Simulated larval dispersal of snapper-grouper species to evaluate the efficacy of spawning Special Management Zones

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SAFMC System Management Plan Workgroup meeting
November 15, 2023

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Science. Education. Community.

Spawning Special Management Zones (2017 for 10yrs*)

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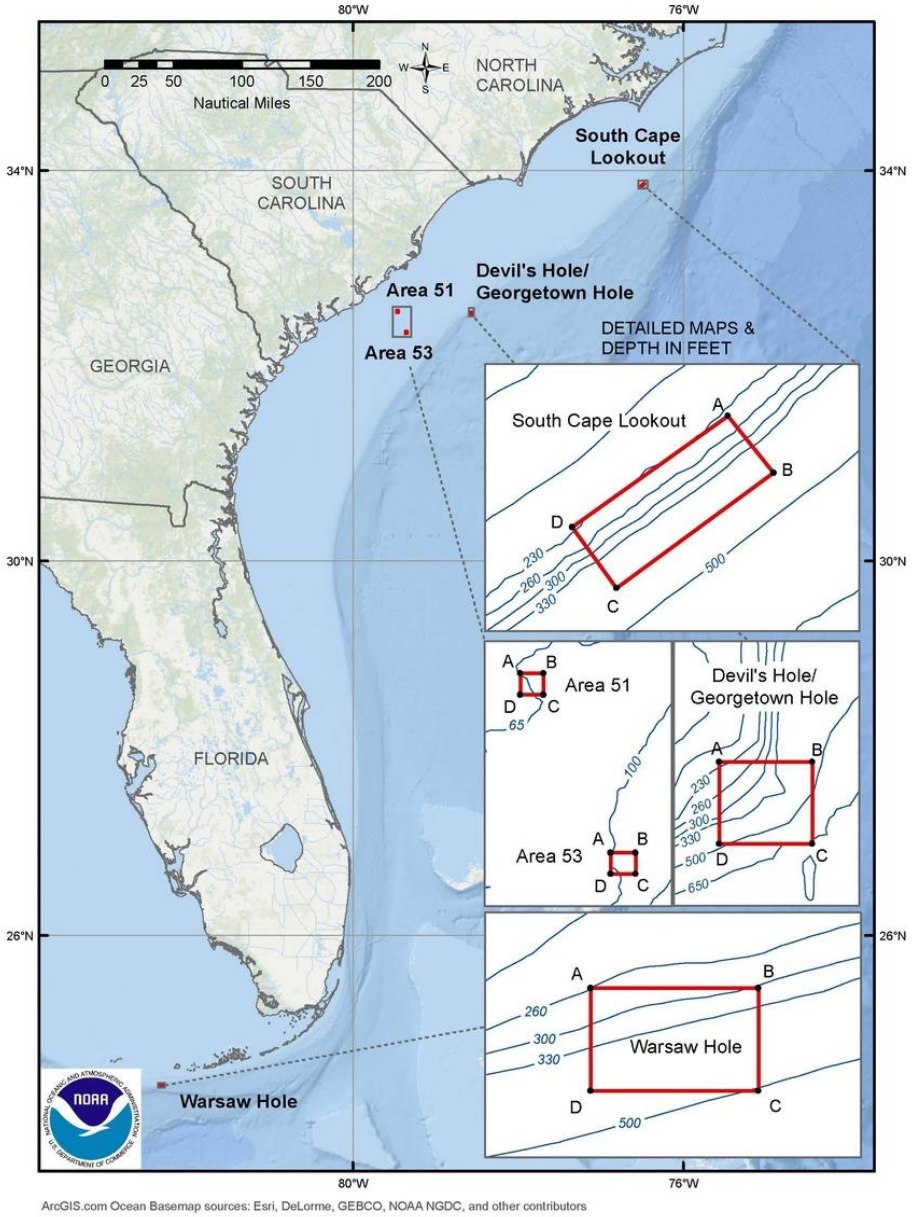
sSMZ	Location	Size (sq km)
Area 51*	SC	7.8
Area 53*	SC	7.8
Devil's Hole	SC	7.9
South Cape Lookout	NC	13.2
Warsaw Hole	FL	9.3

Goal: increase snapper-grouper recruitment to the U.S. South Atlantic.

Fishing for 59 species in the snapper-grouper complex is prohibited year-round.

Locations are thought to be important multi-species spawning sites.



Three main questions:

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1) Settlement dynamics of larvae spawned in each sSMZ?
2) How do sSMZs compare to other spawning areas in the Atlantic?
3) How much recruitment to the Atlantic comes from the sSMZs?

Four focal species:

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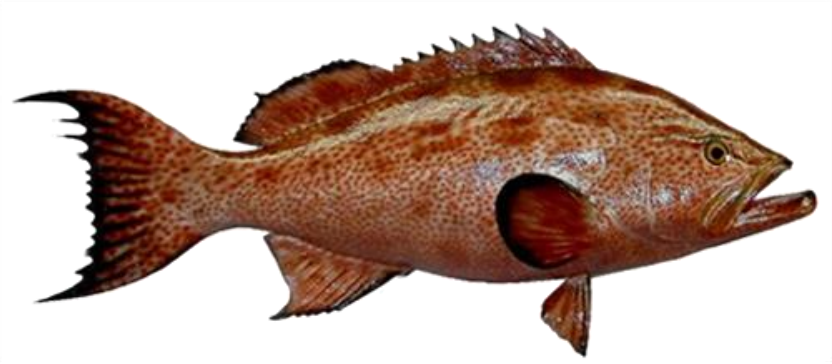
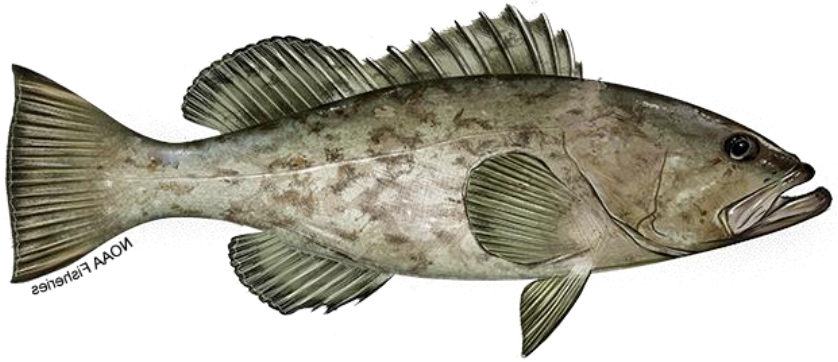
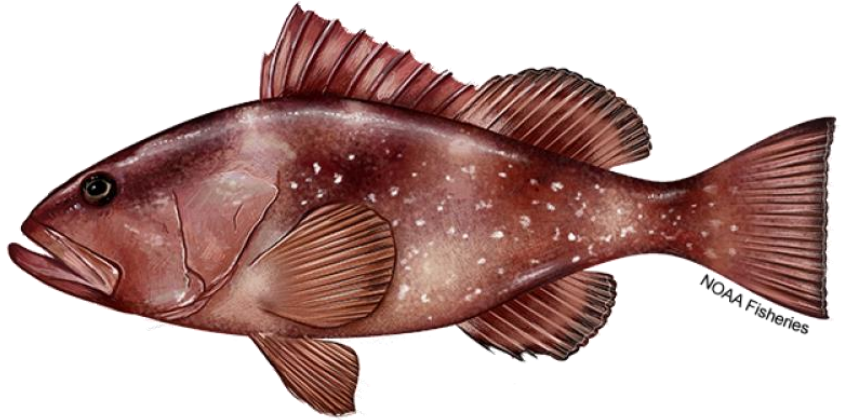
Scamp grouper
Mycteroperca phenax



Red snapper
Lutjanus campechanus



Gag grouper
Mycteroperca microlepis



Red grouper
Epinephelus morio

Connectivity Modeling System (CMS)

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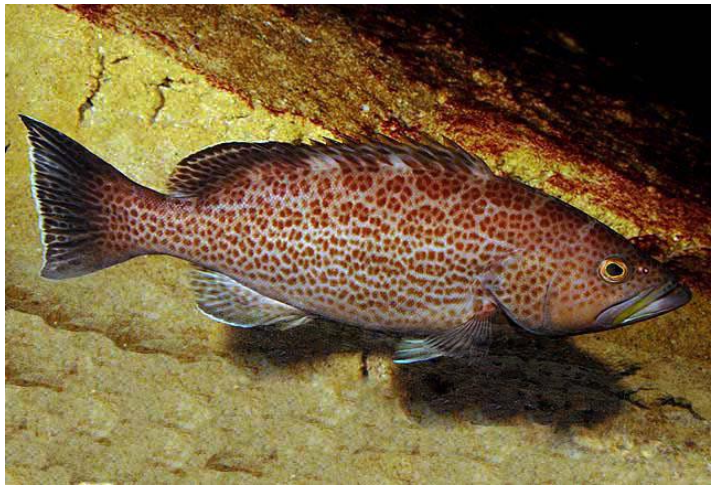
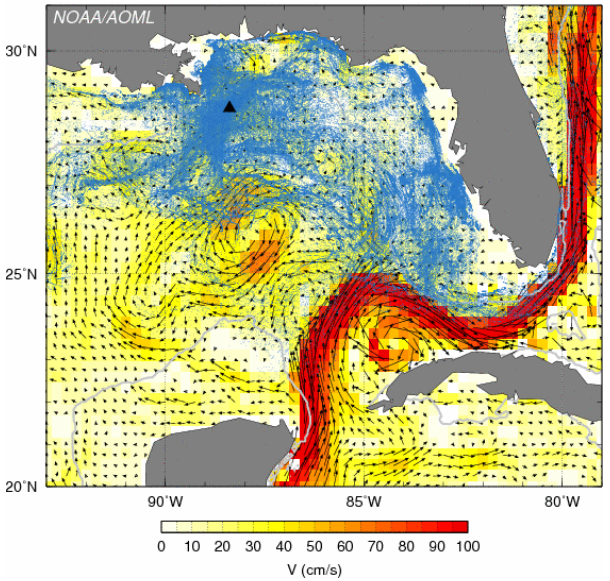
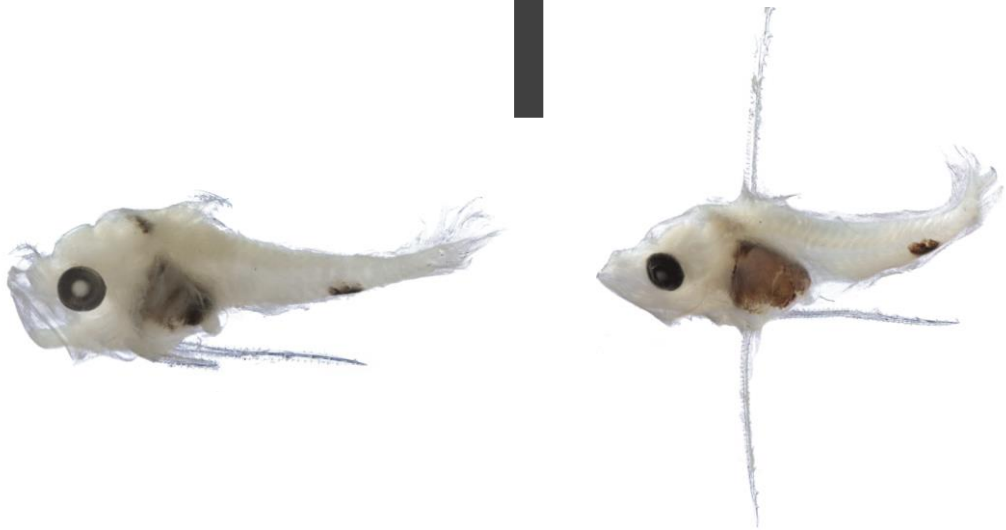


