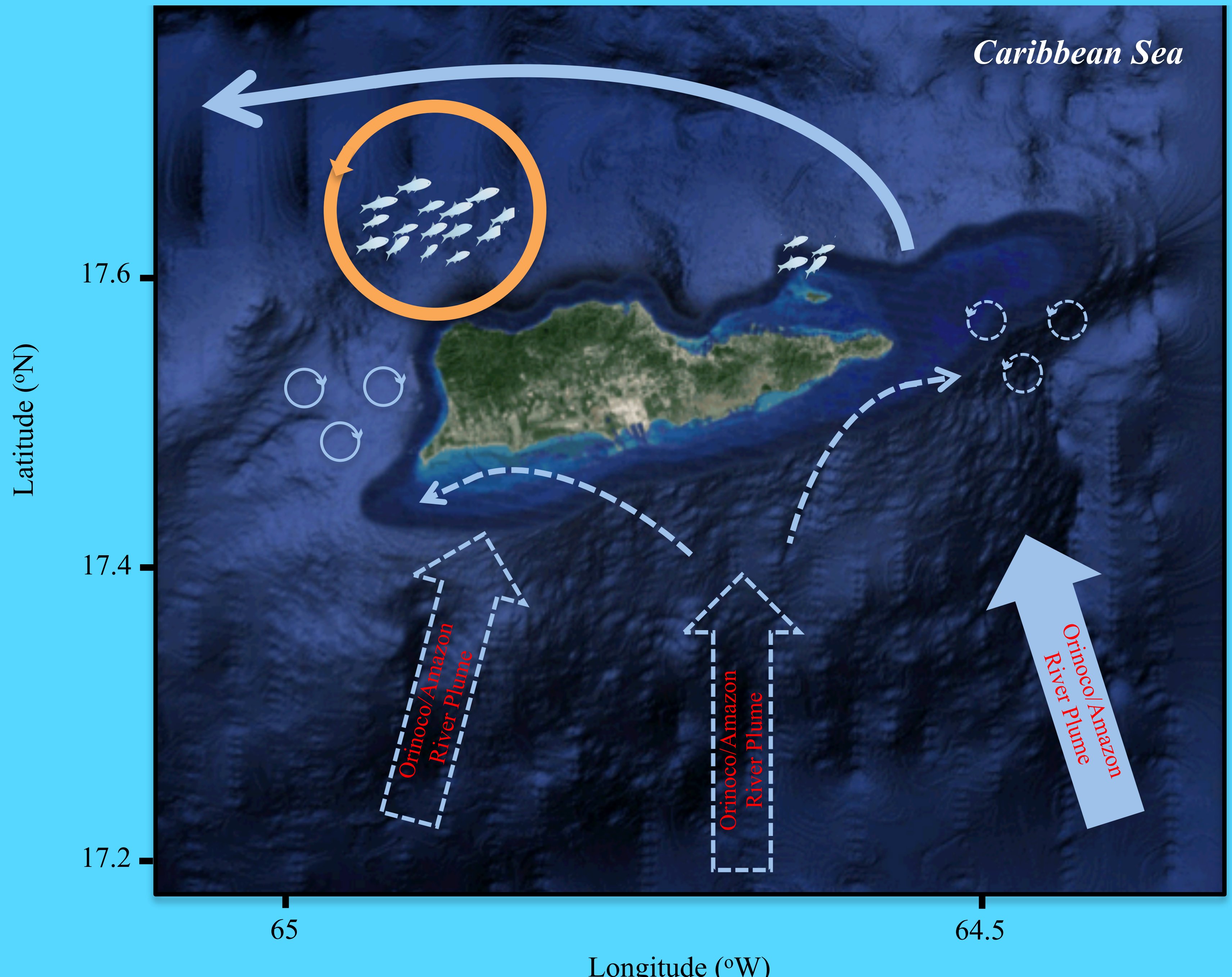
LAURENT CHERUBIN, HARBOR BRANCH OCEANOGRAPHIC INSTITUTE

FRONTAL, WAKE EDDY, TOPOGRAPHY CONTROL AND ECOLOGICAL CONSTRAINTS OF FISH SPAWNING HABITATS

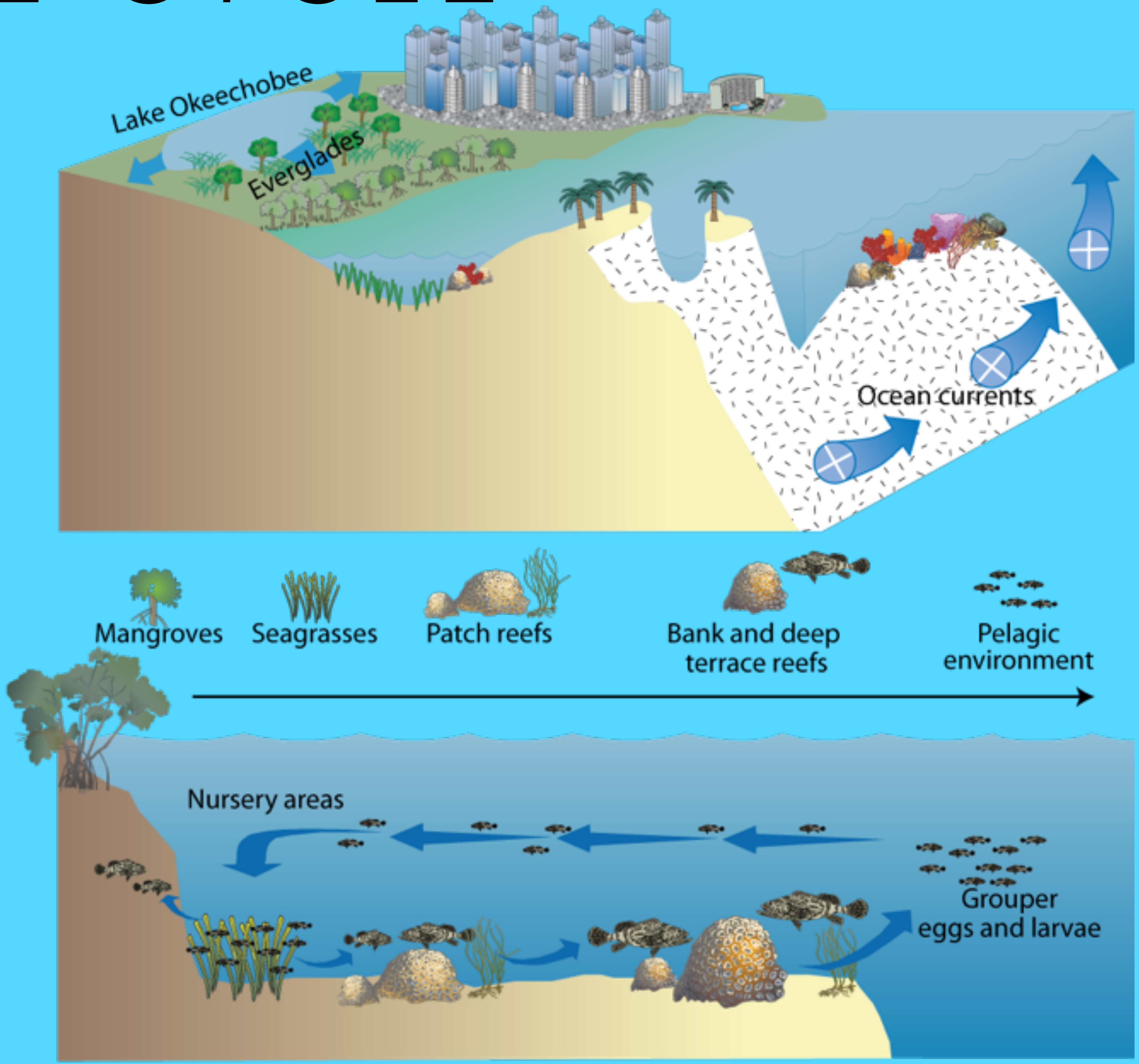


REPRODUCTION AND SURVIVAL

RATIONALE

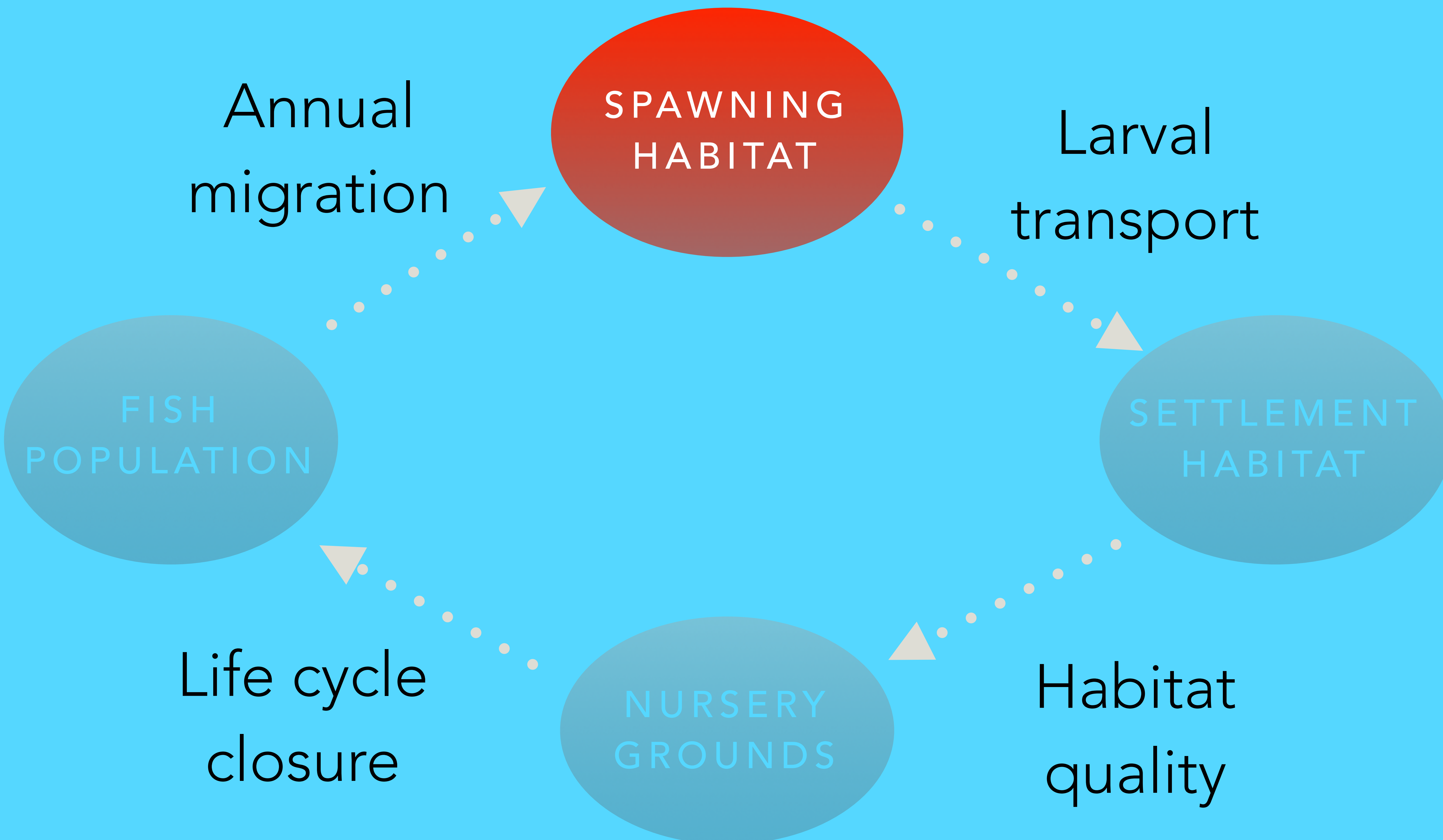
RATIONALE

LIFE CYCLE



RATIONALE

ECOLOGICAL CONSTRAINTS



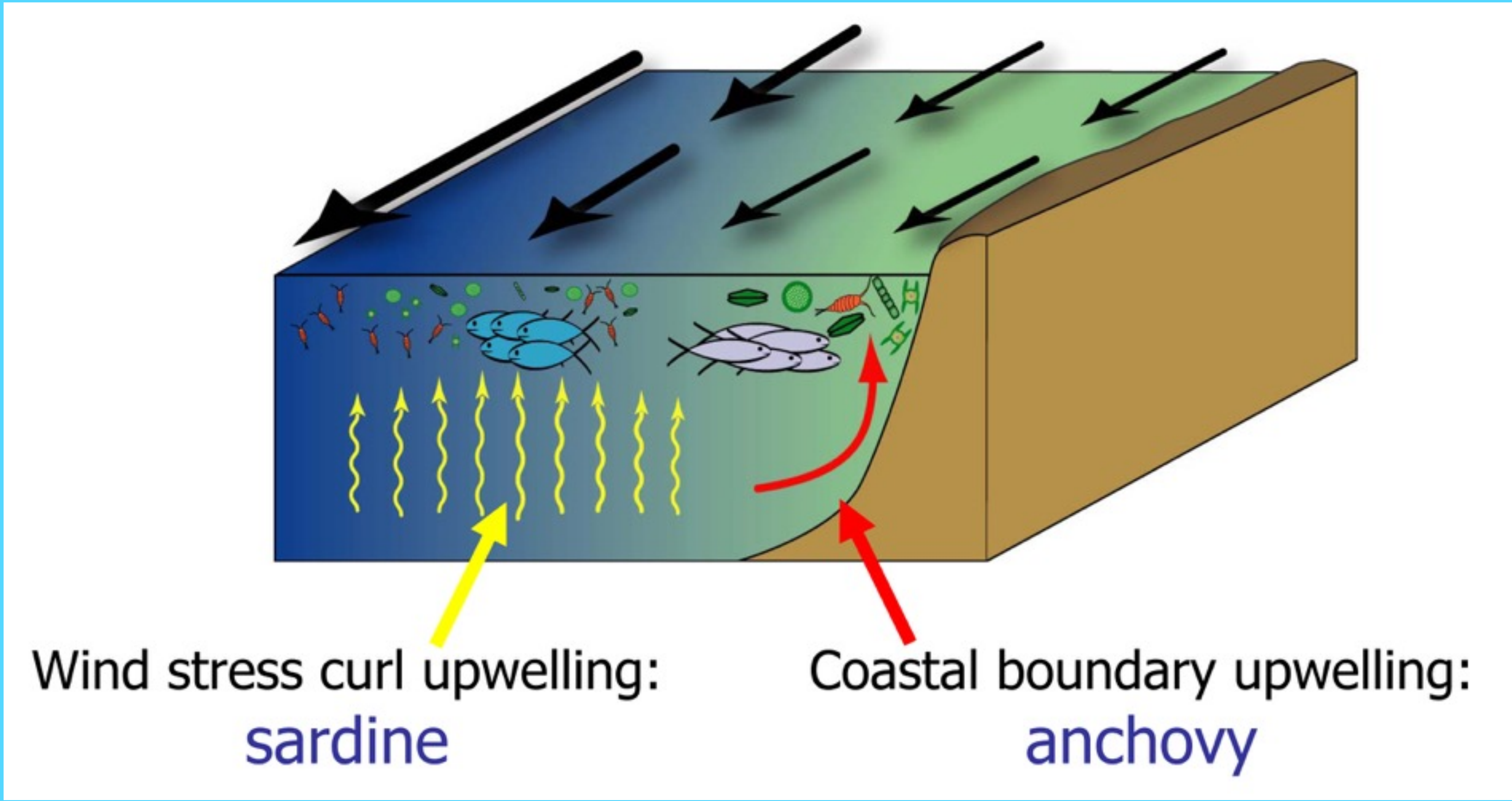
ECOLOGICAL CONSTRAINTS OF THE SPAWNING HABITAT

