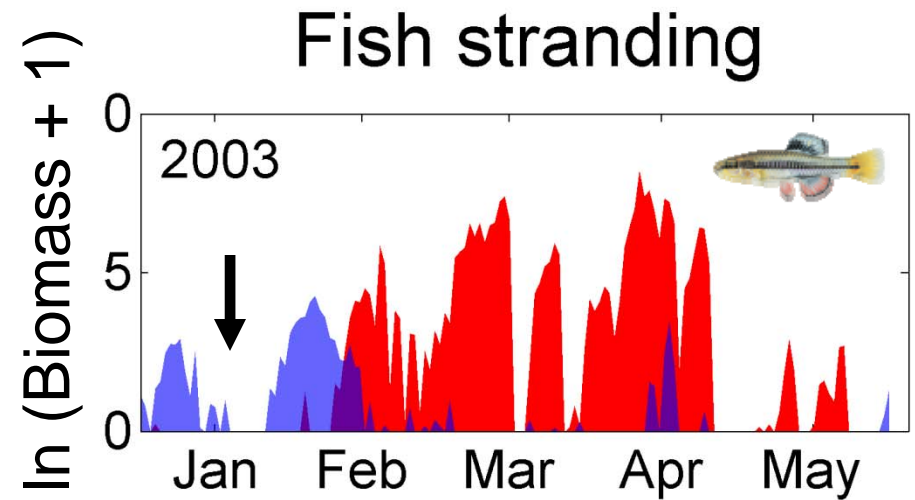
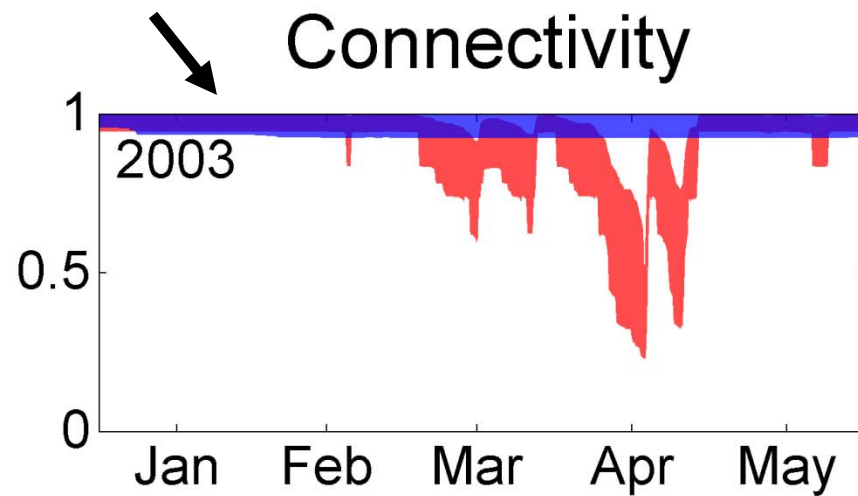