Paris et al., 2013

Connectivity Modeling System





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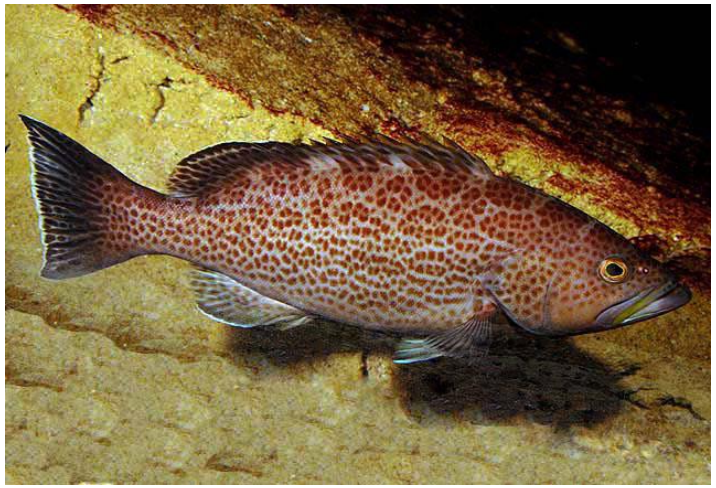
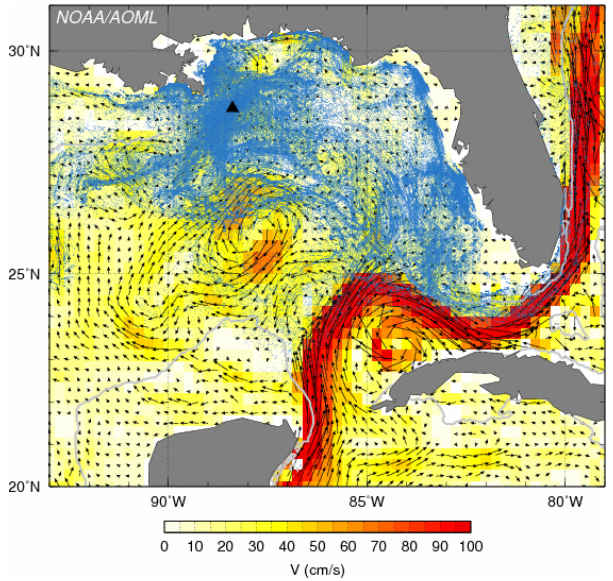
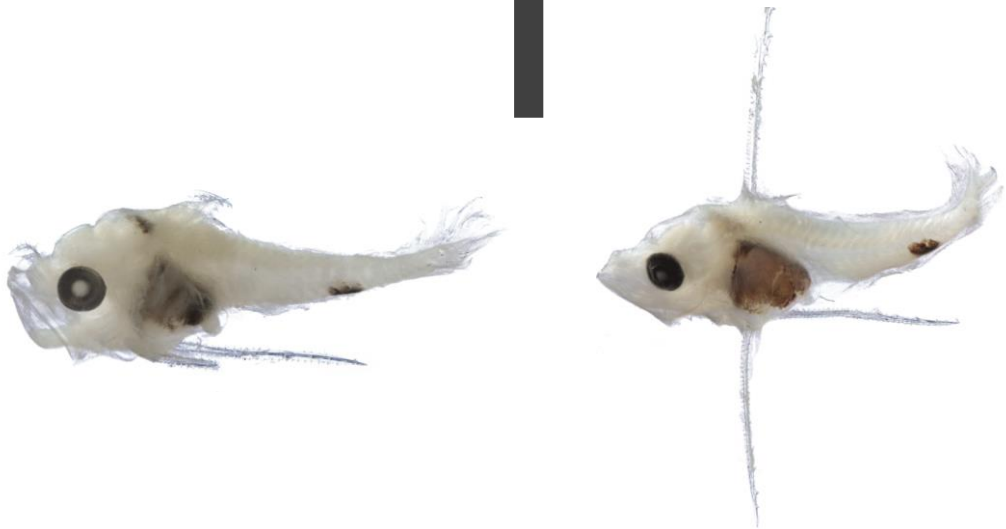


Paris et al., 2013





Regional Navy Coastal Ocean Model

1/30° resolution (<4km)
2014, 2020-2022

Connectivity Modeling System (CMS)

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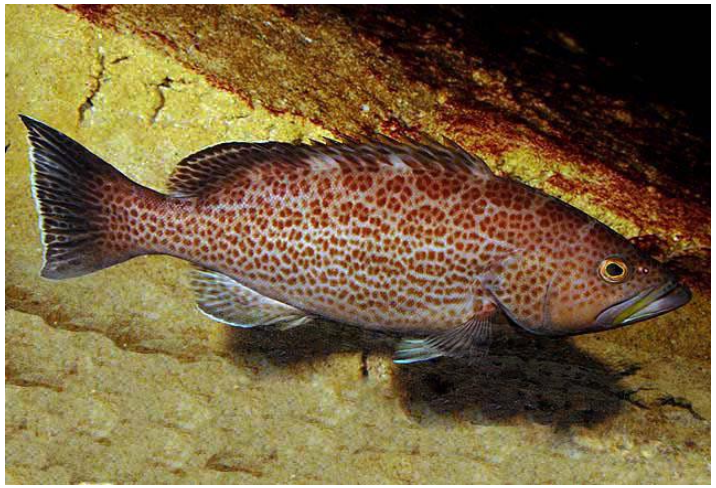

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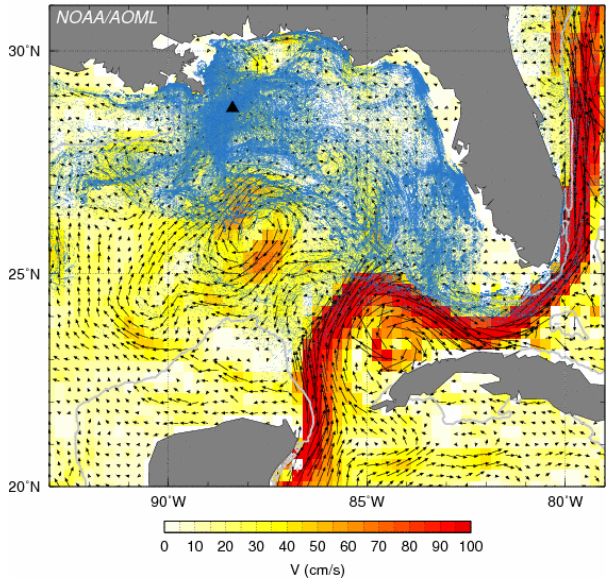

	Gag	Red Grouper	Red Snapper	Scamp
Bottom Depth (m)	44-133	6-114	7-140	14-278
Spawning Season	Feb-April	Jan-June	April-Sept	March-May
PLD (days)	33-52 days	33-52 days	26-30 days	33-52 days
Settlement Criteria	<30m	<30m	10-64m	<30m
Ontogenetic Vertical	Yes	Yes	Yes	Yes

For Each Species:

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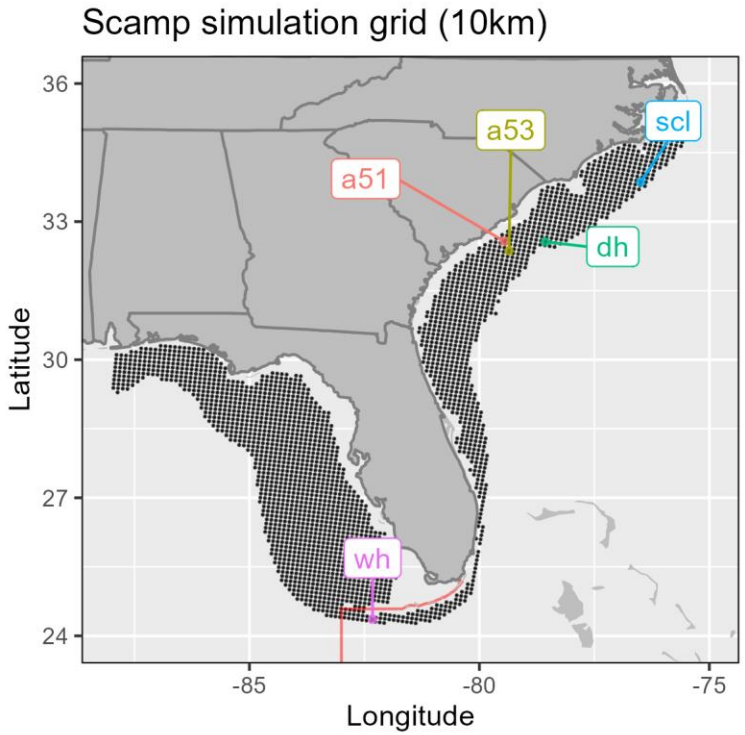
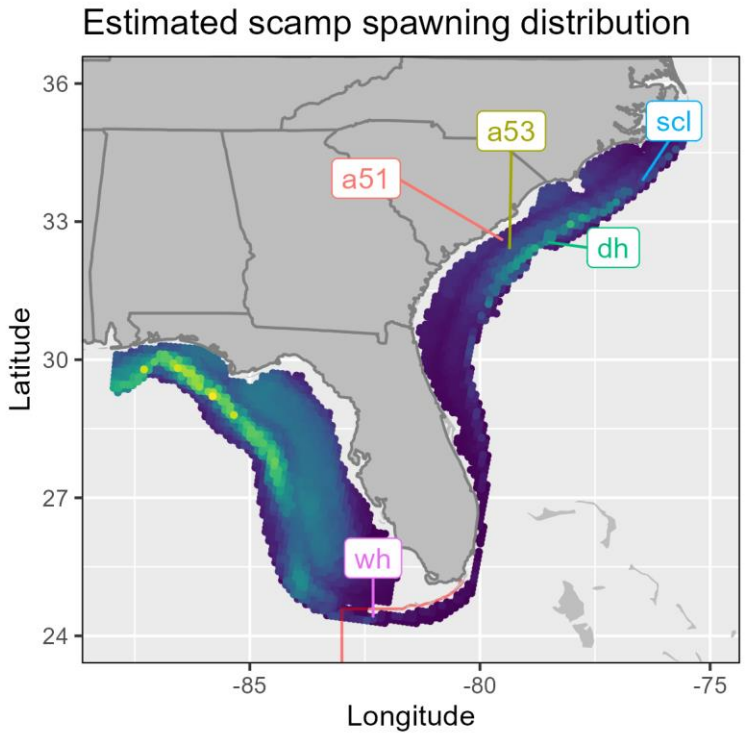
A) Simulated uniform spawning from grid locations (10km) and sSMZs

B) Also modeled the expected spatial distribution of spawning





3 Questions:

1) Settlement dynamics of larvae spawned in each sSMZ?
2) How do sSMZs compare to other spawning areas in the Atlantic?
3) How much recruitment to the Atlantic comes from the sSMZs?