- What constraints the choice of the spawning habitat is what constraints the success of early life development.
- Evolutionary process toward finding the most suitable environment for the larval development.
- What's the most suitable environment?

Ocean triads hypothesis (Bakun, 2009)

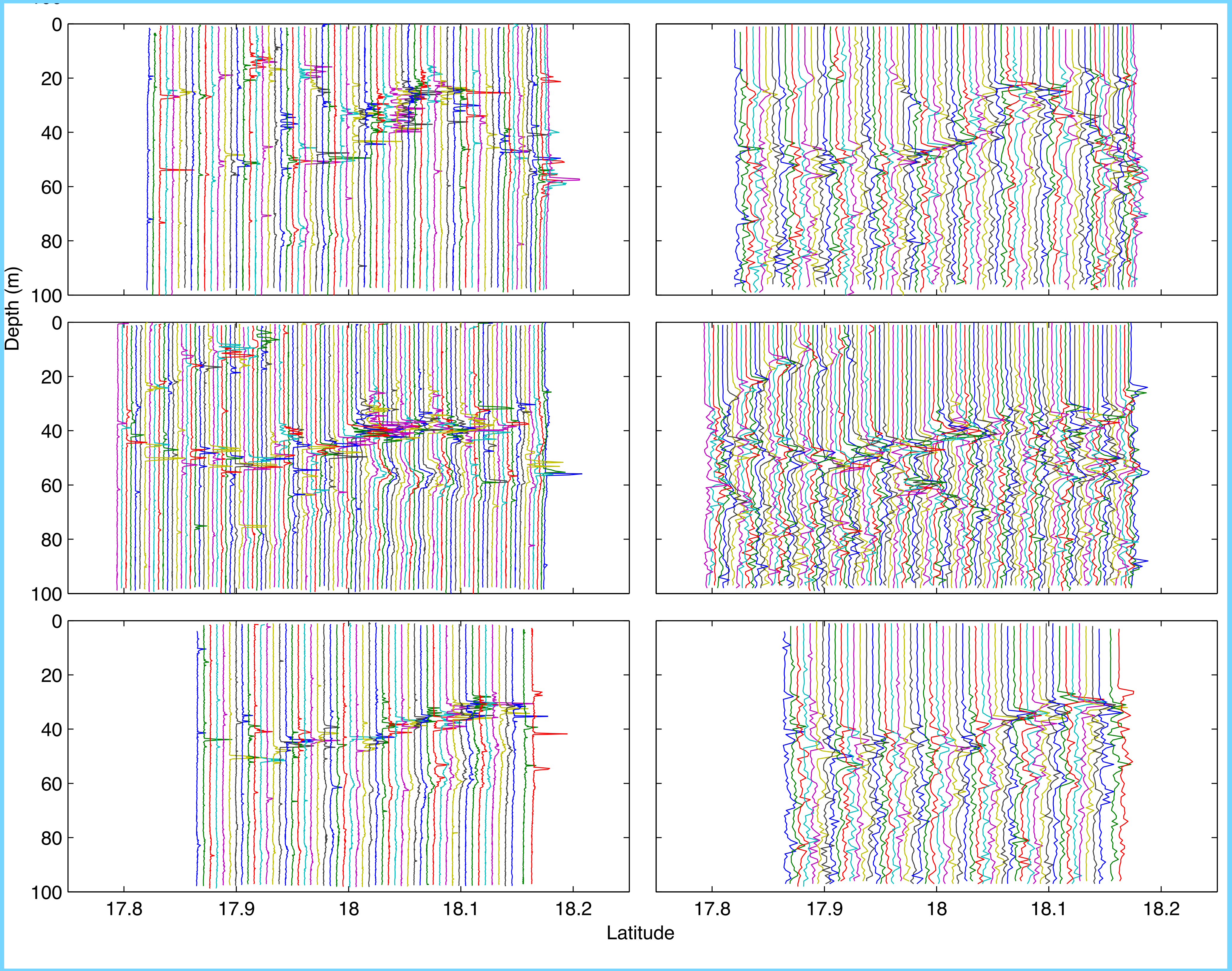
GOOD REPRODUCTIVE AREAS

ENRICHMENT



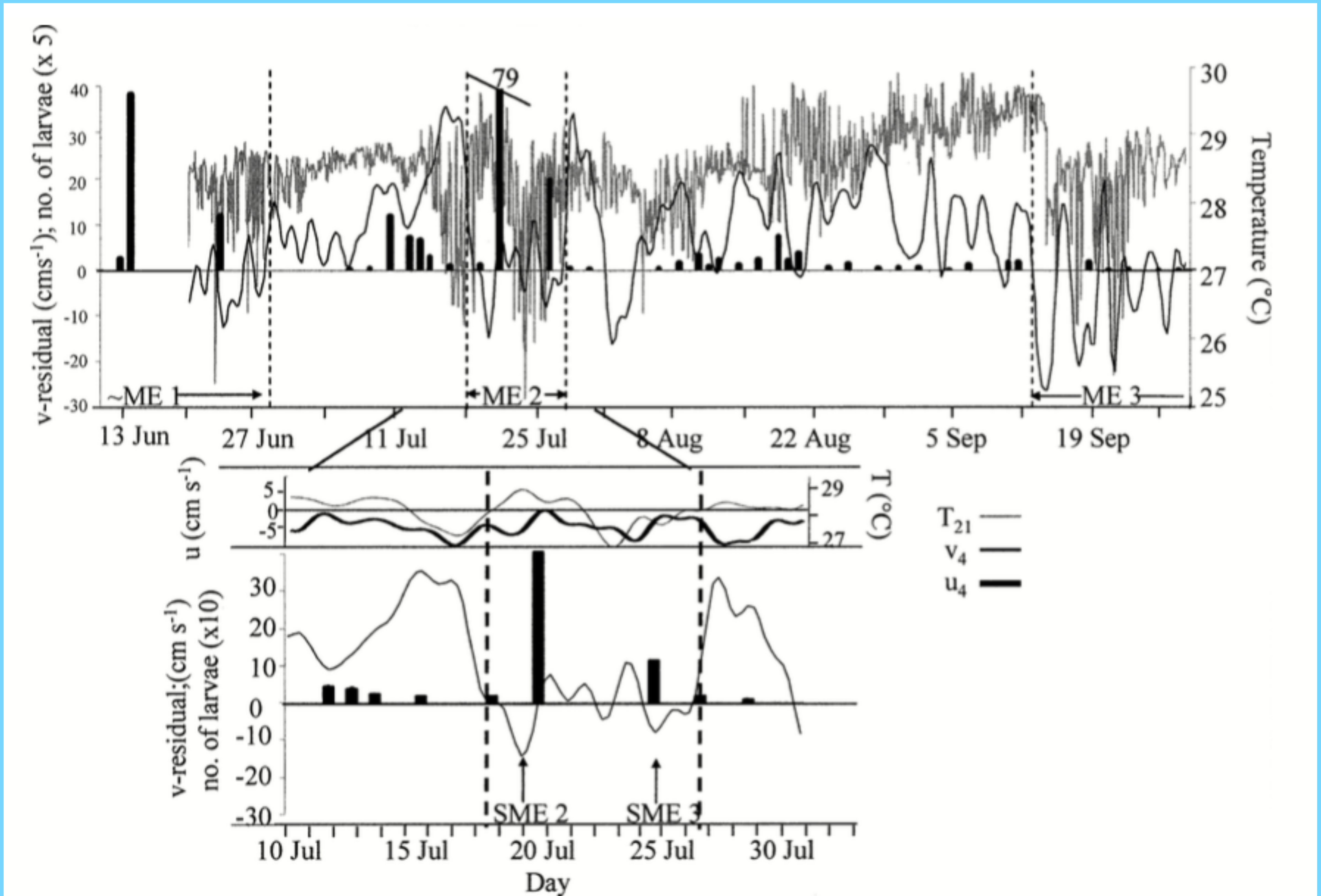
GOOD REPRODUCTIVE AREAS

CONCENTRATION



GOOD REPRODUCTIVE AREAS

RETENTION AND DELIVERY



ECOLOGICAL CONSTRAINTS OF THE SPAWNING HABITAT

Therefore the spatial and temporal occurrence of all three significantly constrains the availability of spawning habitat

Because of spawning site fidelity, strategies for life cycle closures must be robust against interannual environmental variability