Persistent DCI = Persistent stranding



Very high DCI = Low stranding

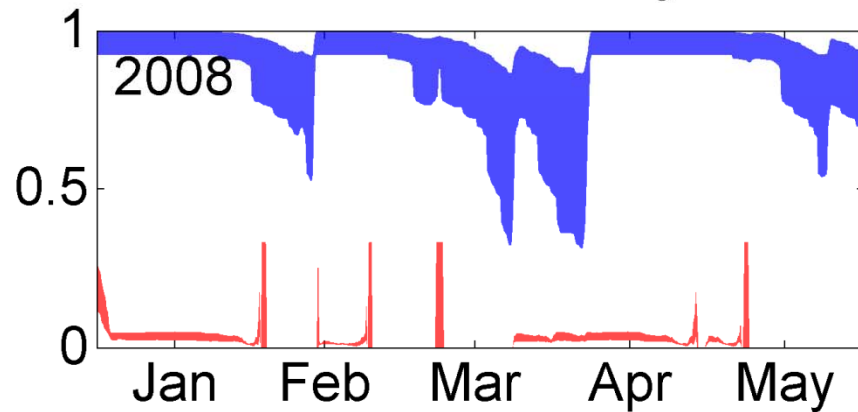
PSU 23
PSU 108



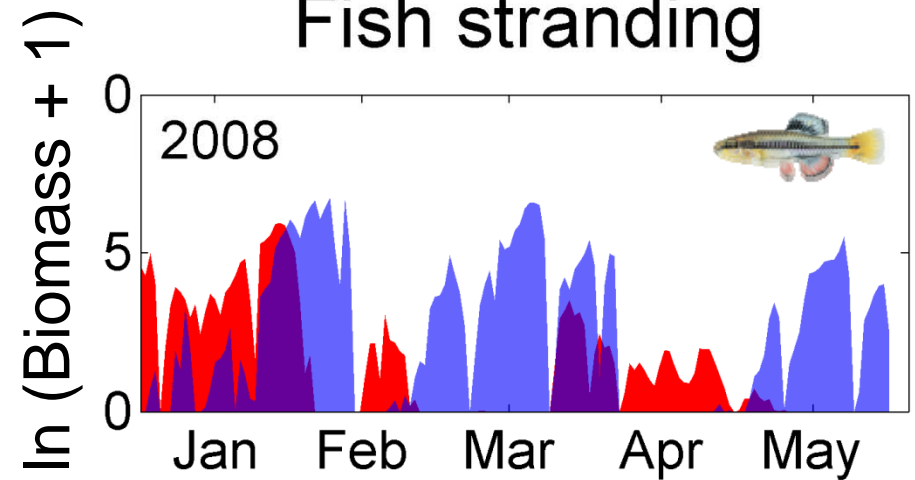
Mixed DCI = Mixed stranding

PSU 23
PSU 108

Connectivity



Fish stranding



Conclusions



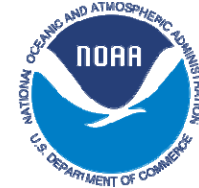
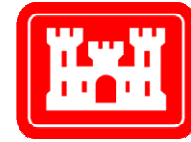
- Spatial modeling provides insights that are not evident in hydrology and empirical data alone
- Fish can be modeled much like hydrology, but have biological behaviors
- Fish stranding is sensitive to water depths and connectivity
- Topographic complexity and diversity of connectivity are required for continuous fish stranding

Thank you!

U.S. Army Corps of Engineers
U.S. Geological Survey
National Oceanic and Atmospheric
Administration
National Park Service
Florida International University
University of Miami