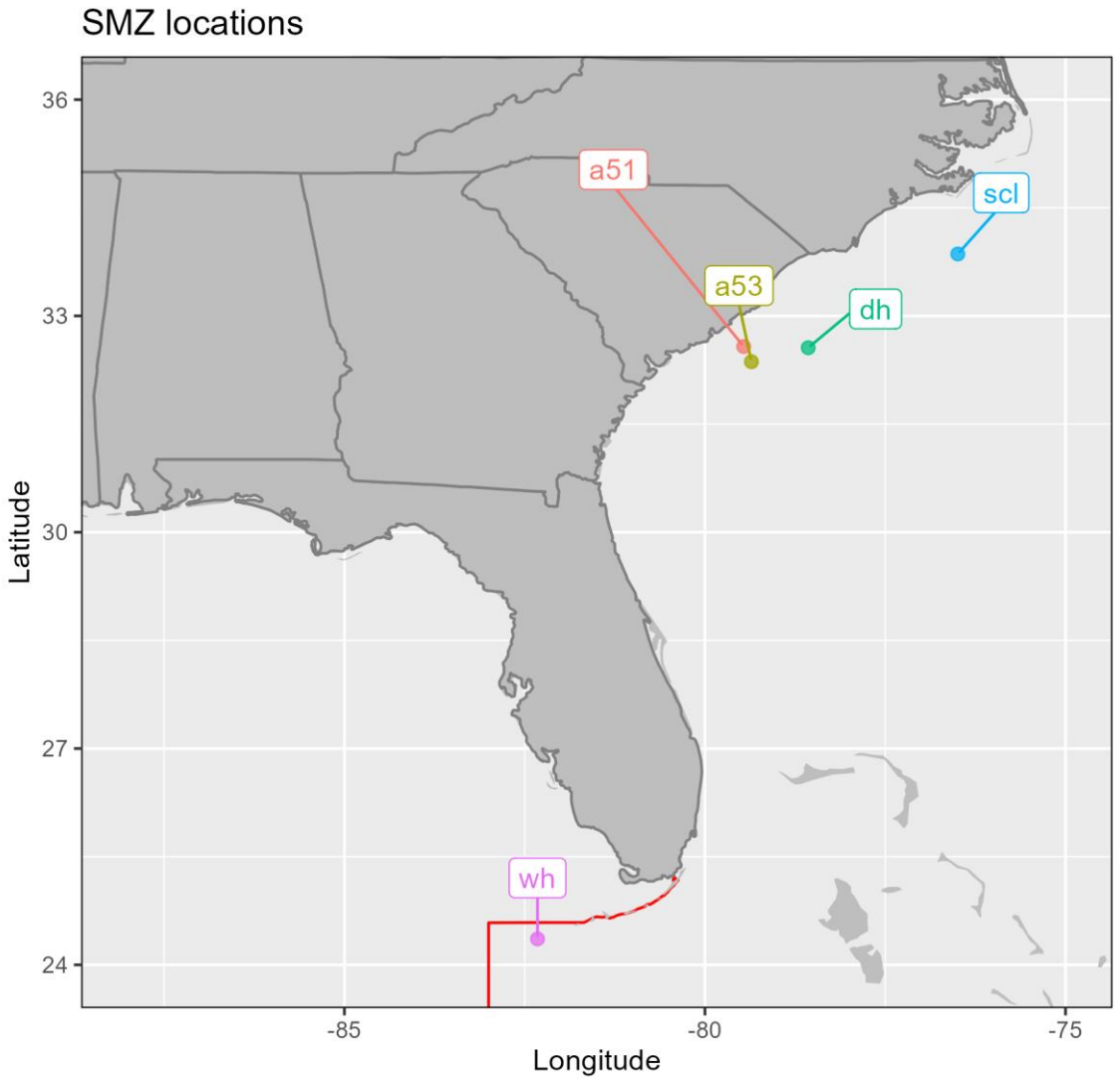
U.S. HWY 1 approximates the boundary between the GOM and ATL

Results

1) Settlement dynamics of larvae spawned in each sSMZ?

No spatial component of spawning
Just oceanography and larval traits/behavior

A. How likely are they to settle?
B. Where do they end up?



Scamp – Area 51 sSMZ

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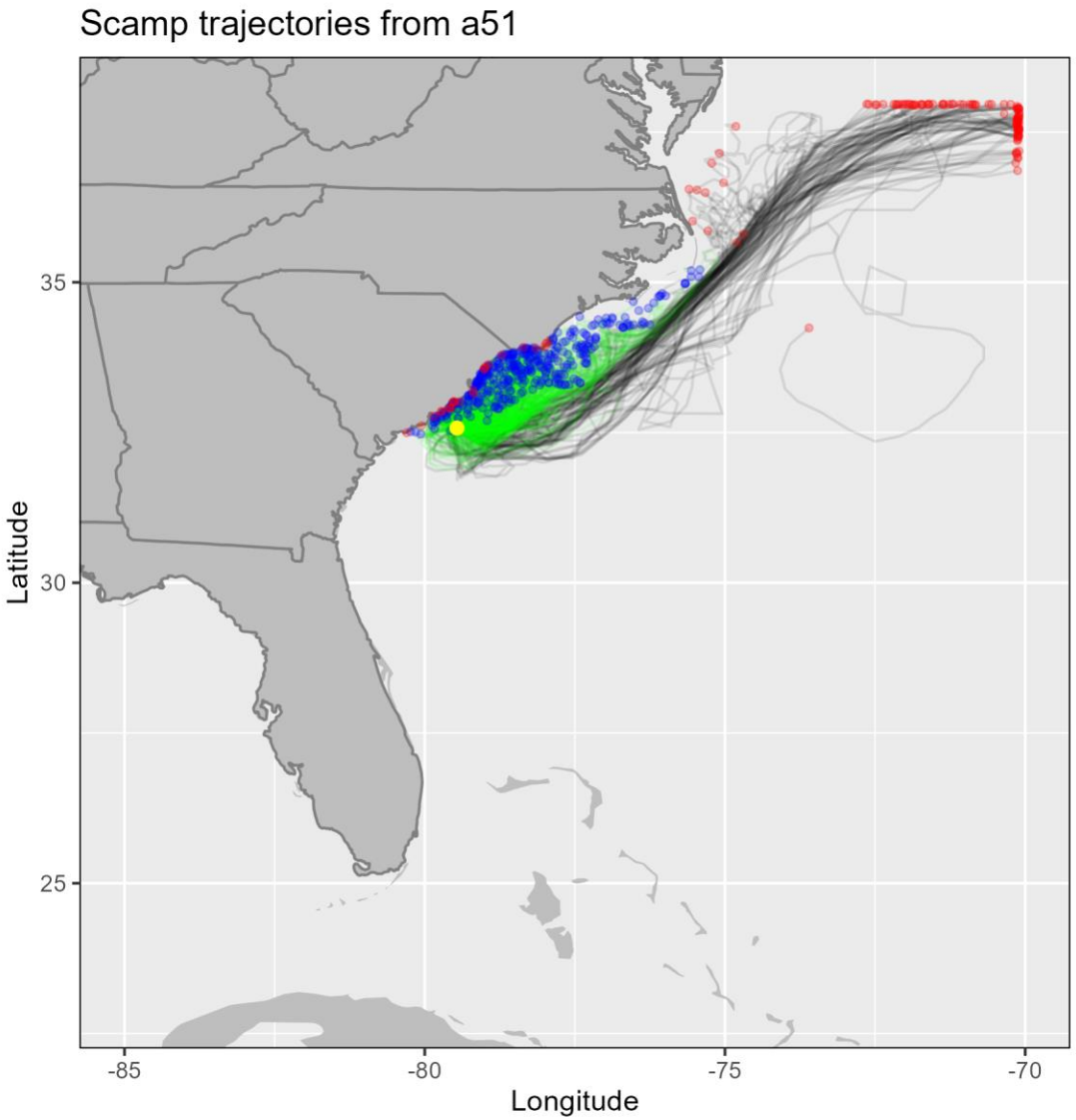
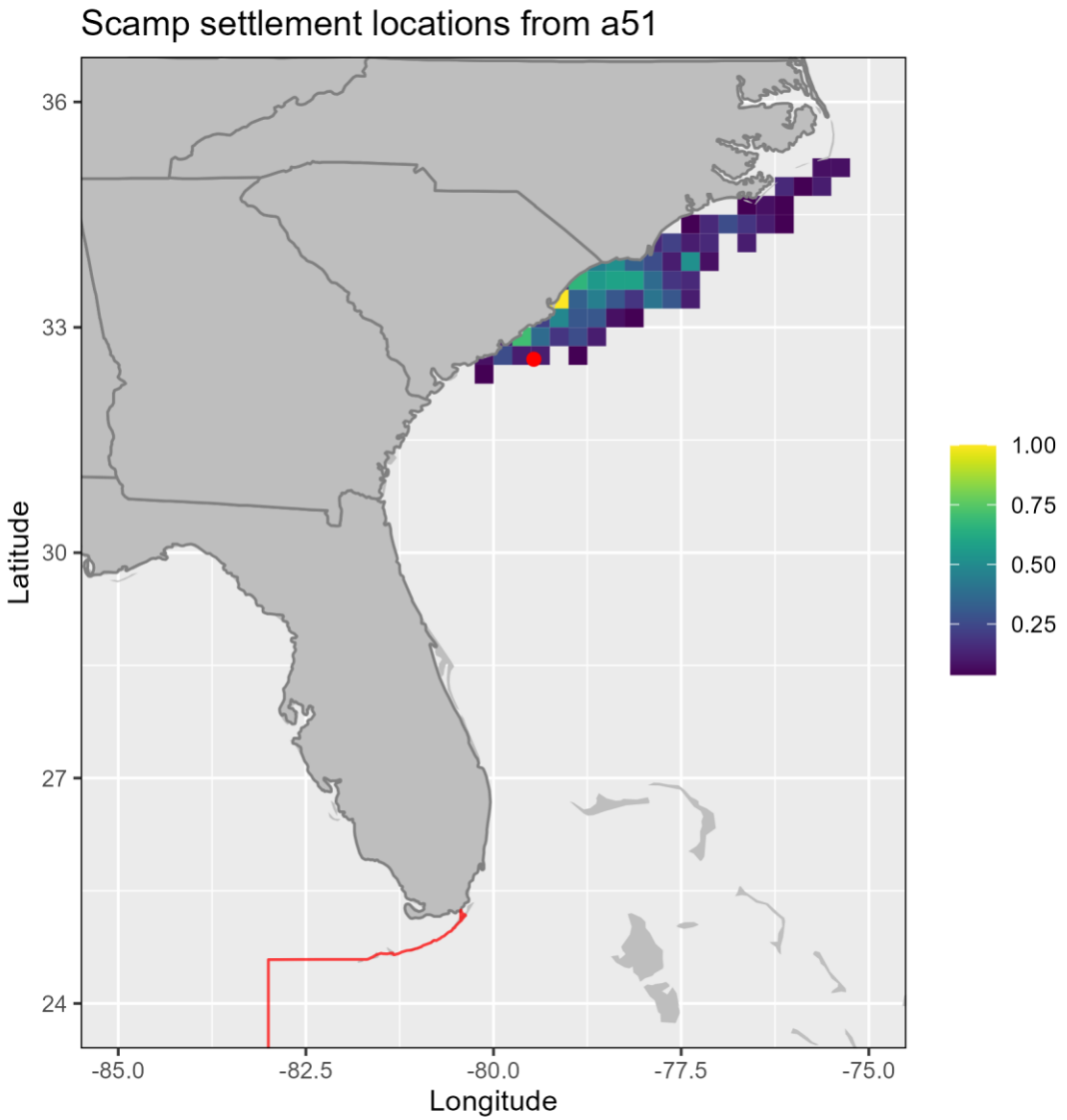
75% settled