Ciannelli et al., 2014

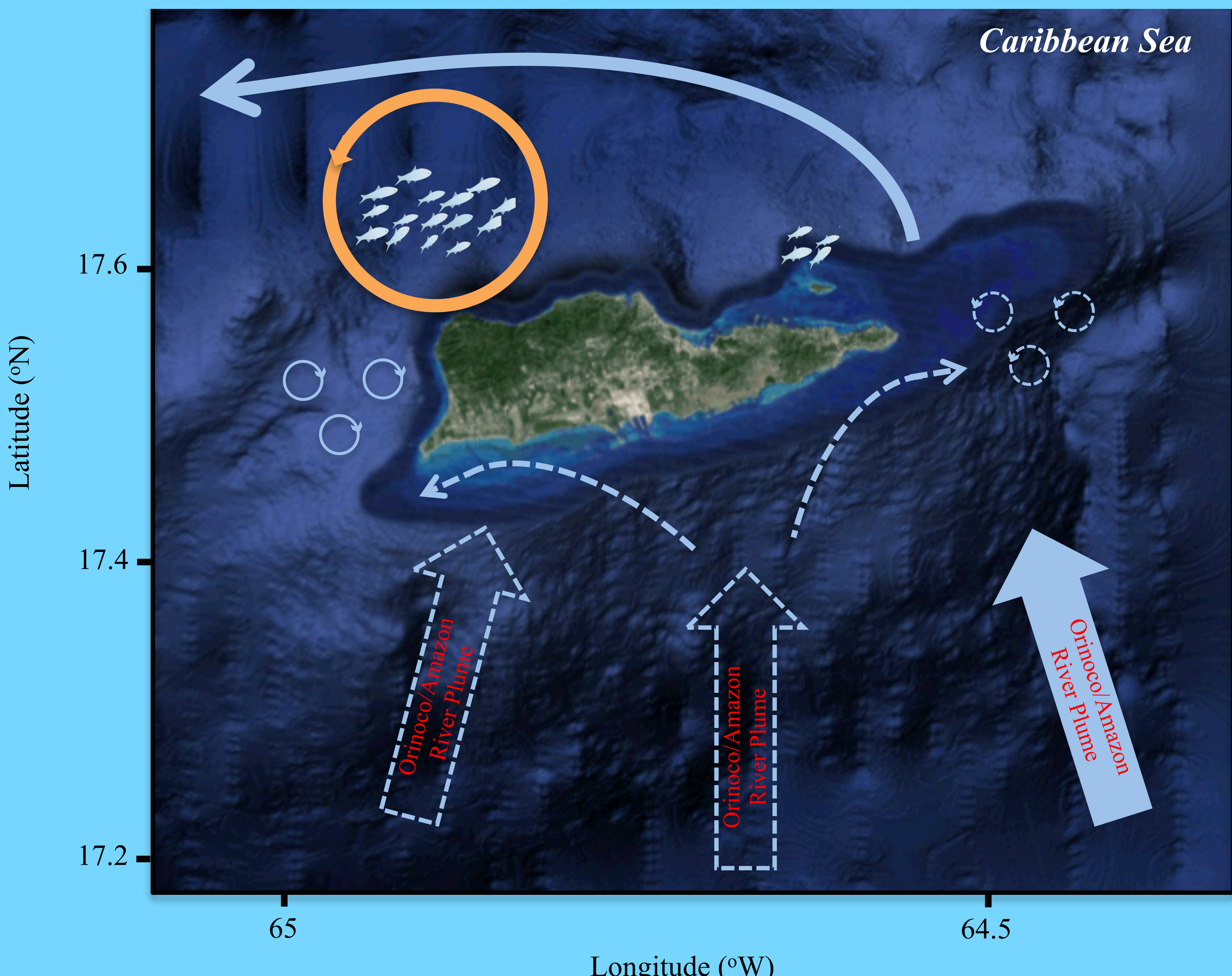
ECOLOGICAL CONSTRAINTS OF THE SPAWNING HABITAT

THREE COMMON STRATEGIES

Ciannelli et al., 2014

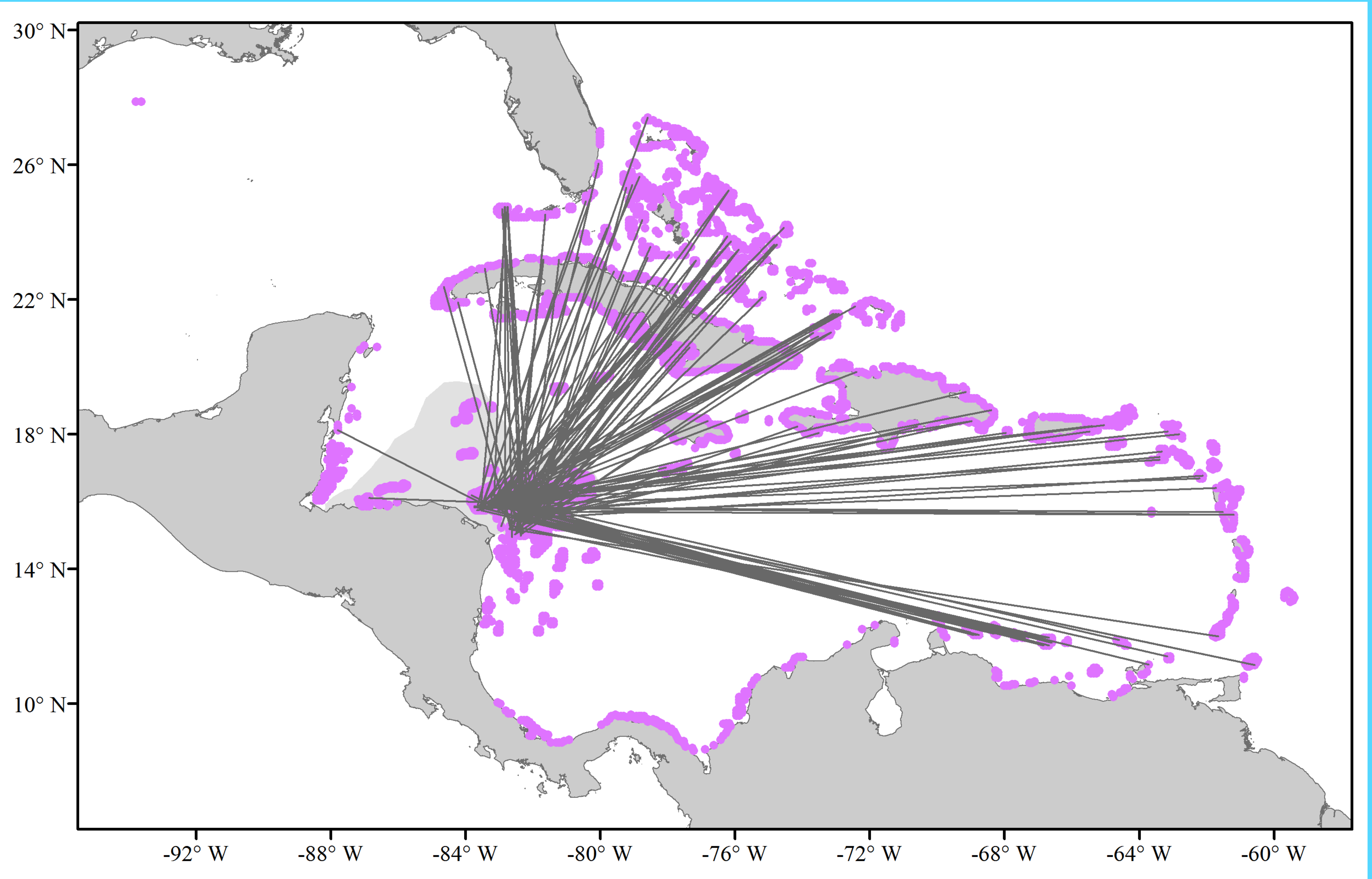
STRATEGY ONE

LOCAL RETENTION AND SELF RECRUITMENT NEAR THE PARENTAL HABITAT AND POPULATION



STRATEGY TWO

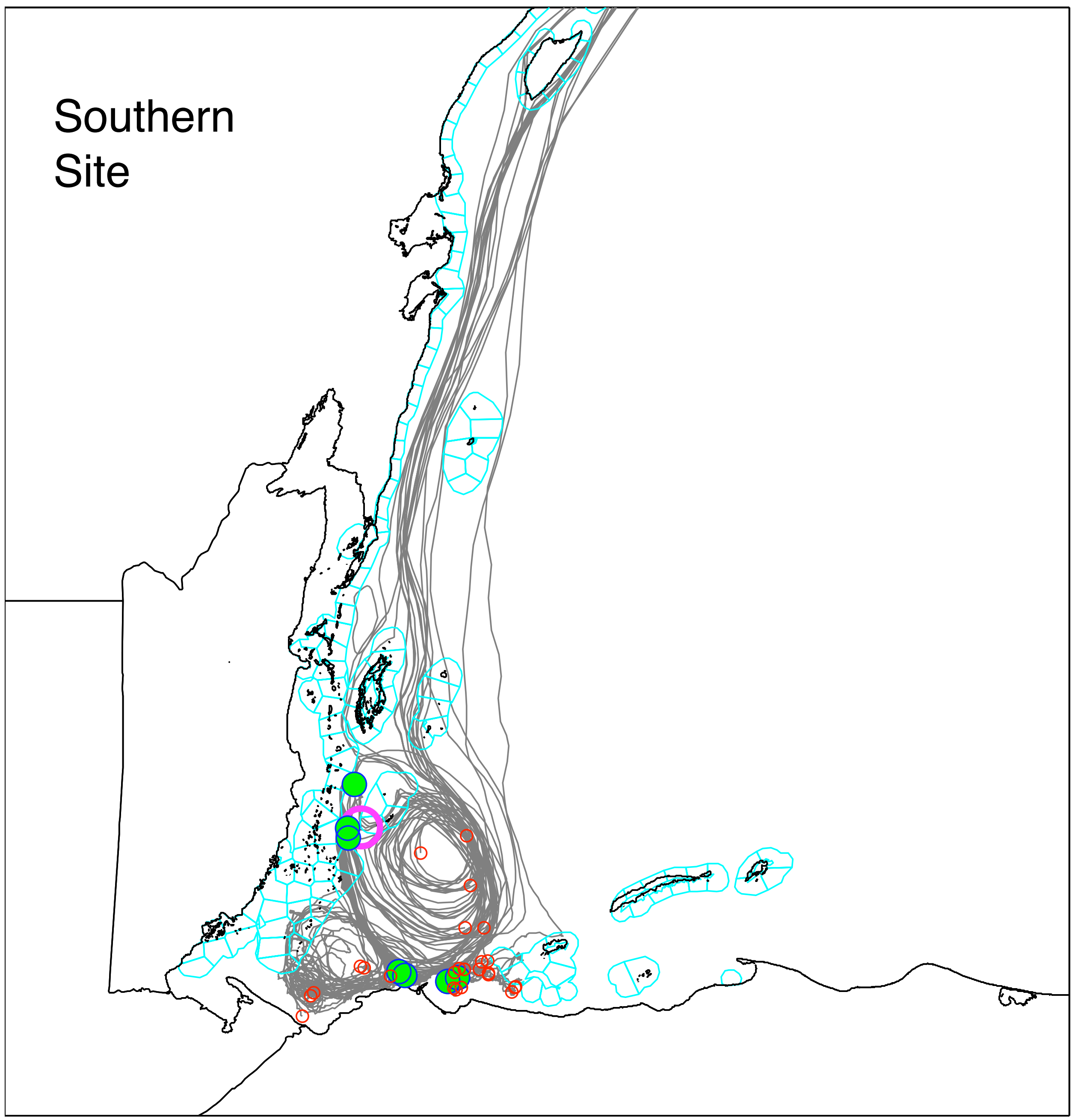
DISPERSAL TOWARD DISTANT SETTLEMENT LOCATIONS (LOBSTER)



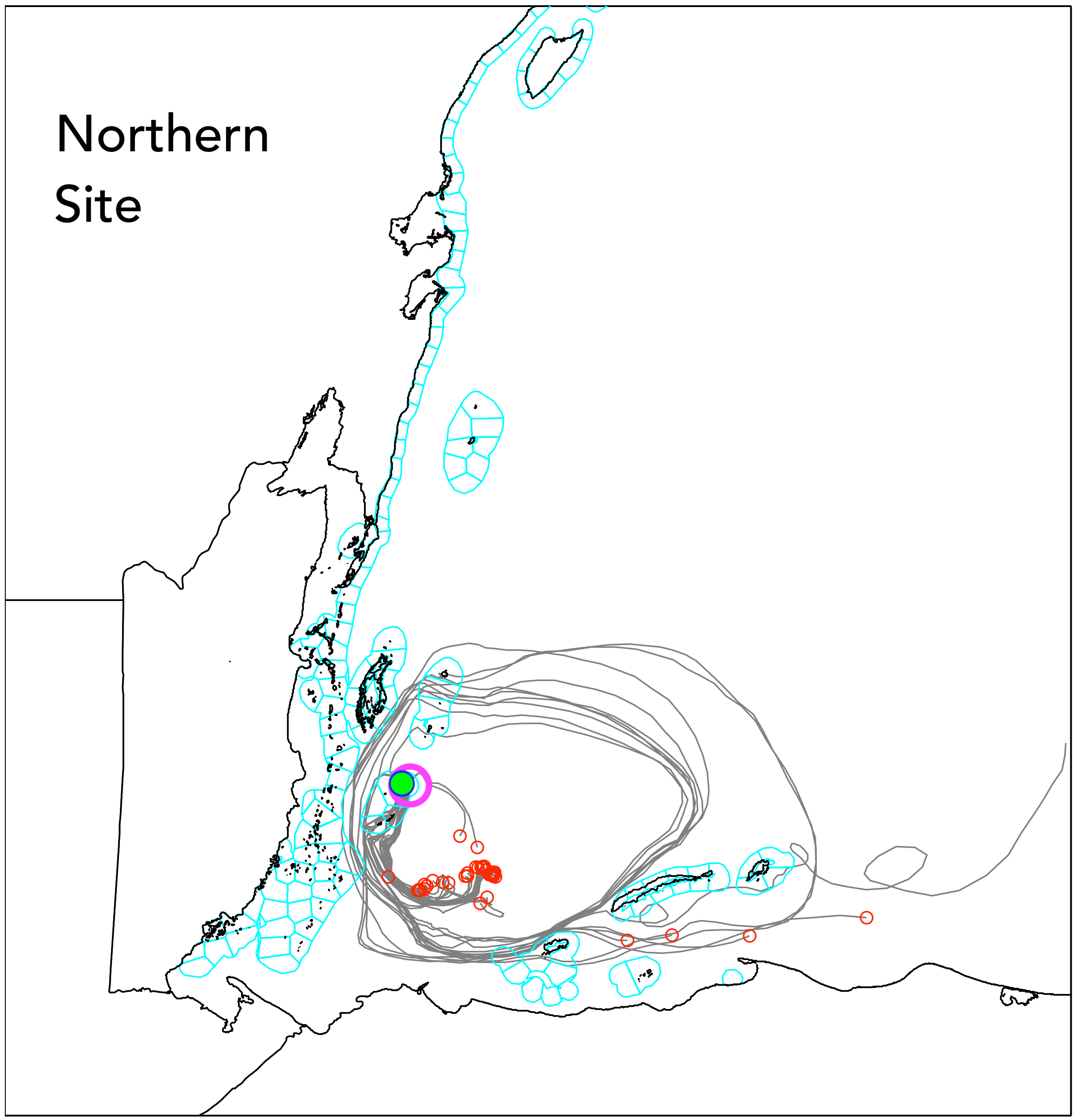
STRATEGY THREE

COMBINATION OF THE PAST TWO: DISPERSAL FROM AND BACK TO THE NATAL SITE AT THE SETTLEMENT AGE (NASSAU GROUPER)

Glovers S 12/05/06, 30m pld42



Glovers N 01/03/07 pld 42, 10 m



OUTLINE

1. Spawning habitats: physical features and characteristics
2. Consistent flow regimes near spawning habitats
3. How the spawning habitats fulfill the ocean triad hypothesis?
4. Discussion
5. Conclusions