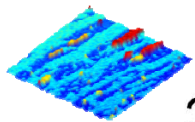
Collaborators

Don DeAngelis
Joel Trexler
Laurel Larsen
Pam Schofield



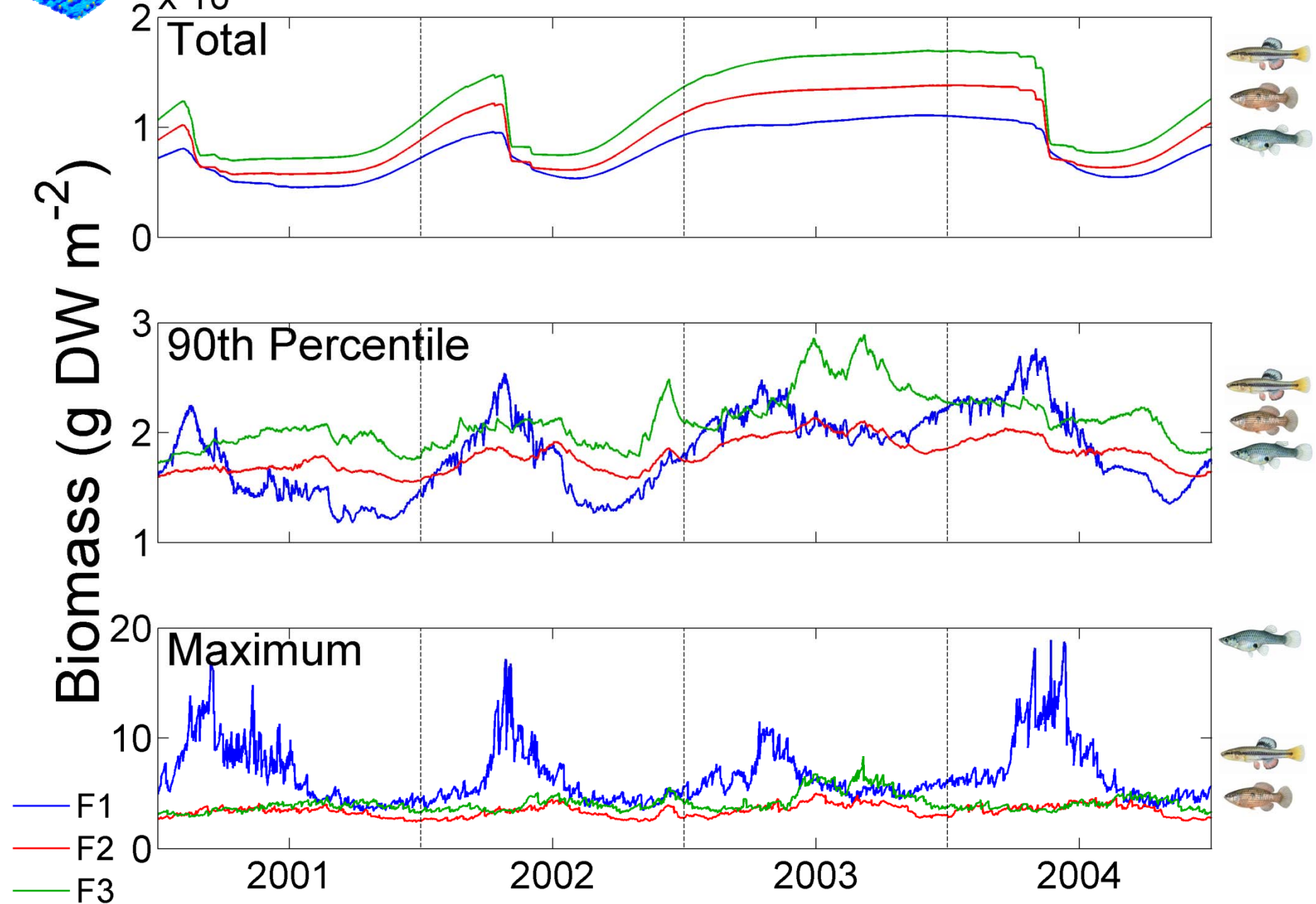
UNIVERSITY
OF MIAMI

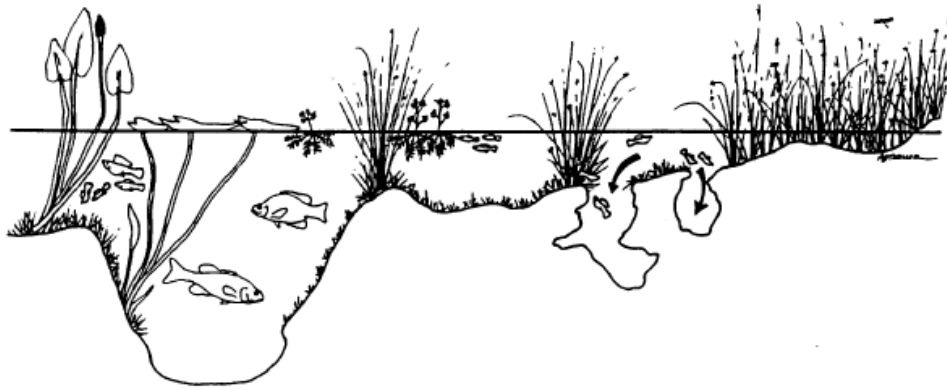
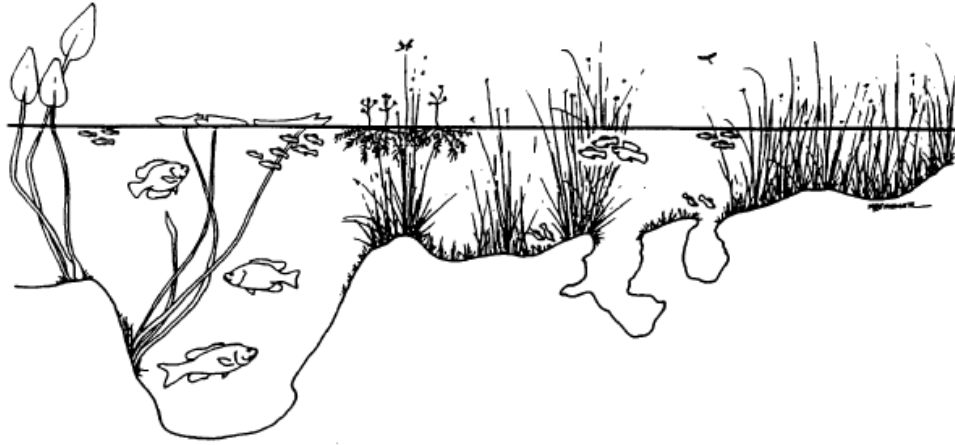