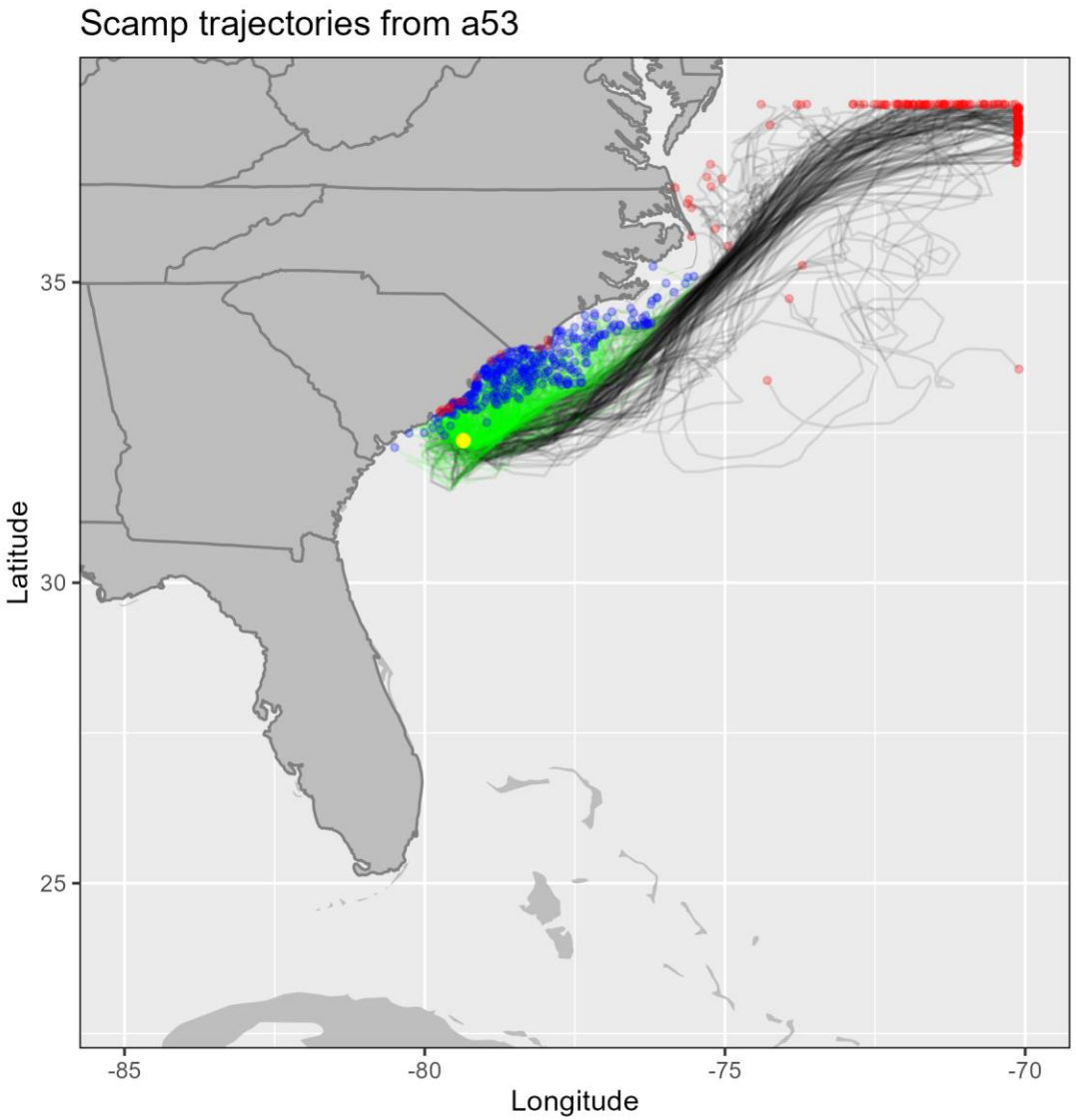


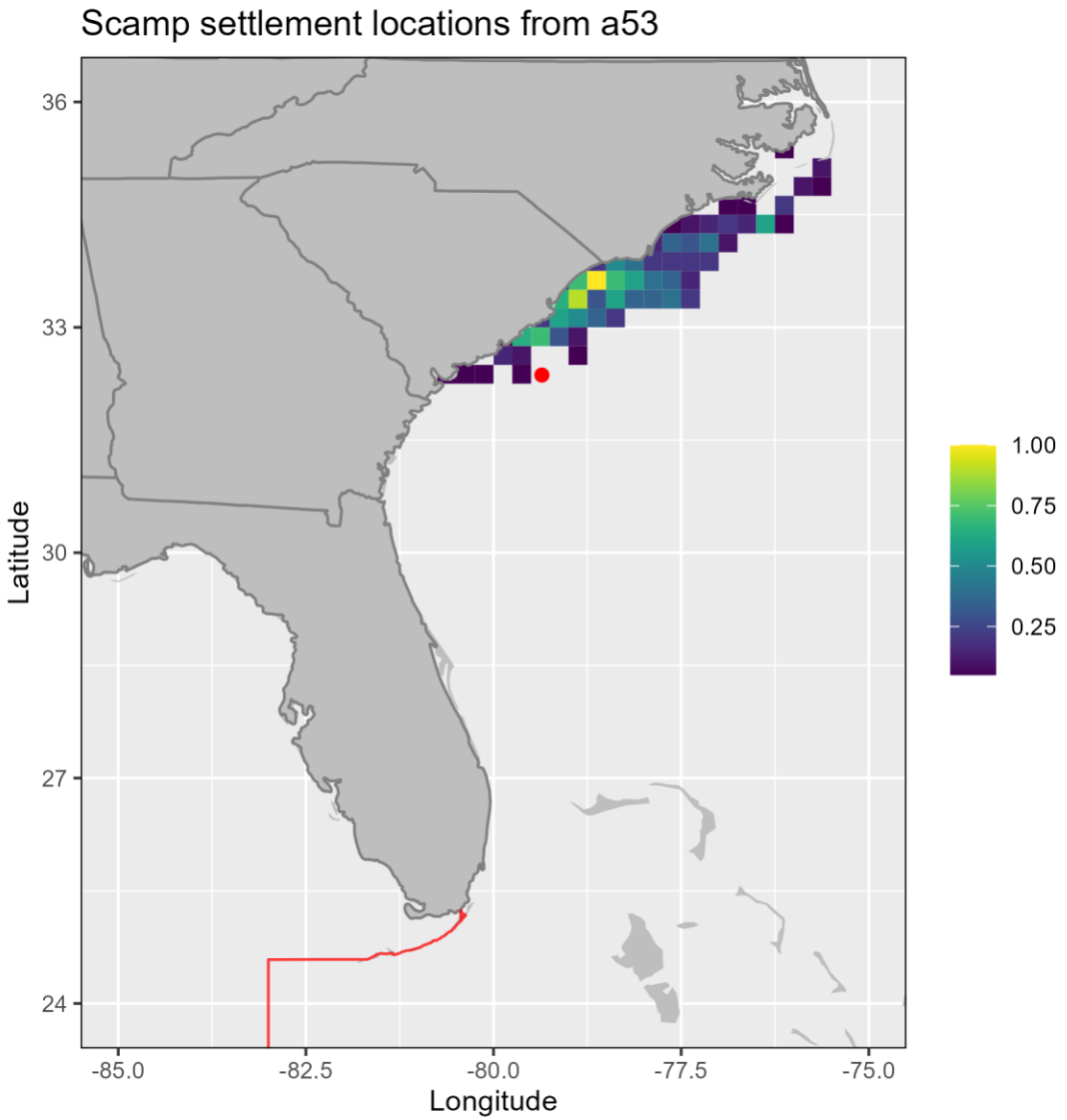


Scamp – Area 53 sSMZ

Gulf of Maine Research Institute

66% settled





Scamp – Devil's Hole sSMZ

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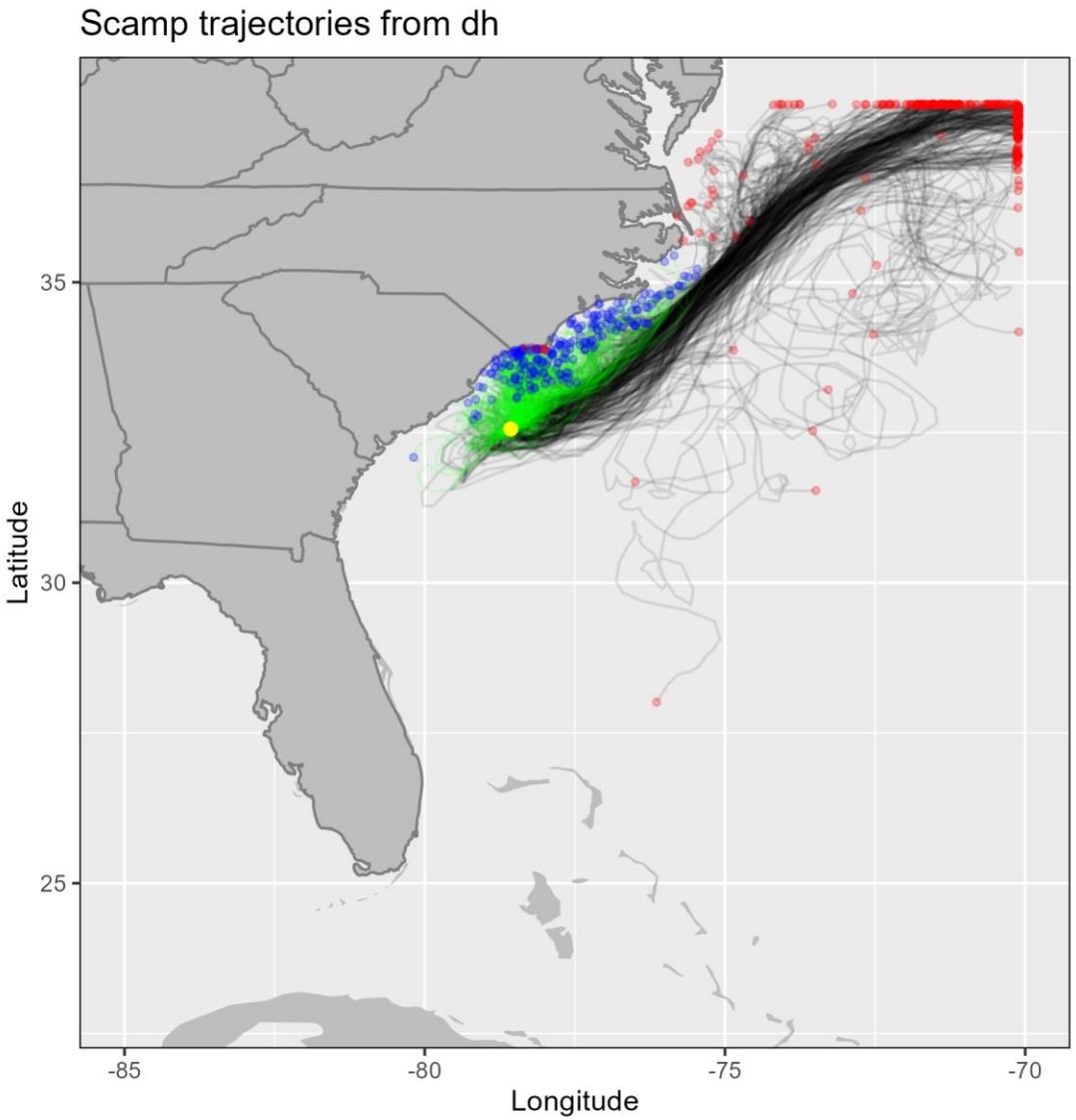