TWO CASE STUDIES

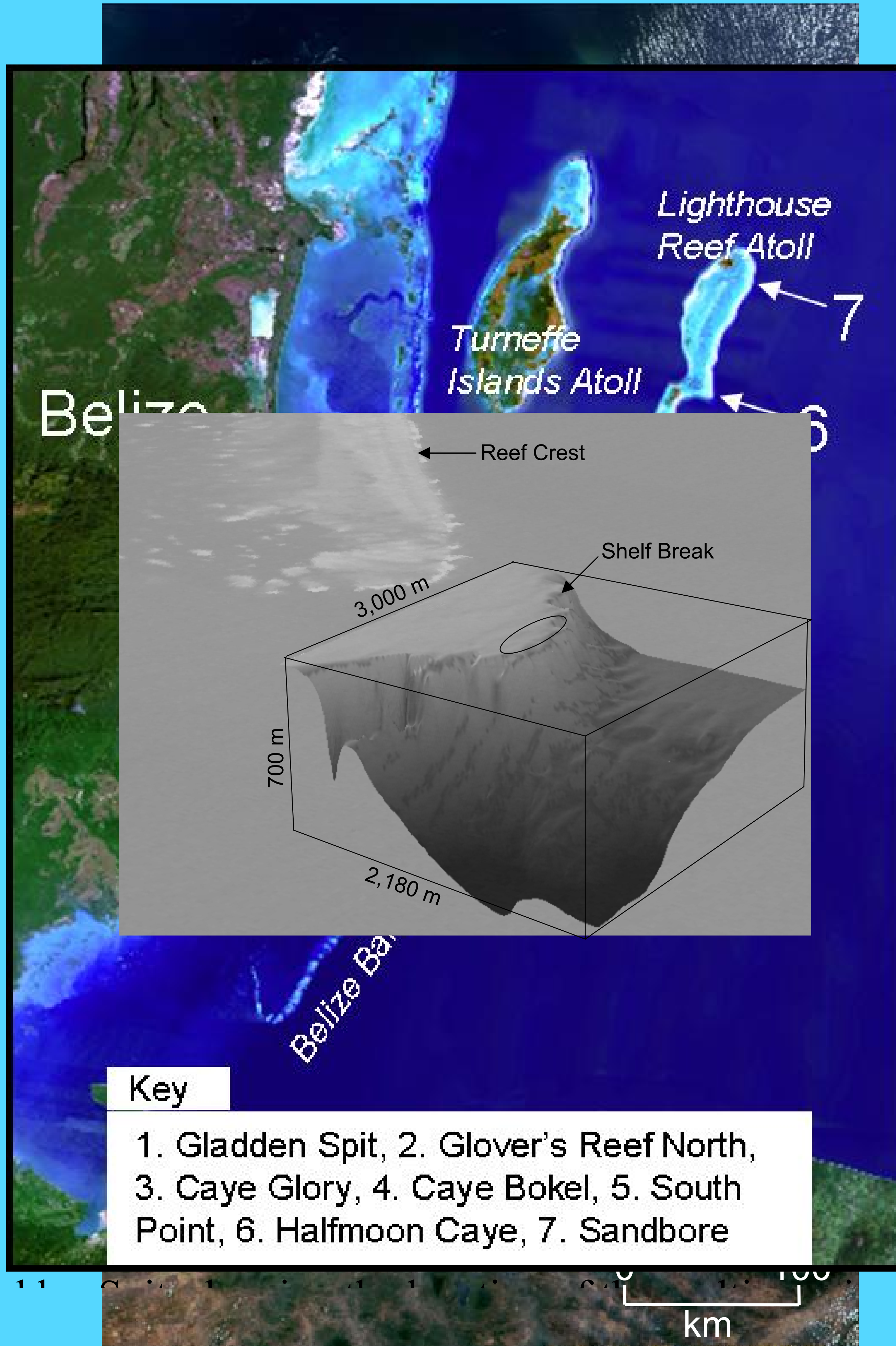
MESO-AMERICAN REEF
CARIBBEAN ISLAND WAKE

SPAWNING HABITATS

MESO-AMERICAN REEF

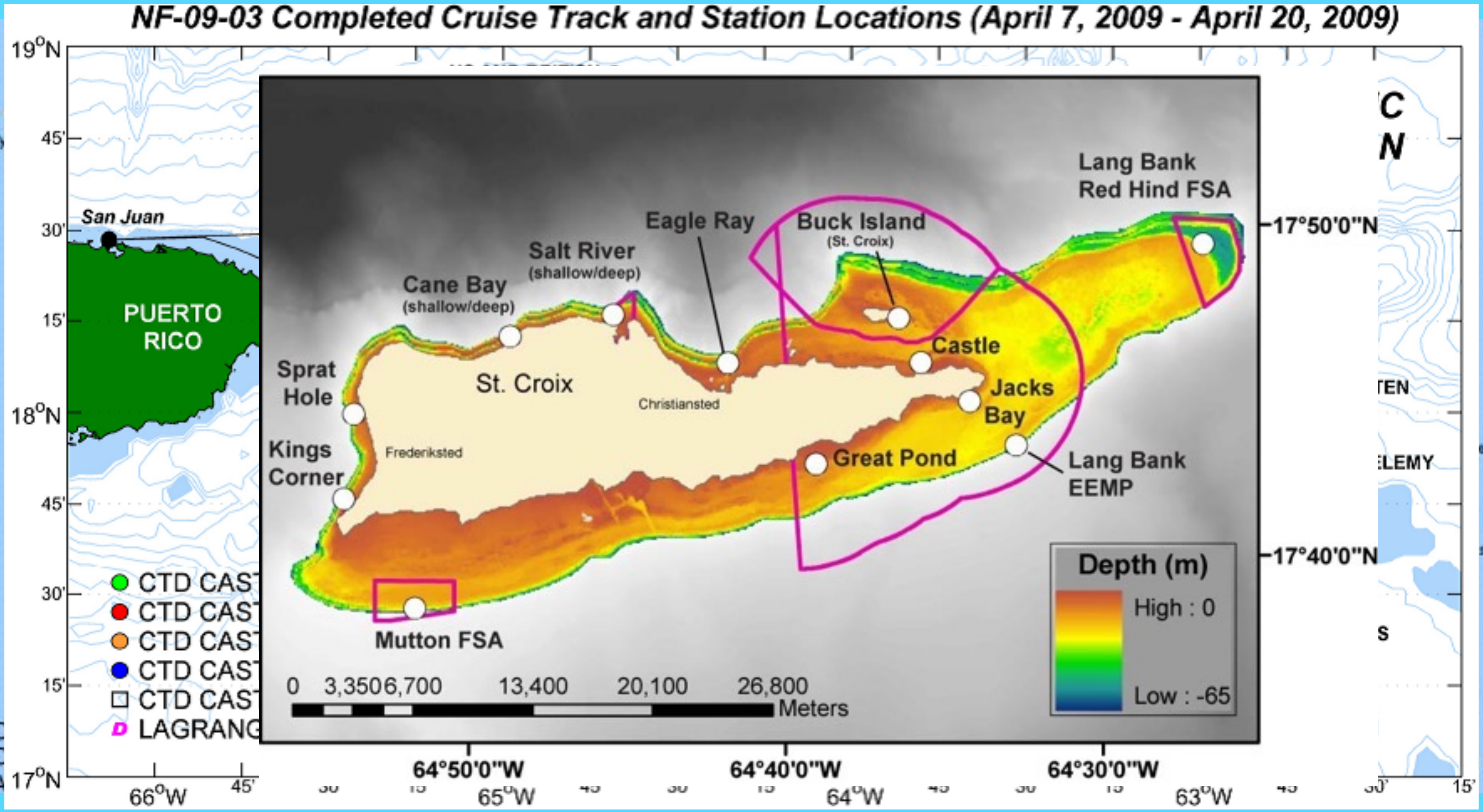
- Multi-species spawning sites
- Mostly capes and promontories
- Mostly to the south of 19°N

Heyman et al., 2007



CARIBBEAN SEA

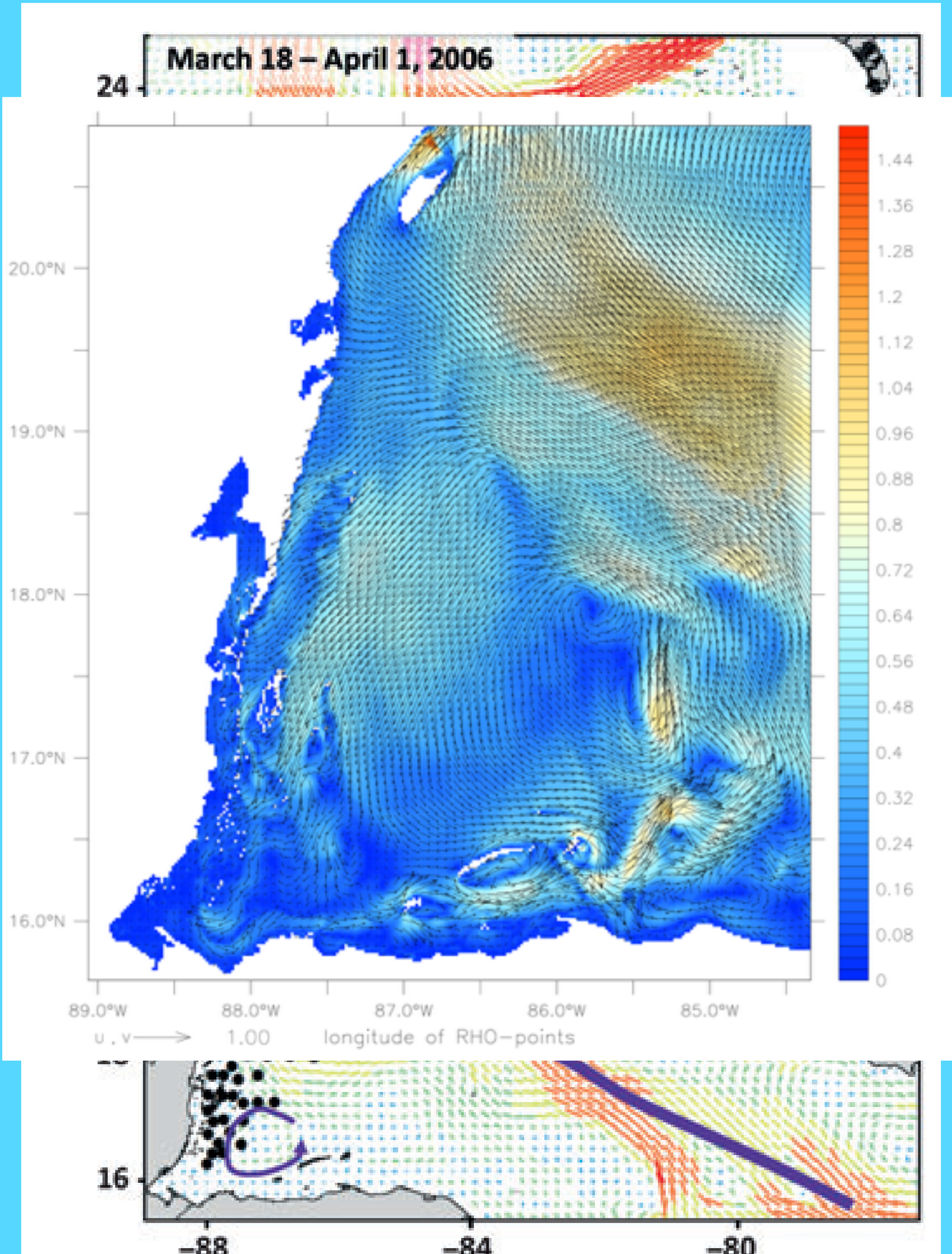
ST. CROIX U.S. V.I.



SEASONAL FLOW CONSISTENCY

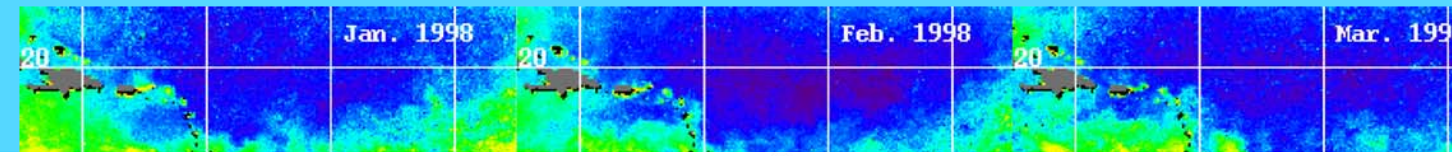
MESO-AMERICAN CIRCULATION

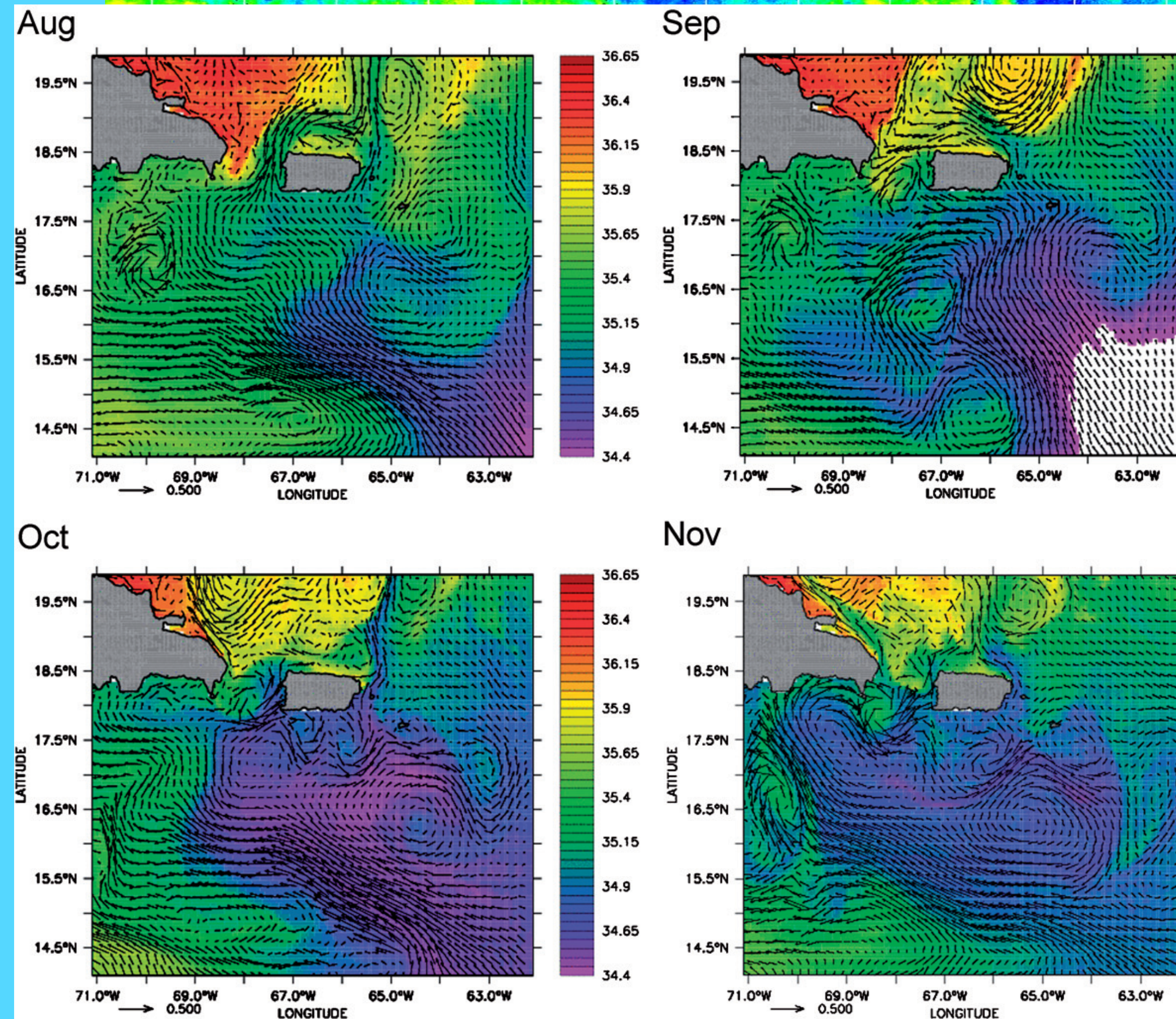
- Caribbean Current impingement zone: 17°-19°N
- Cyclonic eddy near the MBRS increase the flow southward near the spawning sites
- southward flow can be sustained for several months