Fish biomass (2001-2004)

PSU 23





Wading bird prey availability

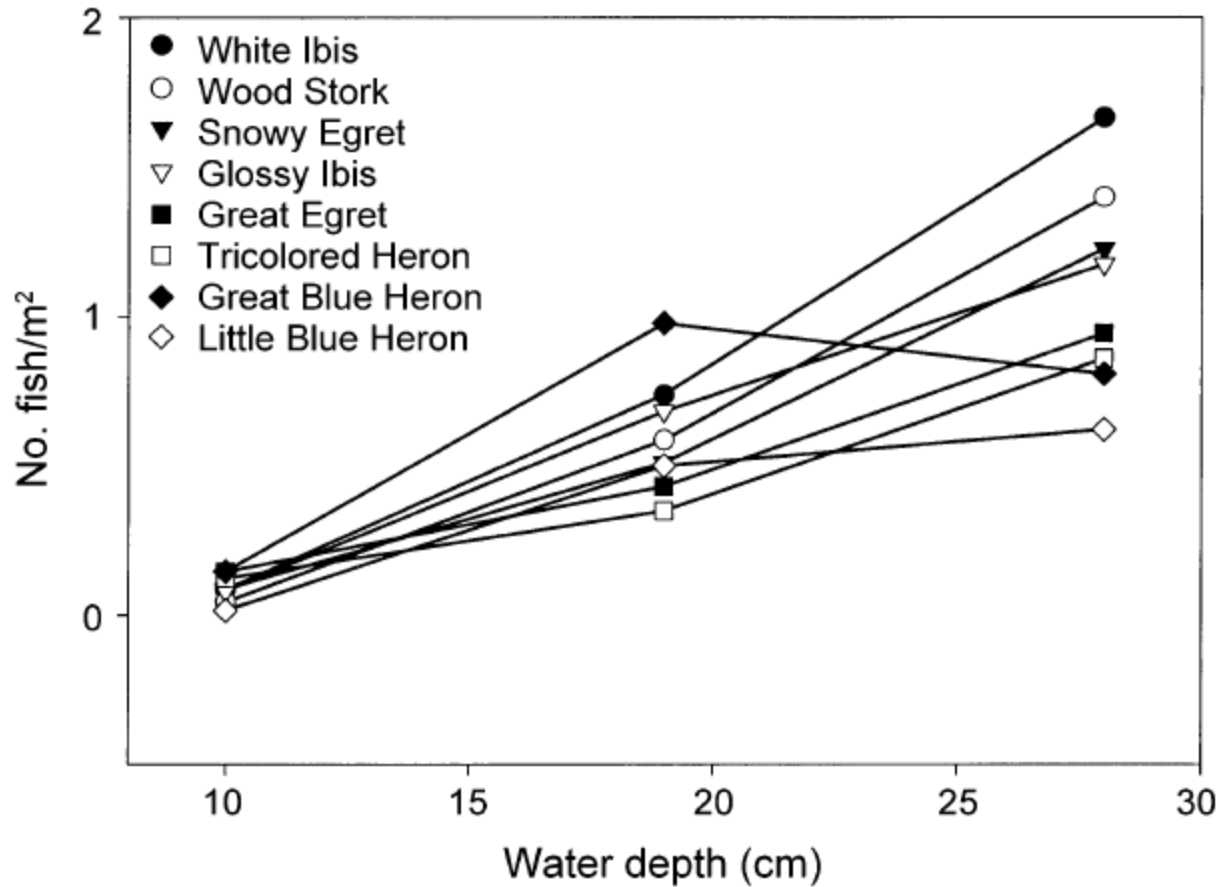


FIG. 6. Giving-up density for eight bird species preying upon fish increased with increasing water depth treatments of 10 cm, 19 cm, and 28 cm.