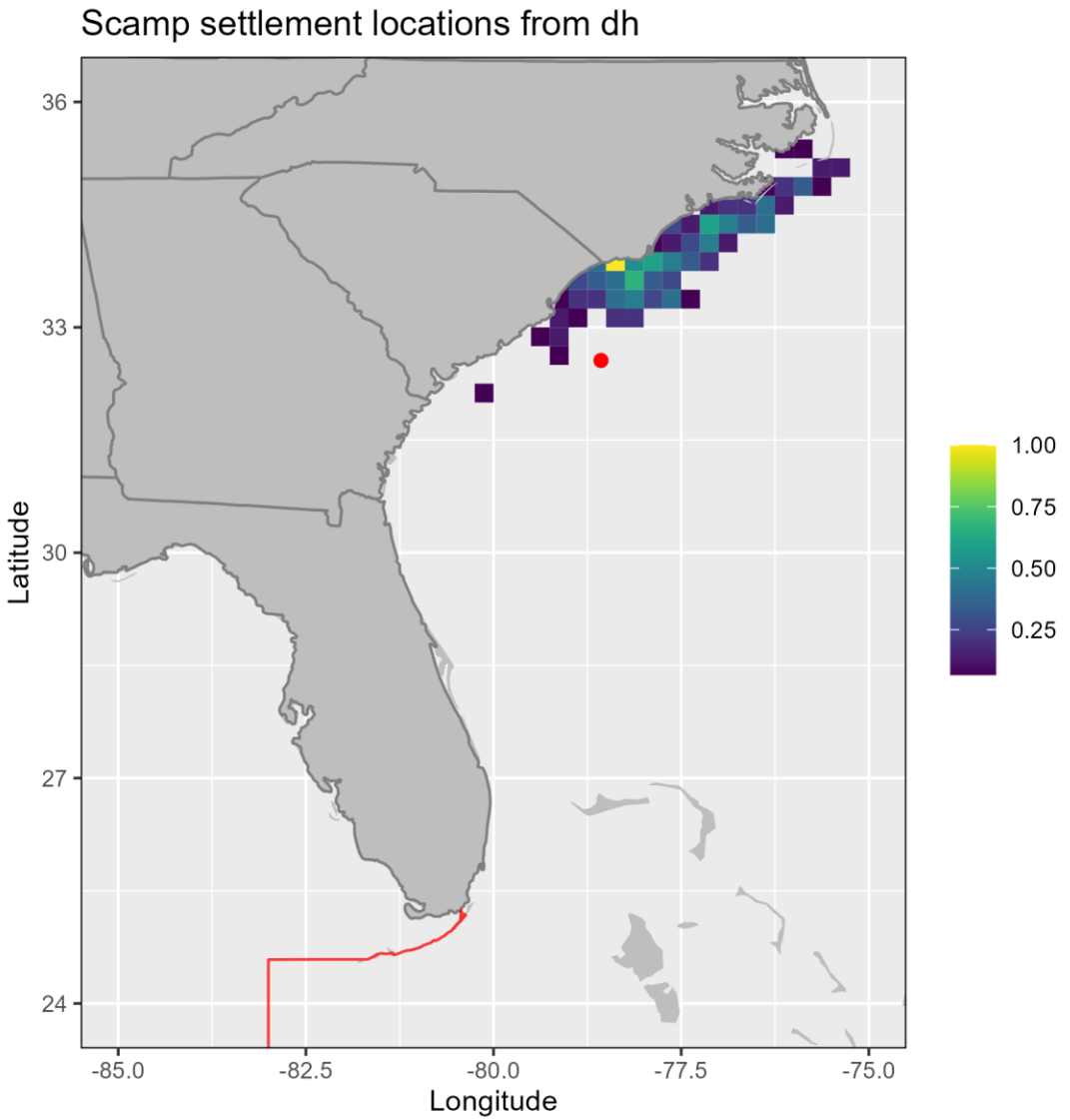
41% settled





Scamp – South Cape Lookout sSMZ

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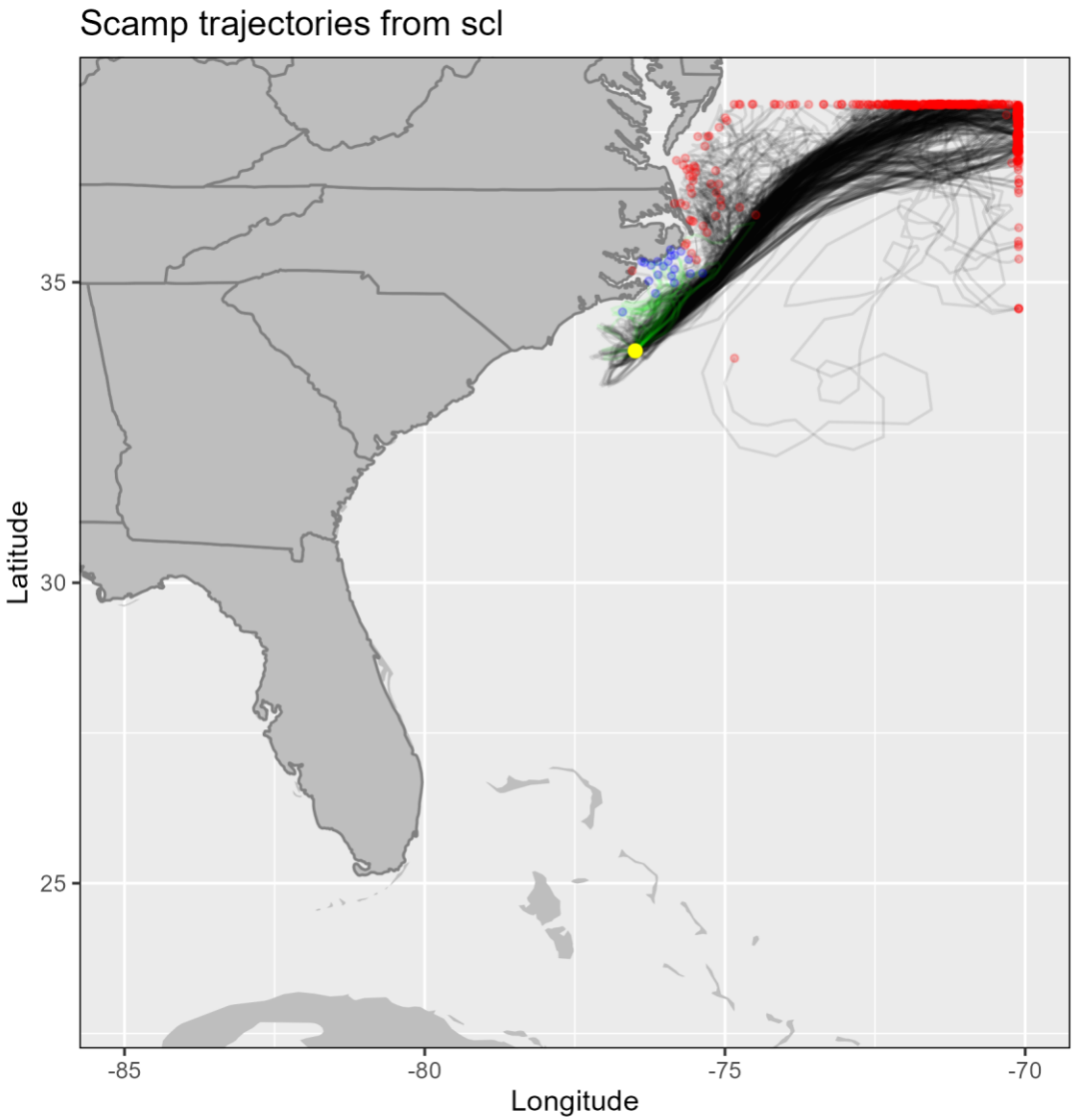
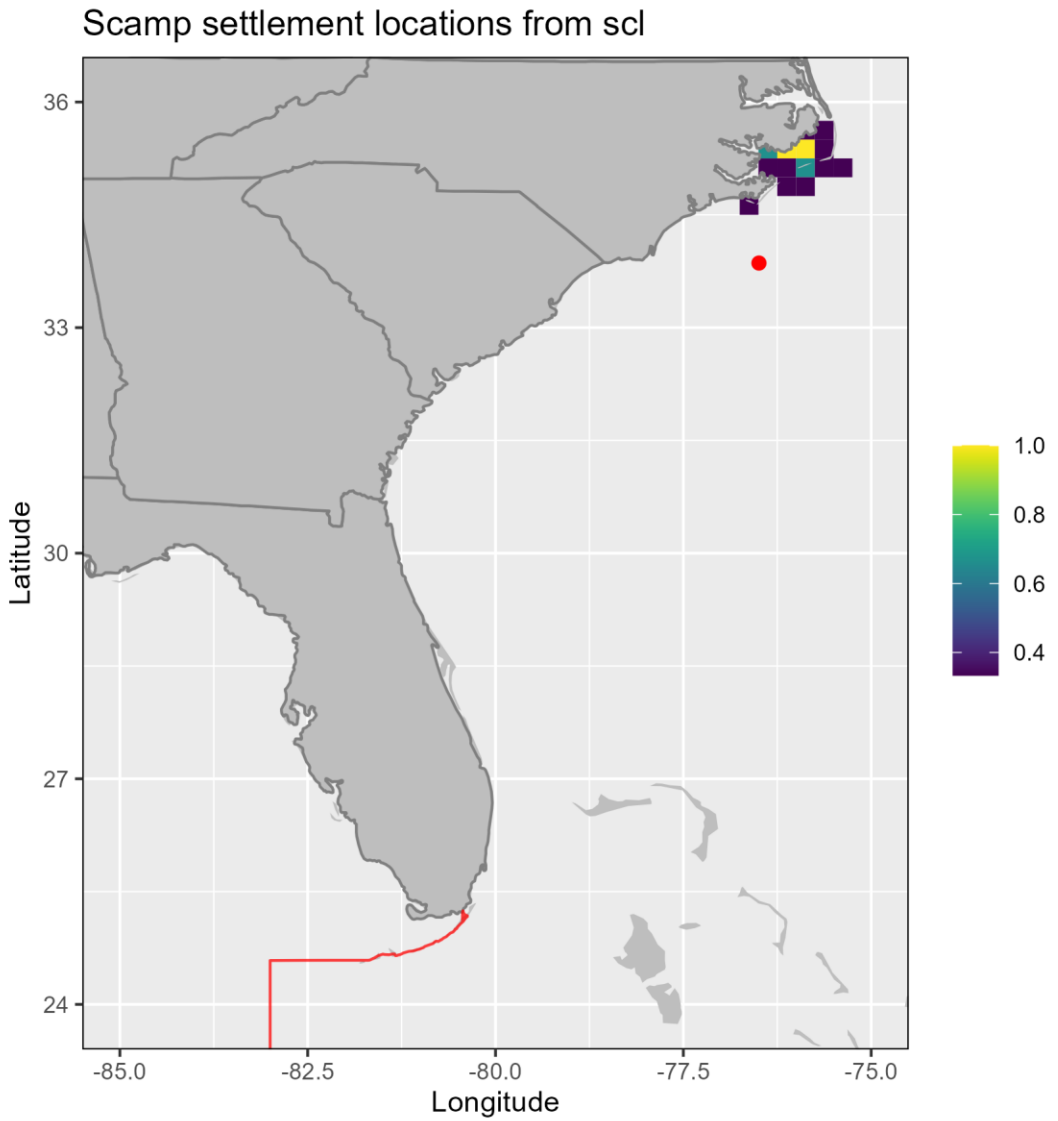
4% settled