Mulhing et al., 2013

AMAZON AND ORINOCO PLUME TRANSPORT

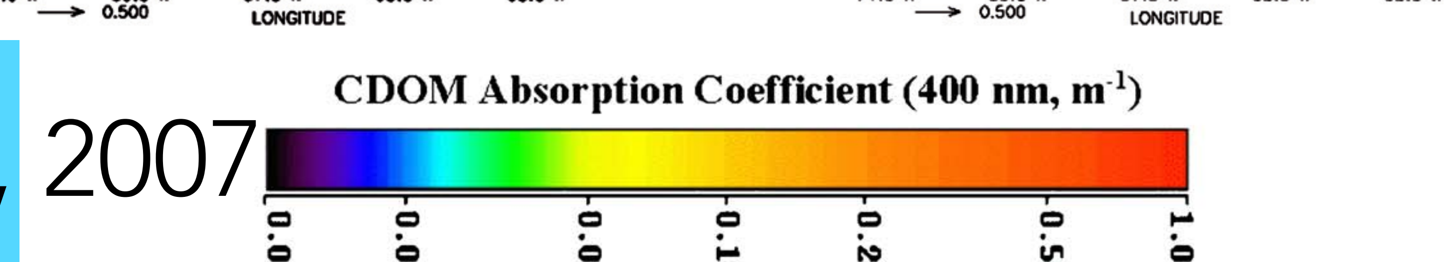




- Riverine water seasonal forcing: July-December
- Northwestward propagation of the river plume

Cherubin and Richardson, 2007

Hu et al., 2004



EFFECTS OF SPAWNING HABITAT ON OCEAN TRIAD

MESO-AMERICAN REEF

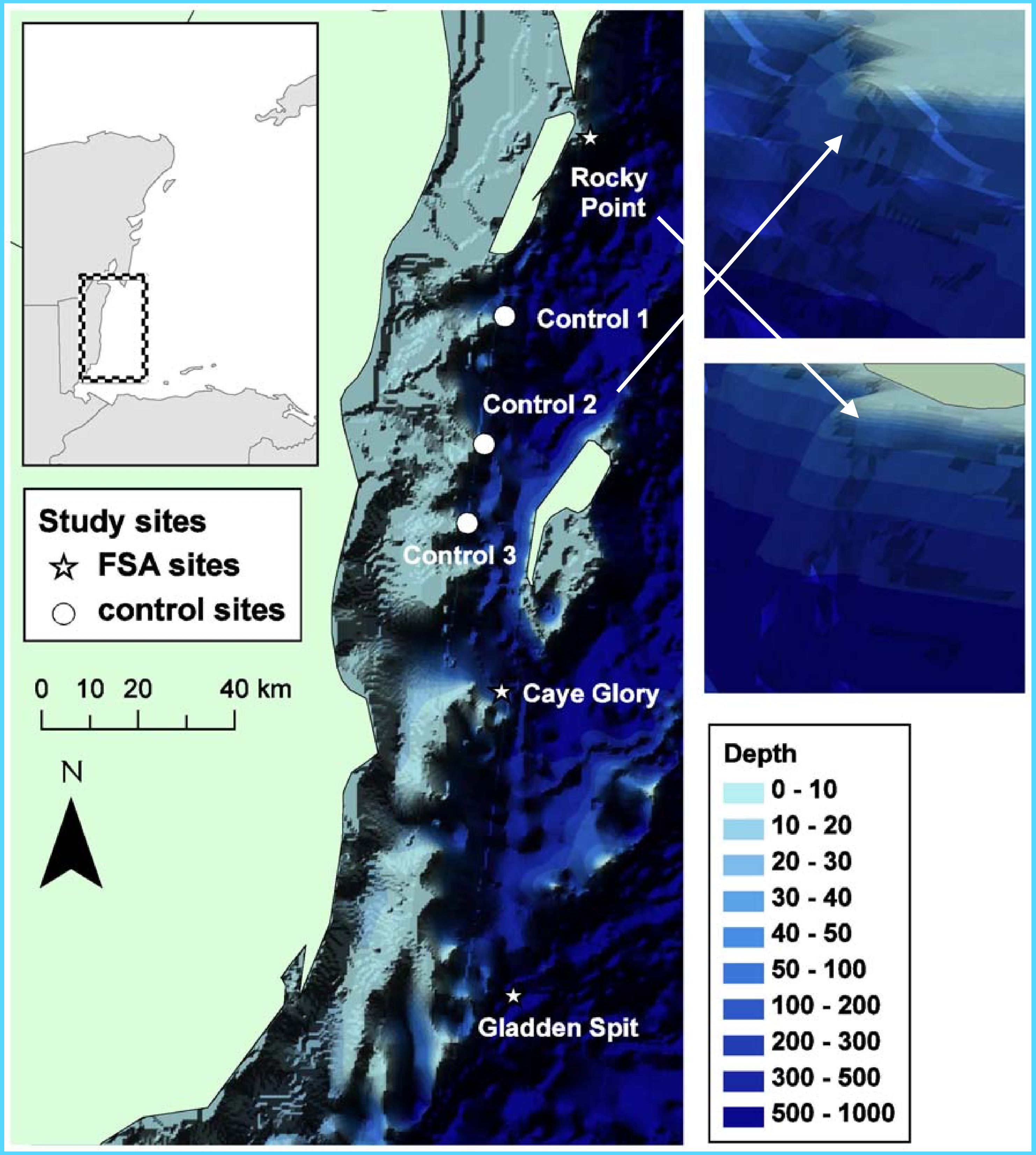
- ROMS simulation

  400m/32 levels

- Difference between spawning and non spawning cape:

  $Re_f = Hc/C_D D$

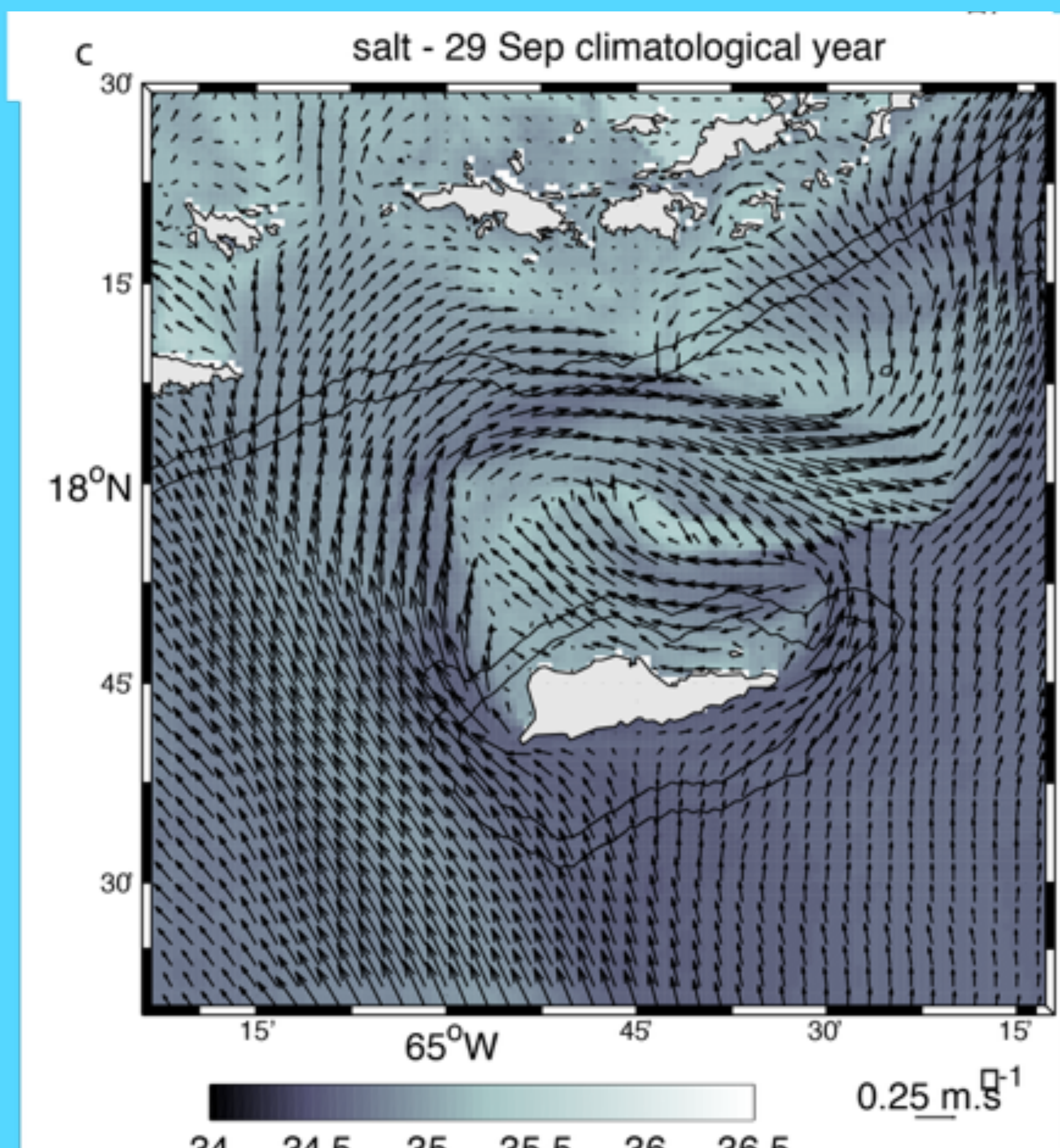
  $Bu = (R_d/D)^2$

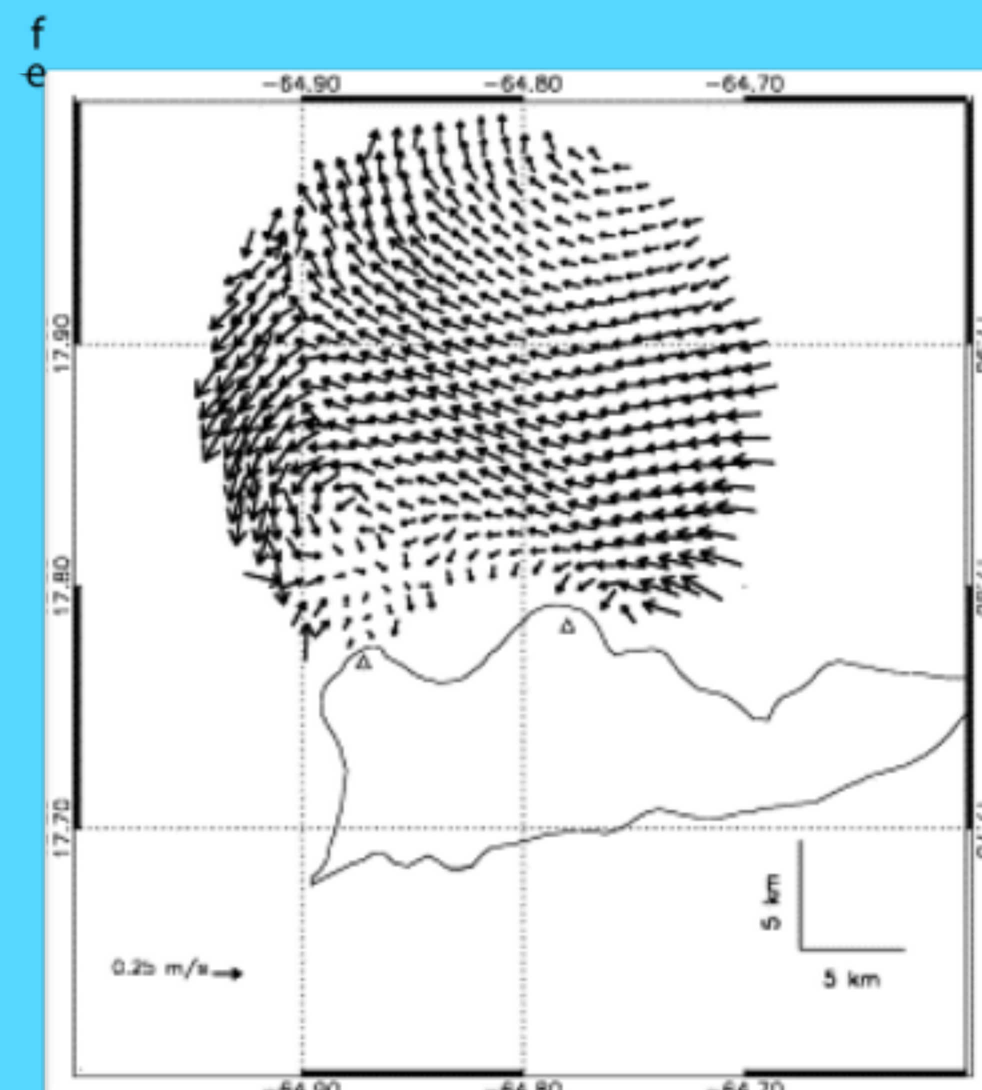


Karnauskas et al., 2011

Caribbean Island wake effect

ROMS SIMULATION:1KM/25 LEVELS

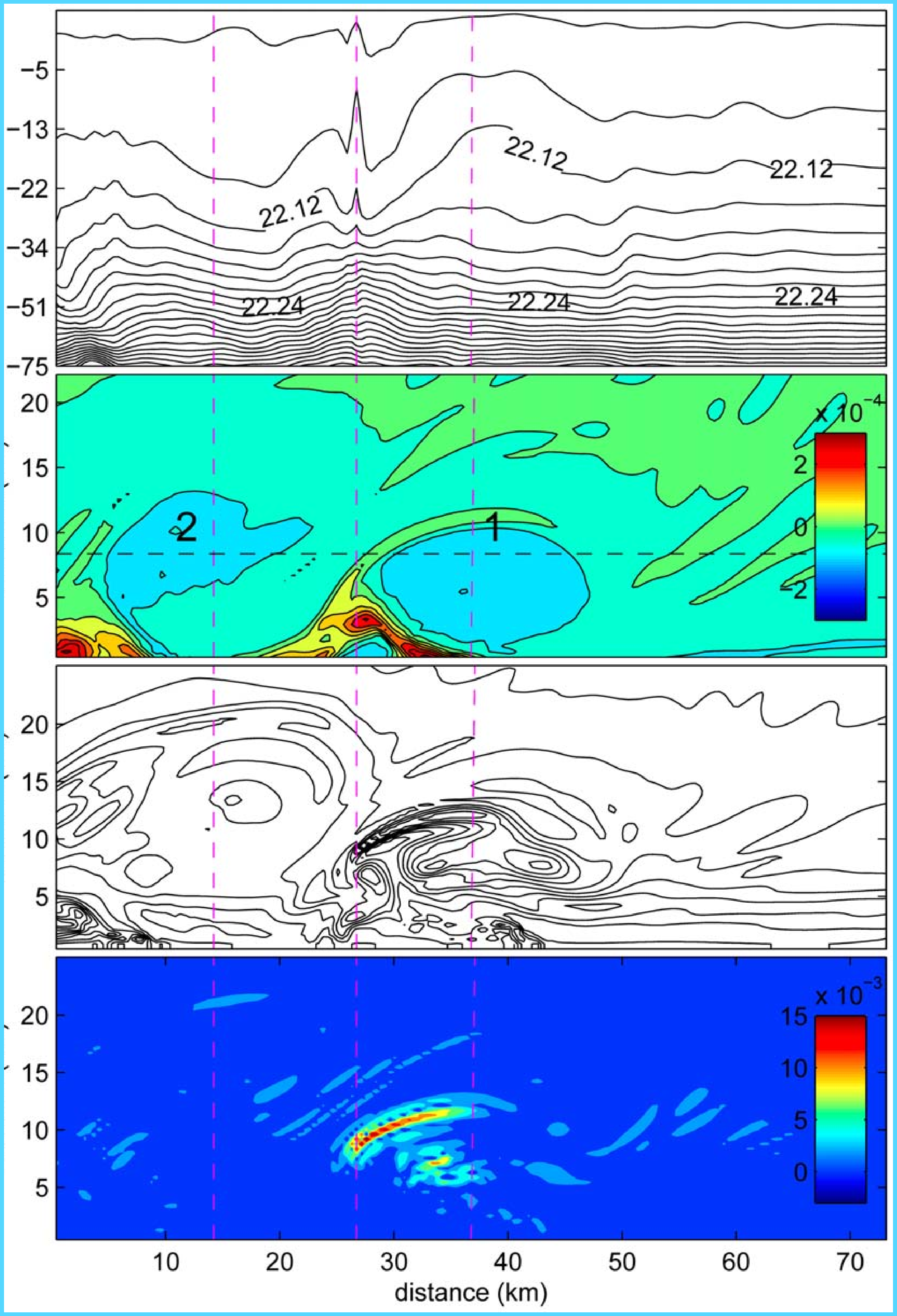




Cherubin and Garavelli, 2015

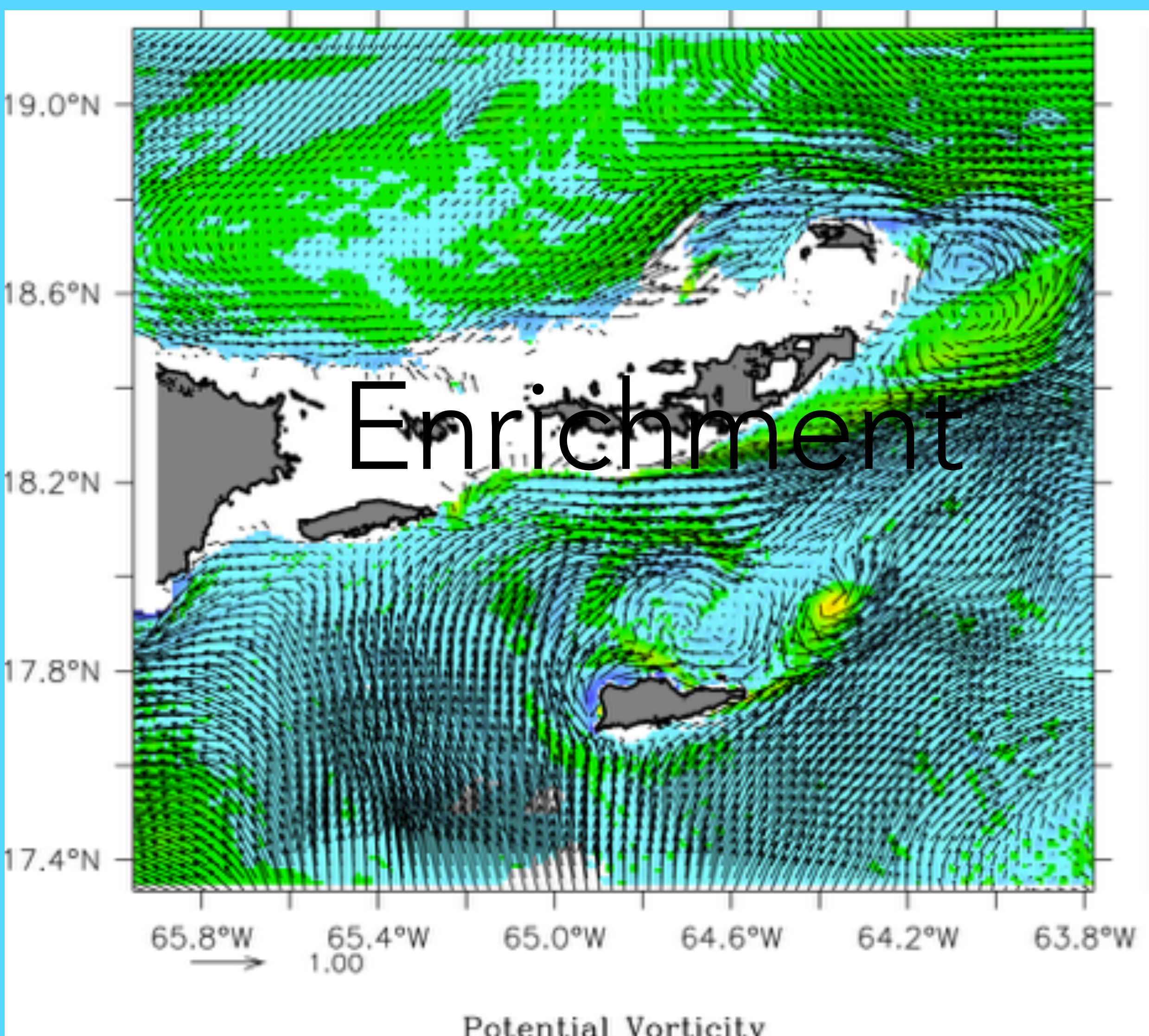
MESO-AMERICAN REEF

Enrichment

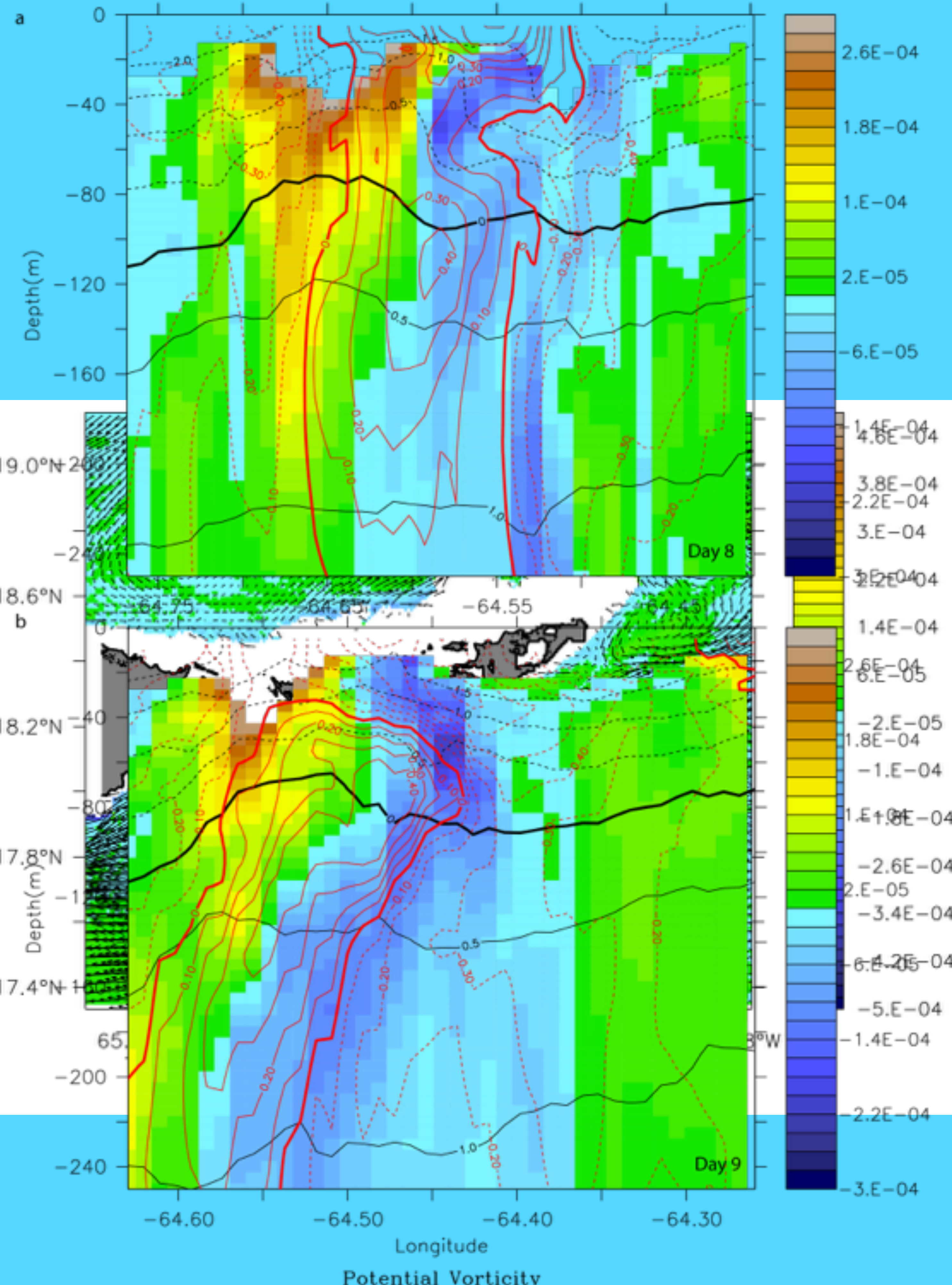


Karnauskas et al., 2011

CARIBBEAN ISLAND WAKE



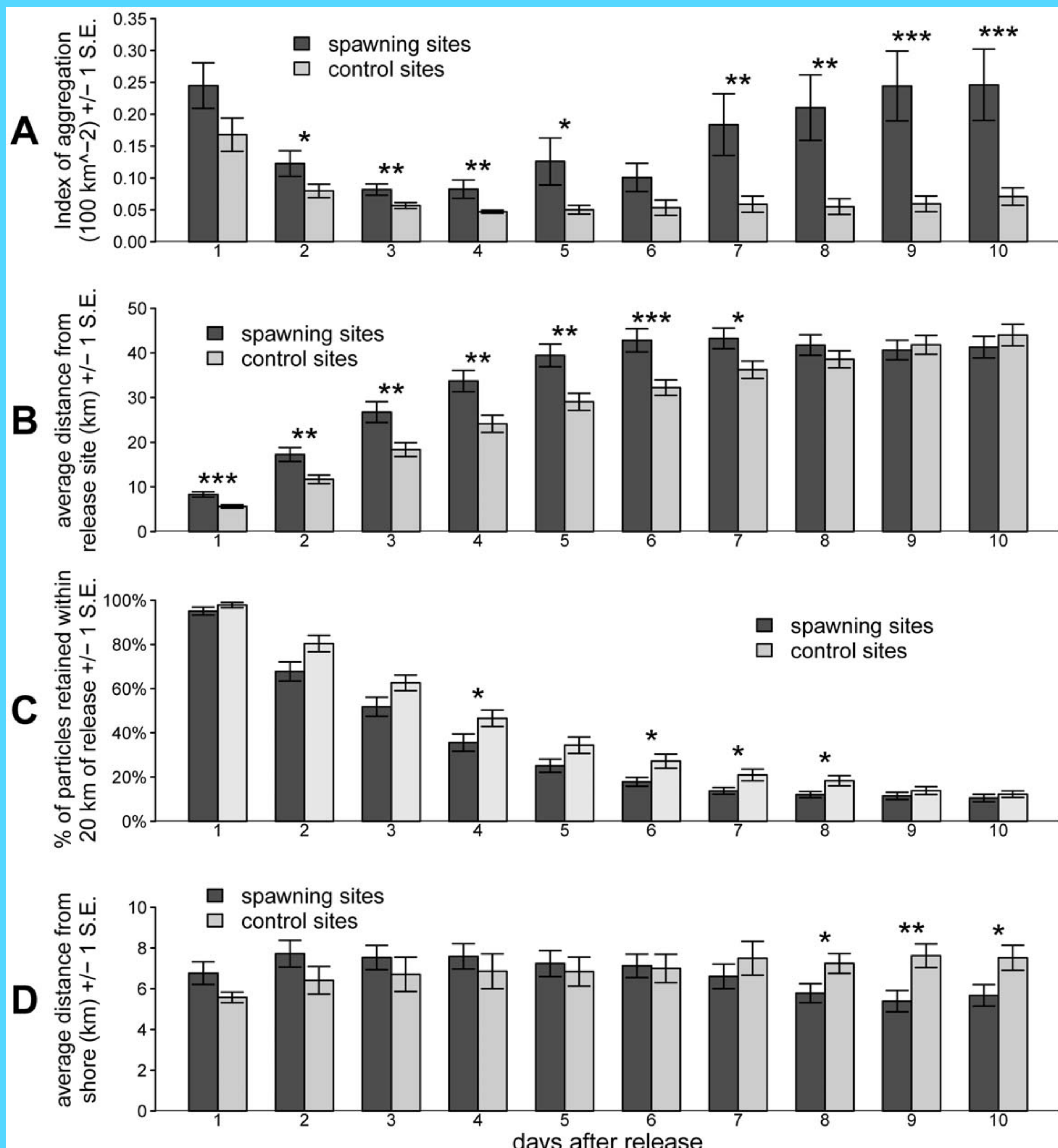
Enrichment



Cherubin and Garavelli, 2015

MESO-AMERICAN REEF

PARTICLES RETENTION DIFFERENCE



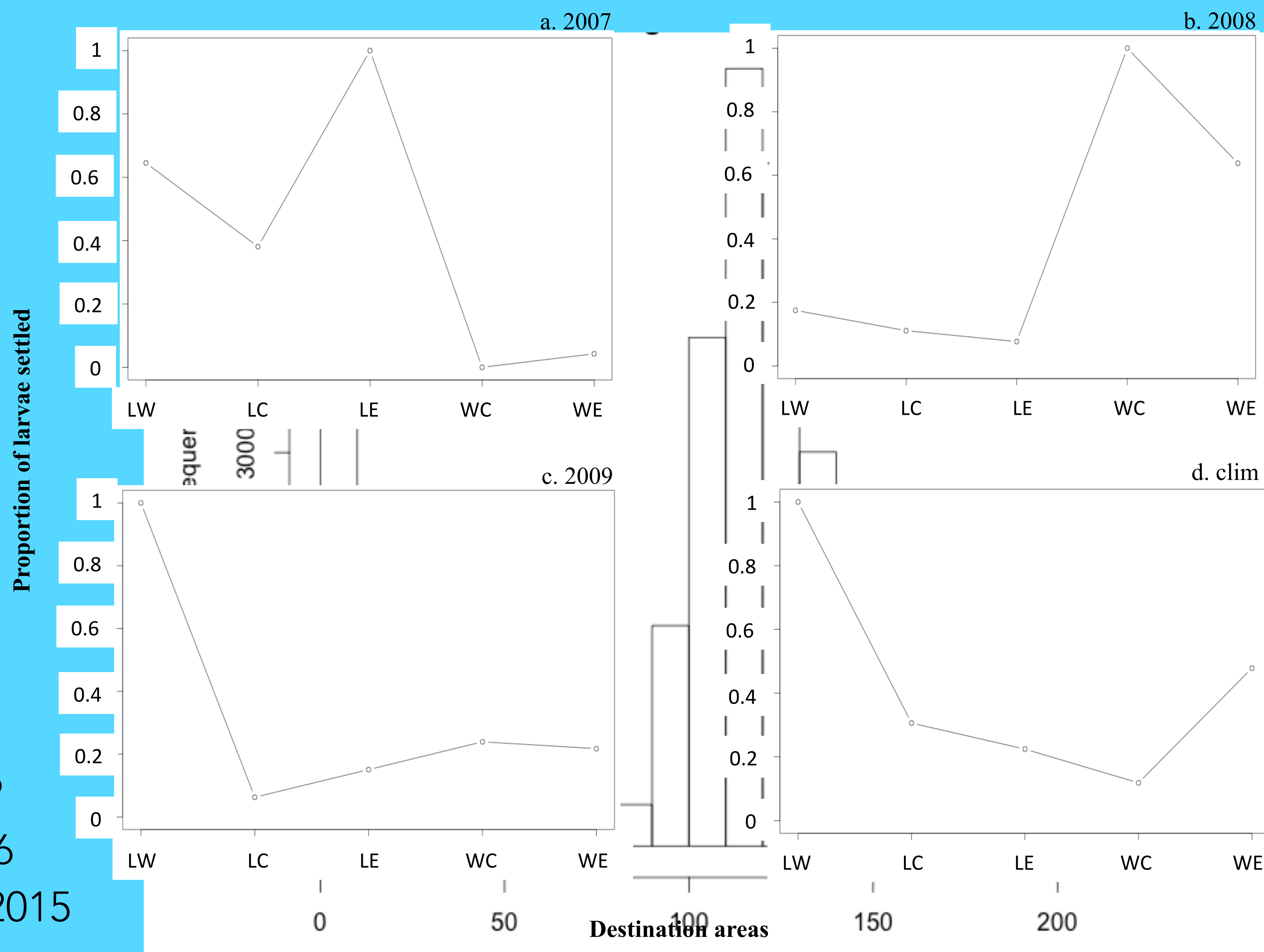
Concentration

Retention

Karnauskas et al., 2011

CARIBBEAN ISLAND WAKE

Concentration
Retention



Swearer et al., 1999
Hamilton et al., 2006
Cherubin & Garavelli, 2015

DISCUSSION

MESO-AMERICAN REEF

MOST SIGNIFICANT CAPE PARAMETER DIFFERENCE

Site	*max depth (m)*	*mean width (m)*	*Re_f*	*Ro*	*R_d (km)*	*Bu*
Rocky Point FSA	500	3,000	55.6	0.8	17.1	32.6