Scamp – Warsaw Hole sSMZ

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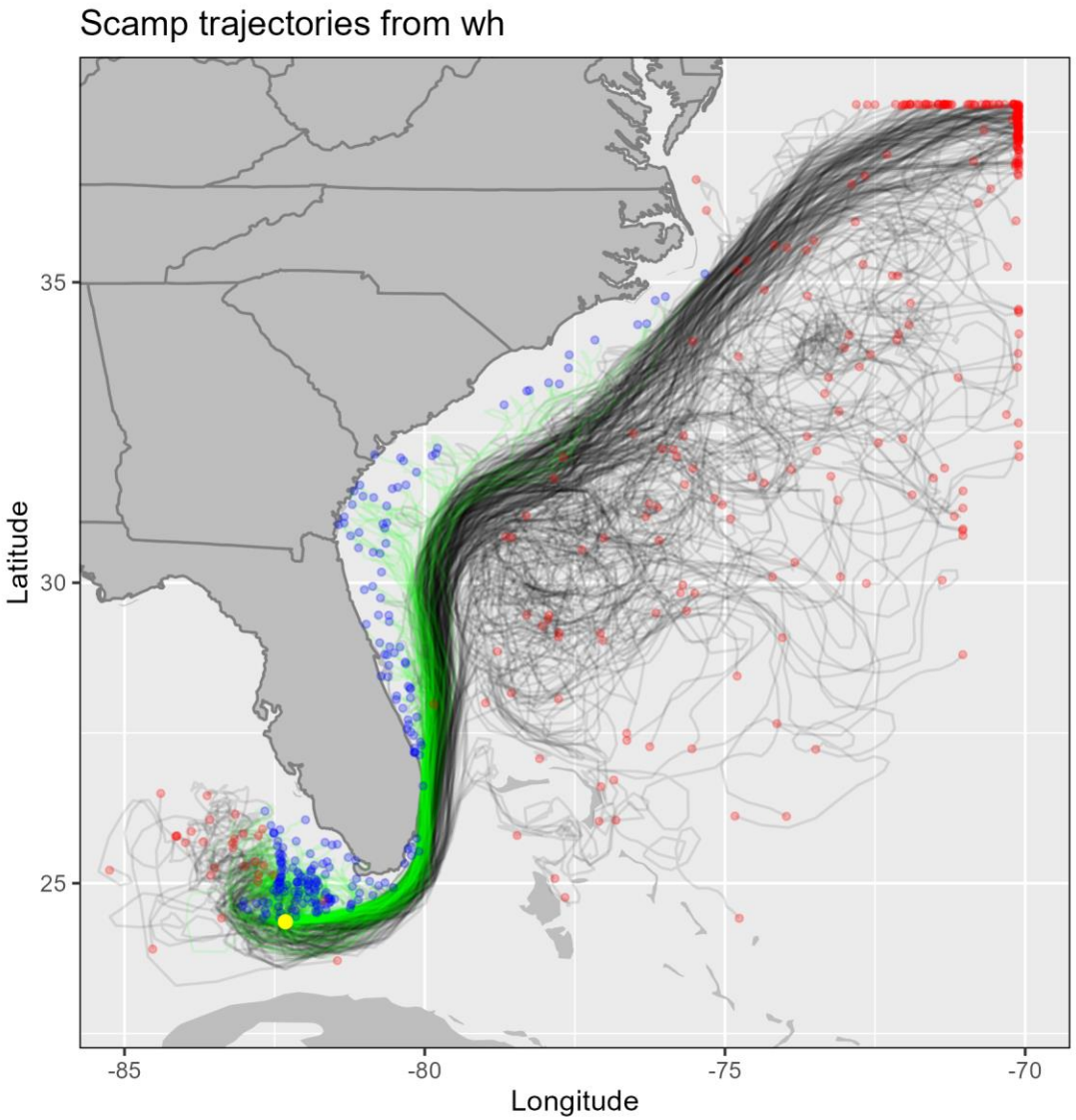
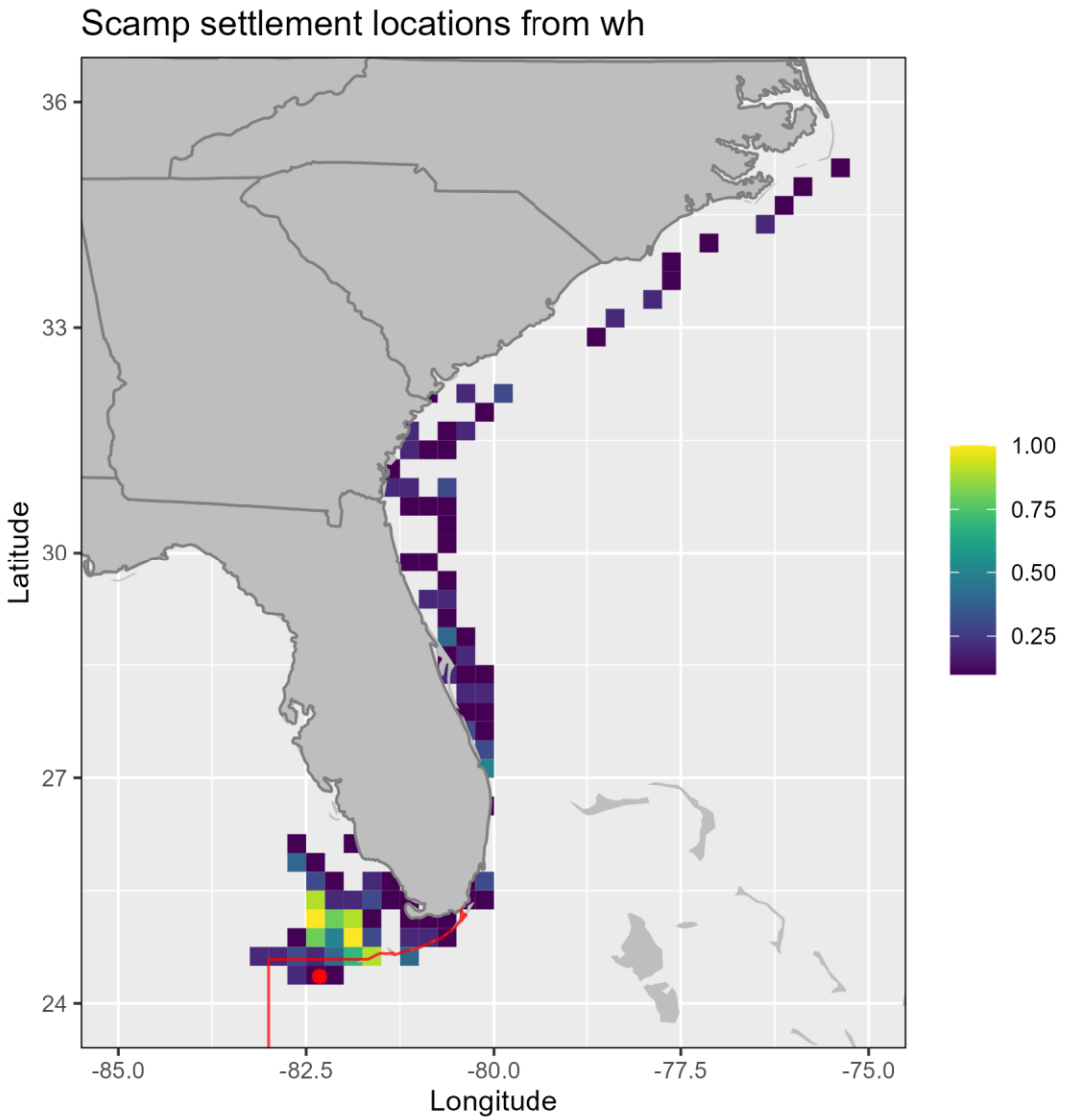
22% settled in the GOM, 20% settled in the ATL, 58% did not





1) Settlement Dynamics from Each sSMZ?

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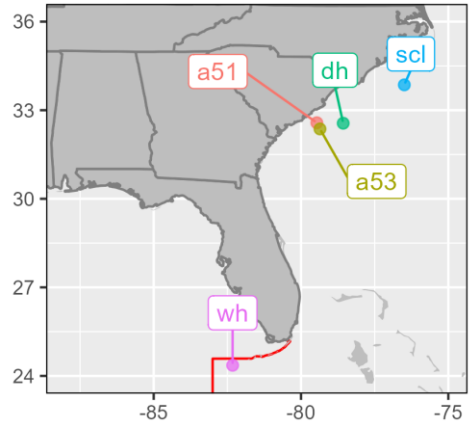
Percent of larvae that settled in the Atlantic: oceanography and larval traits

sSMZ	Gag	Red Grouper	Red Snapper	Scamp
Area 51	75	74	29	75
Area 53	65	67	37	66
Devil's Hole	40	41	35	41
South Cape Lookout	4	4	4	4
Warsaw Hole*	23	28	18	20



* A similar proportion of larvae settled in the Gulf of Mexico

1) Settlement Dynamics from Each sSMZ?