Caye Glory FSA	500	7,000	23.8	0.4	17.1	6.0
Gladden Spit FSA	500	8,000	20.8	0.3	17.1	4.6
Control 1	500	3,750	44.4	0.7	17.1	20.9
Control 2	450	4,500	33.3	0.6	17.1	14.5
Control 3	250	3,750	22.2	0.7	17.1	20.9

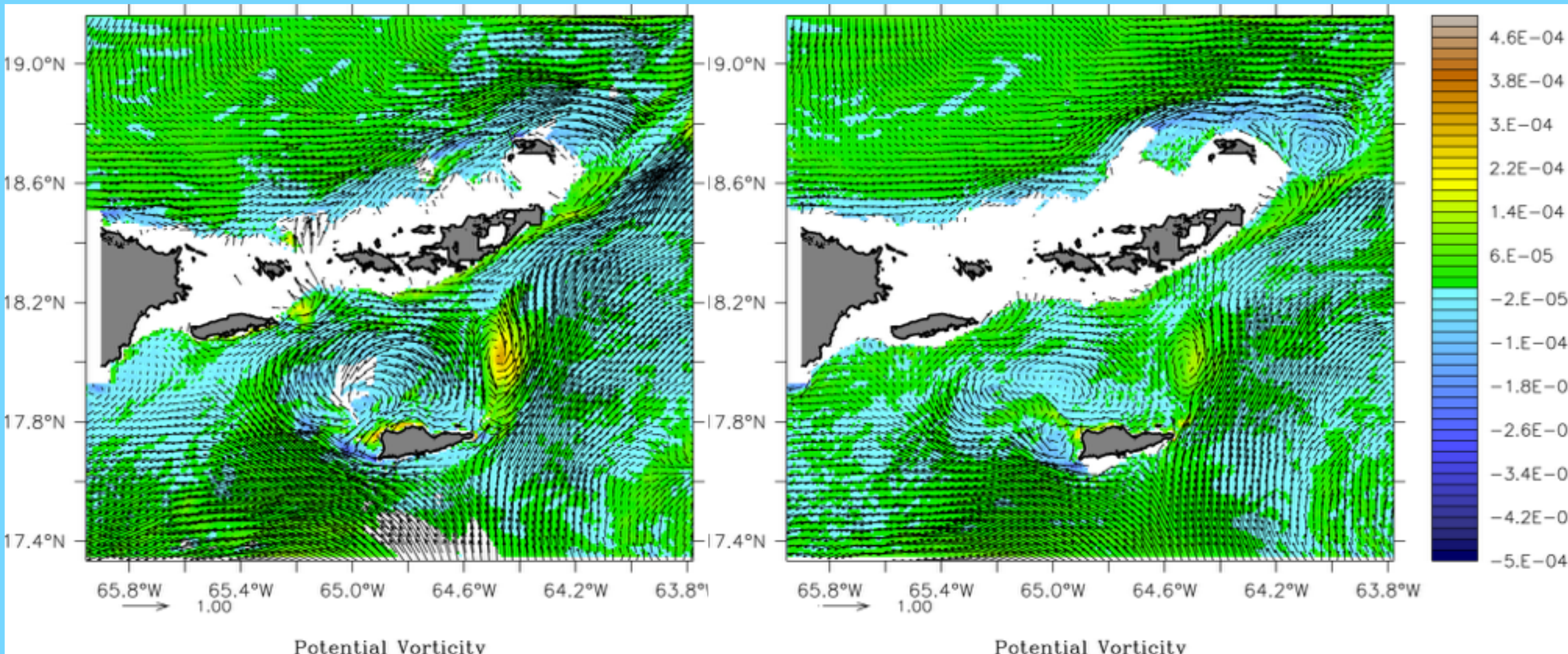
Karnauskas et al., 2011

eddy attribute	*mean value FSA sites*	*mean value control sites*	*site effect Pr(>F)*	*control vs. spawning site Pr(>F)*
diameter (km)	18.5	15.3	0.45	0.20
longevity (days)	5.9	6.3	0.46	0.61
linear velocity (km/d)	13.3	13.2	0.55	0.95
Δ potential vorticity (m^{-1} s^{-1})	5e-04	3e-04	*0.03	**0.002
frequency (d. between formation)	4.2	5.4	0.50	0.46

Most significant difference between capes: eddy potential vorticity anomaly

CRITICAL ROLE OF TOPOGRAPHY

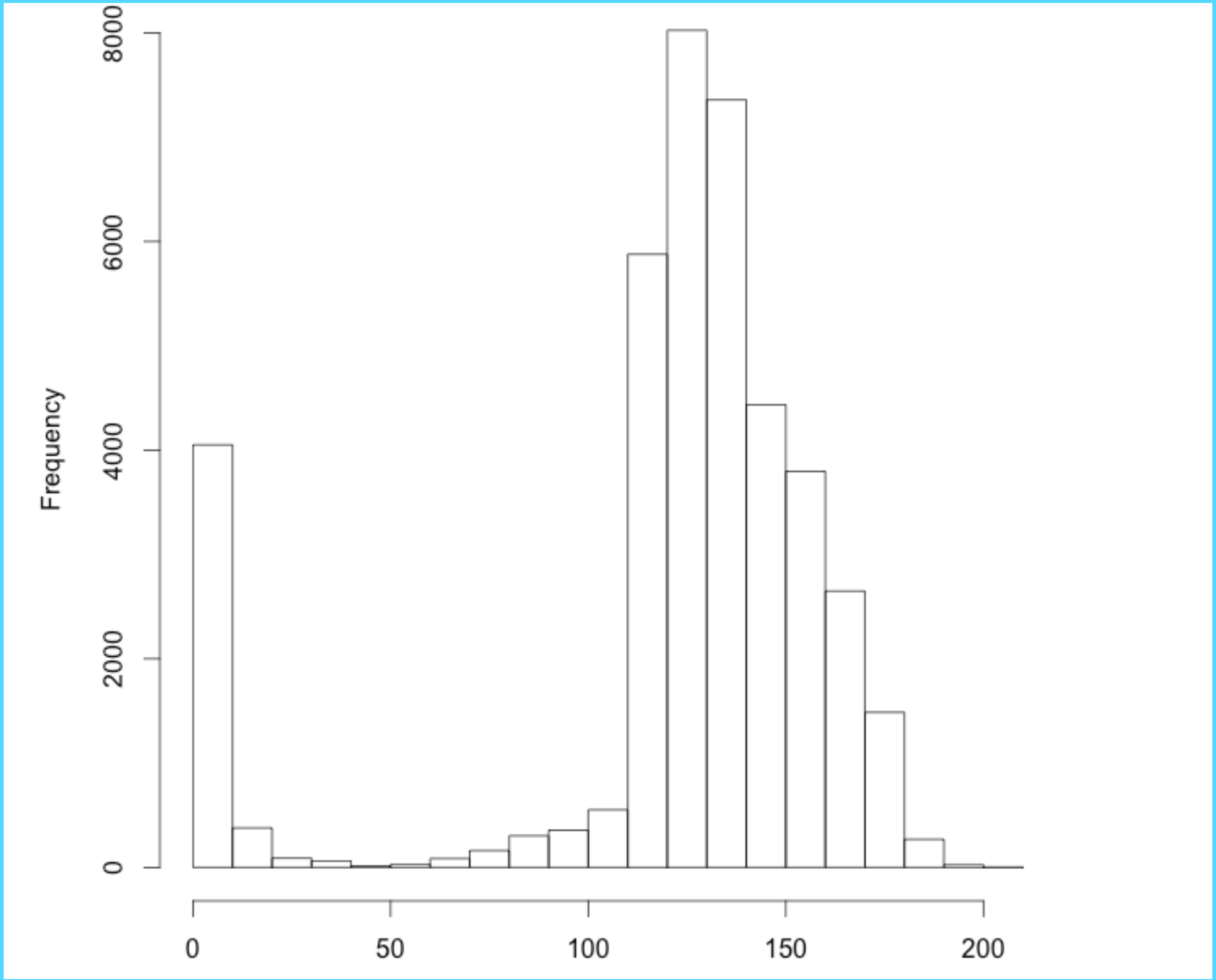
- Meso-American Reef
  - Is the form drag the significant factor that controls the flow regimes at the spawning capes? (Magaldi et al., 2008)
  - Could larger form drag produce larger vorticity in shedding eddies?



Is dilution of extreme vorticity values by mixing leads to coherent anticyclonic vortex? (Molemaker et al., 2015)

CARIBBEAN ISLAND WAKE: INCREASED FORM DRAG EFFECT

REDUCED LOCAL RETENTION



CRITICAL ROLE OF TOPOGRAPHY

- Caribbean island wake
  - Angle of incidence of the large scale flow controls the wake type, hence the retention and concentration effects
  - Main control: form drag on the flow

CONCLUSIONS

ECOLOGICAL CONSTRAINTS OF THE SPAWNING HABITAT

- Marine organisms have evolved toward the same reproduction goal but have adapted to their local environment in order to maximize their survival although they rely on the same topographic control which seems to be the main constraint.

- This study shows the subtle role of topographic effects on flow perturbations: form drag of spawning sites

  - Increases eddy strength and coherency => Controls the Lagrangian properties of the flow hence the strength of the Ocean Triad interplay

ECOLOGICAL CONSTRAINTS OF THE SPAWNING HABITAT

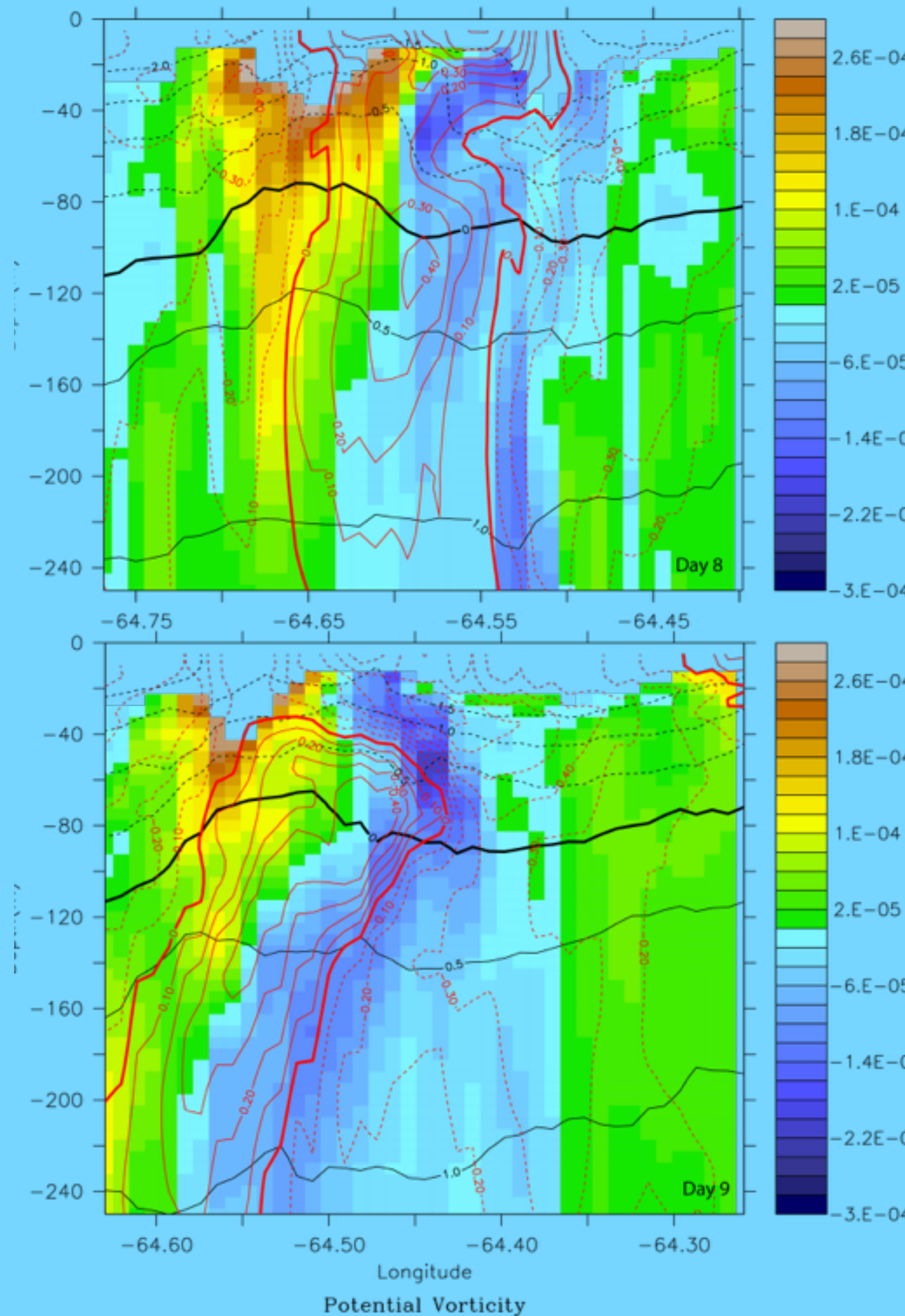
- This type of spawning habitats further warrants:
  - consistent seasonal variability because of consistent large scale flow seasonality
  - spawning habitat system resiliency because of topographic effects consistency, hence survival
- Do these spawning habitats have enough resiliency in the face global change to remain spawning habitats?

ACKNOWLEDGMENTS

- Collaborators: L. Garavelli, M. Karnauskas, C. Paris
- Support: USGS, NSF, Conservation International, Oak Foundation

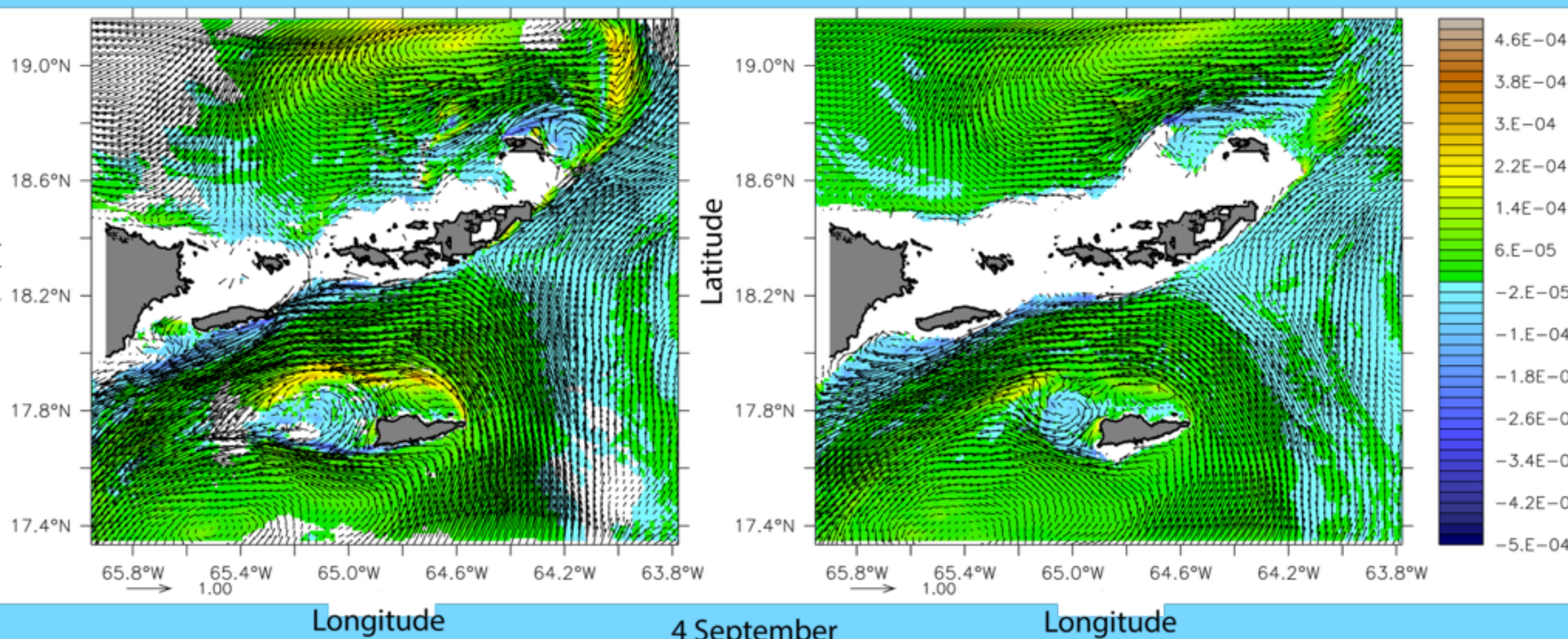
TOPOGRAPHY DRIVEN ISLAND WAKE

- Angle of incident flow controls the wake type and eddy strength
- At the island scale lower form drag enhances local retention
- Promotes concentration and enrichment



TOPOGRAPHY EFFECT

CYCLONIC WAKE



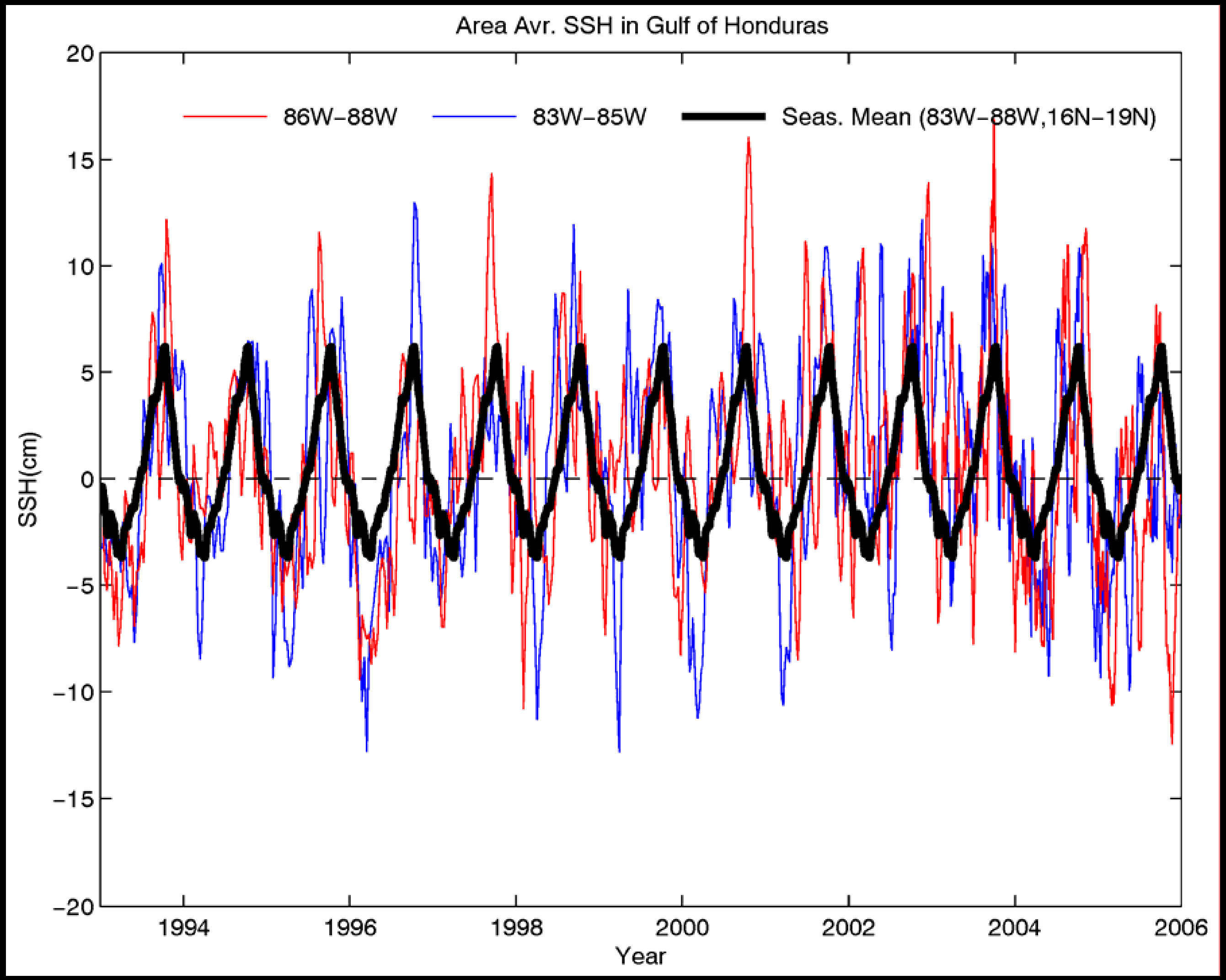
4 September

SPAWNING HABITAT

CONSISTENCY OF SOUTHWARD FLOW DURING SPAWNING SEASON

OR

SPAWNING SEASON WAS SELECTED AT THIS TIME BECAUSE OF THE CURRENT CONSISTENCY



Heyman et al., 2007

Experiment set-up

ROMS - 400M/32 LEVELS

Karnauskas et al., 2011