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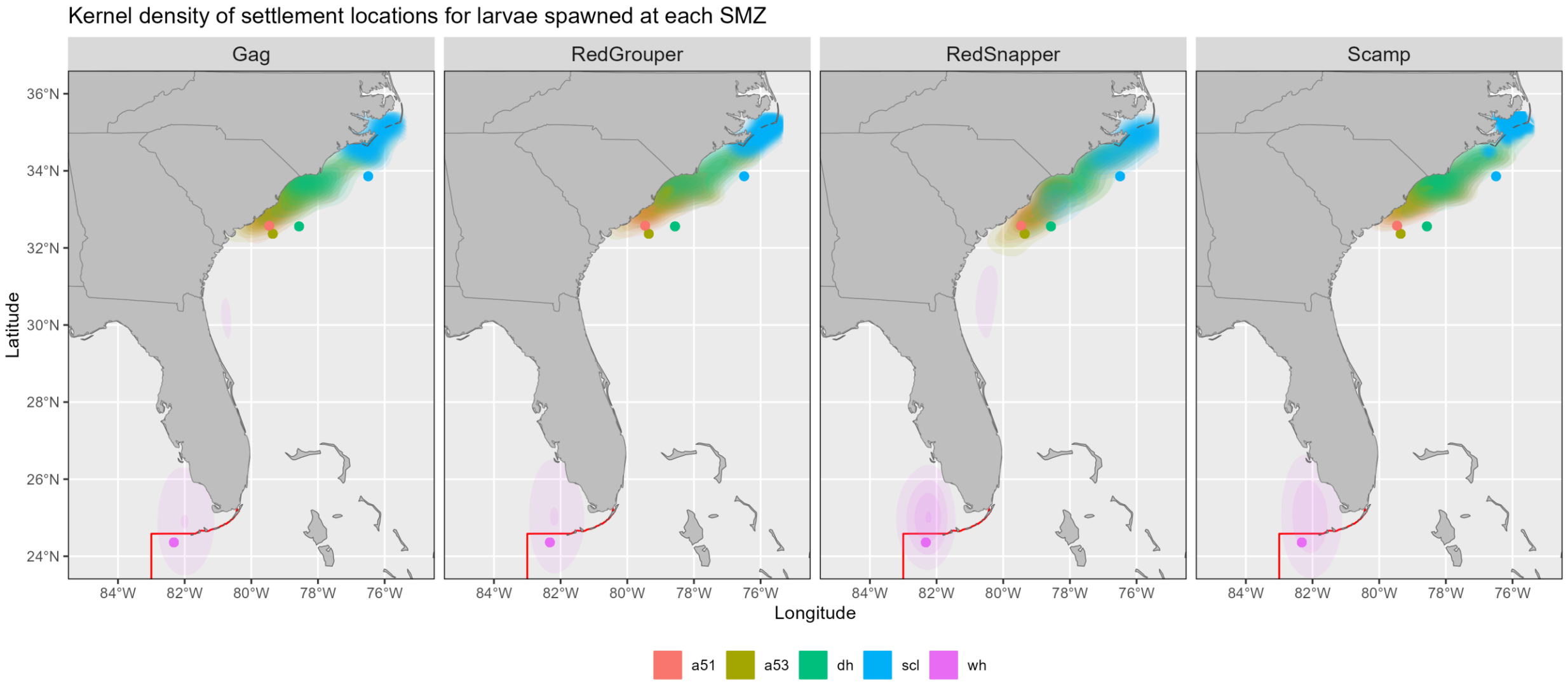

Results

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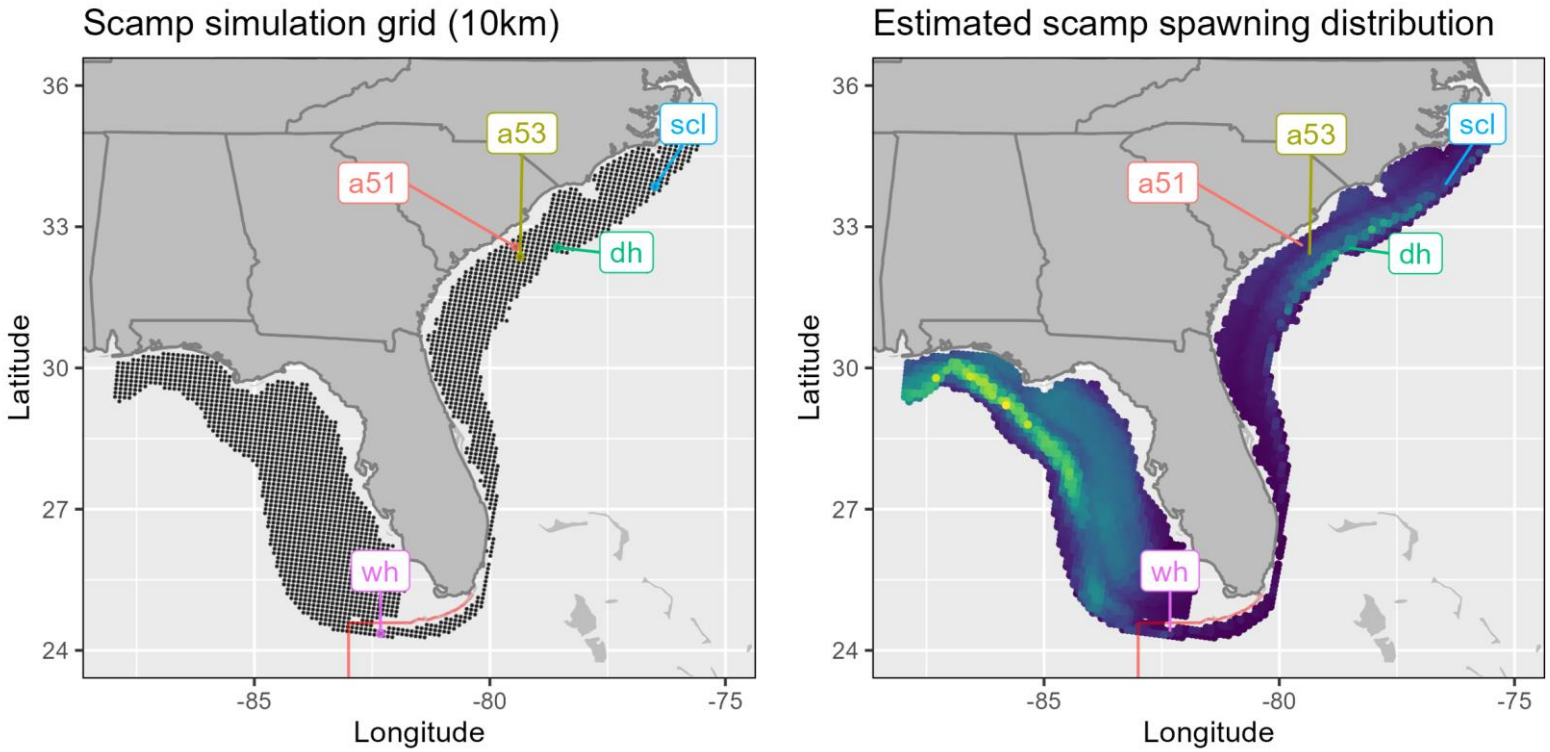
2) How do sSMZs compare to other spawning locations in the Atlantic?

A. Percent settlement in Atlantic
B. Relative spawning
C. Recruitment to ATL



Scamp results

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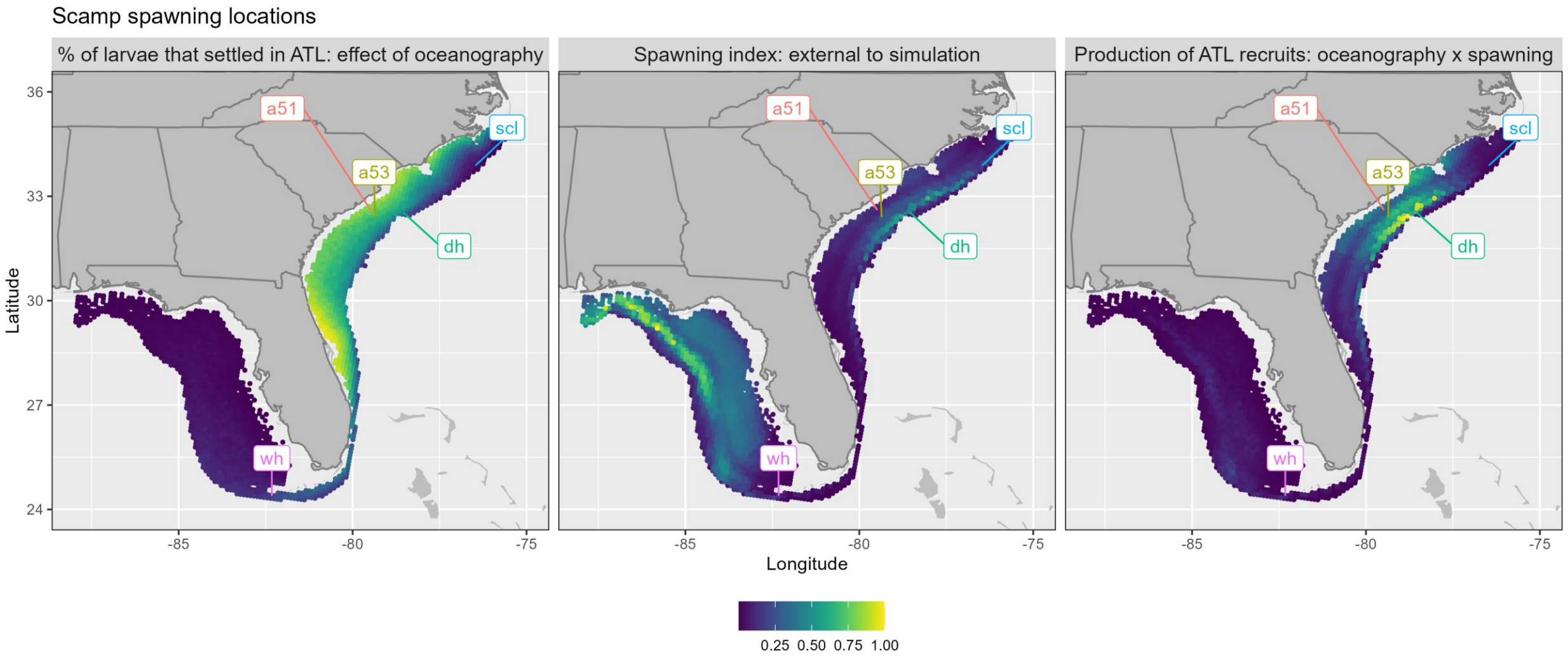
Oceanography x Spawning = Recruitment



Scamp results

Gulf of Maine Research Institute

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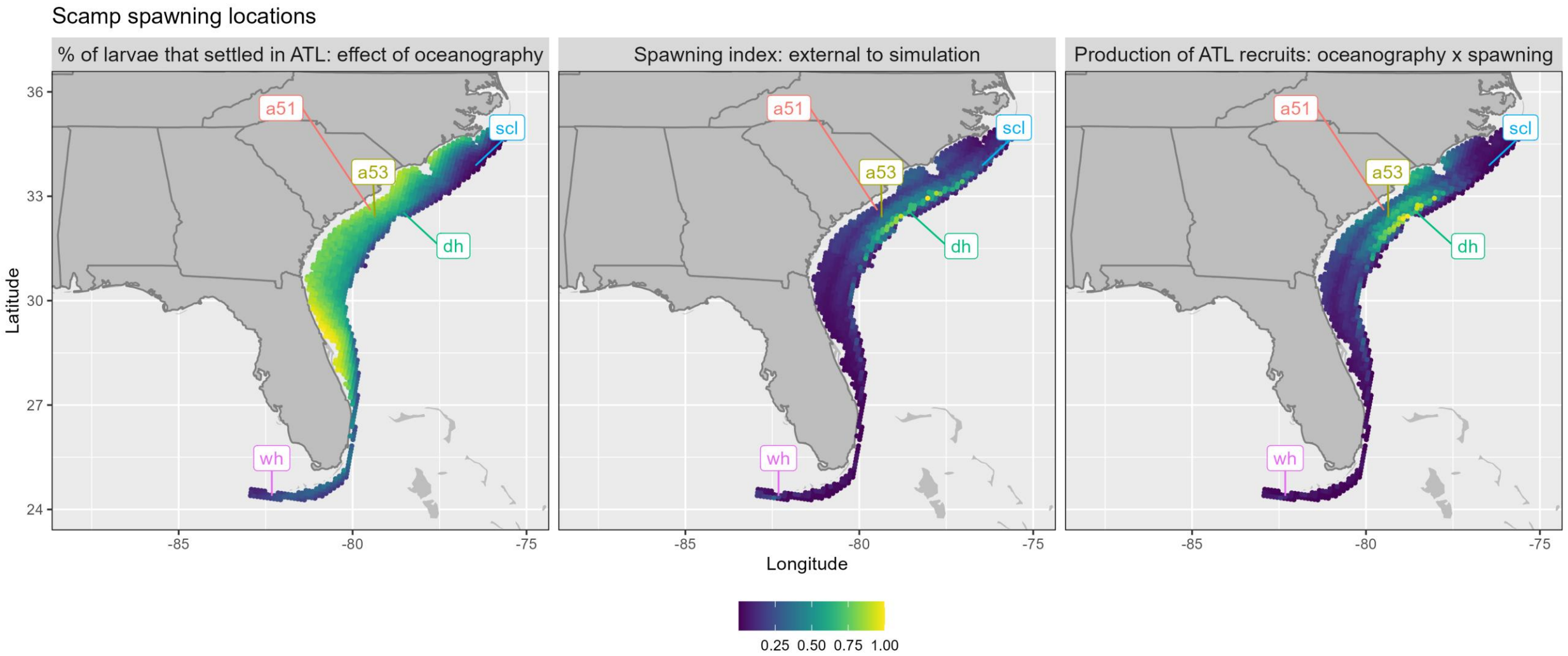
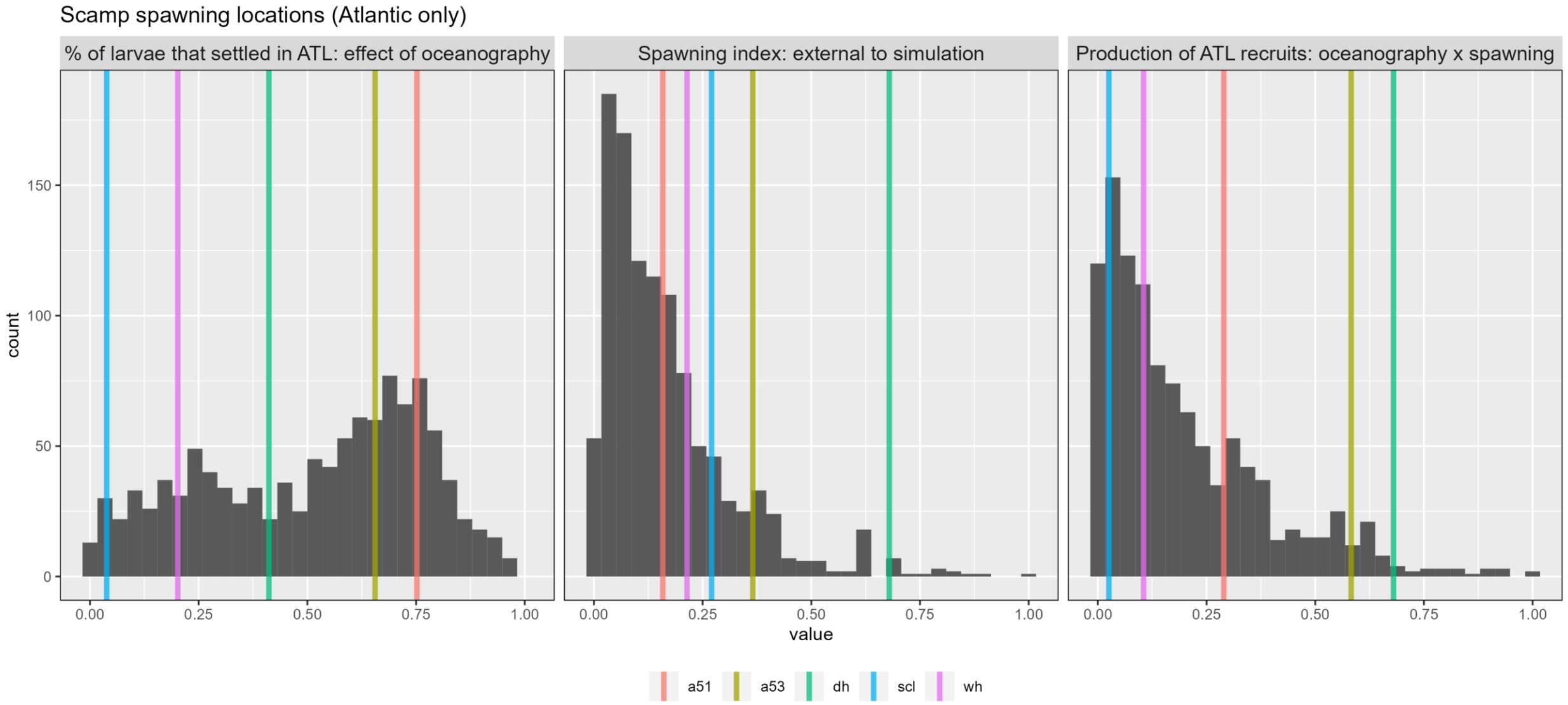


Scamp results

Gulf of Maine Research Institute

Oceanography x Spawning = Recruitment



2) How do sSMZs Compare to Other Spawning Areas?

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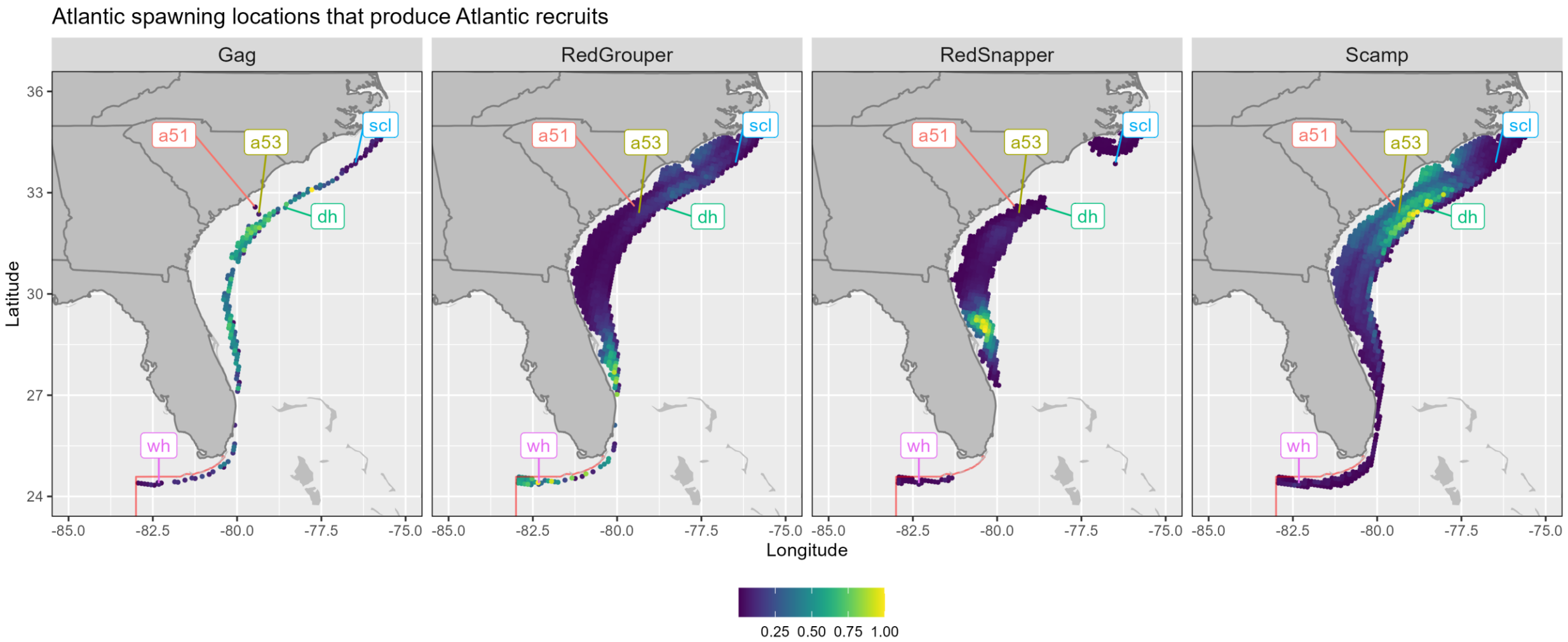

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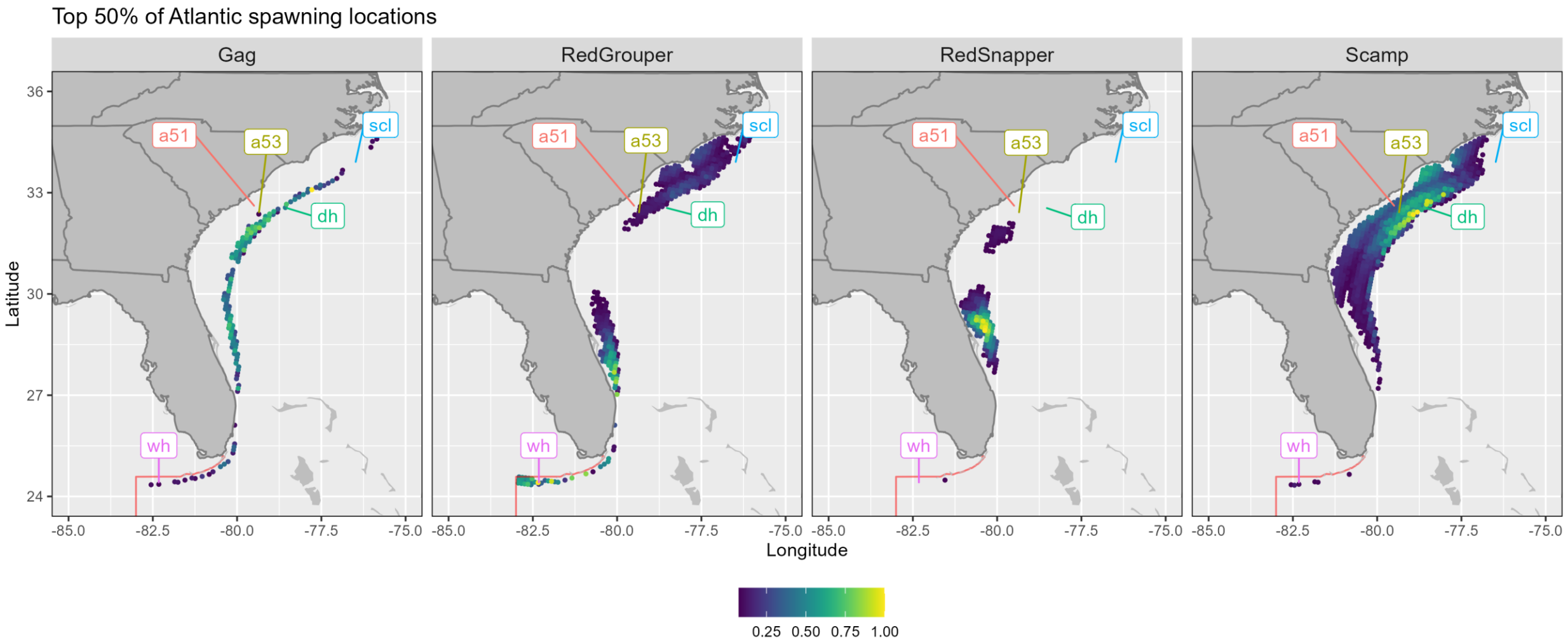

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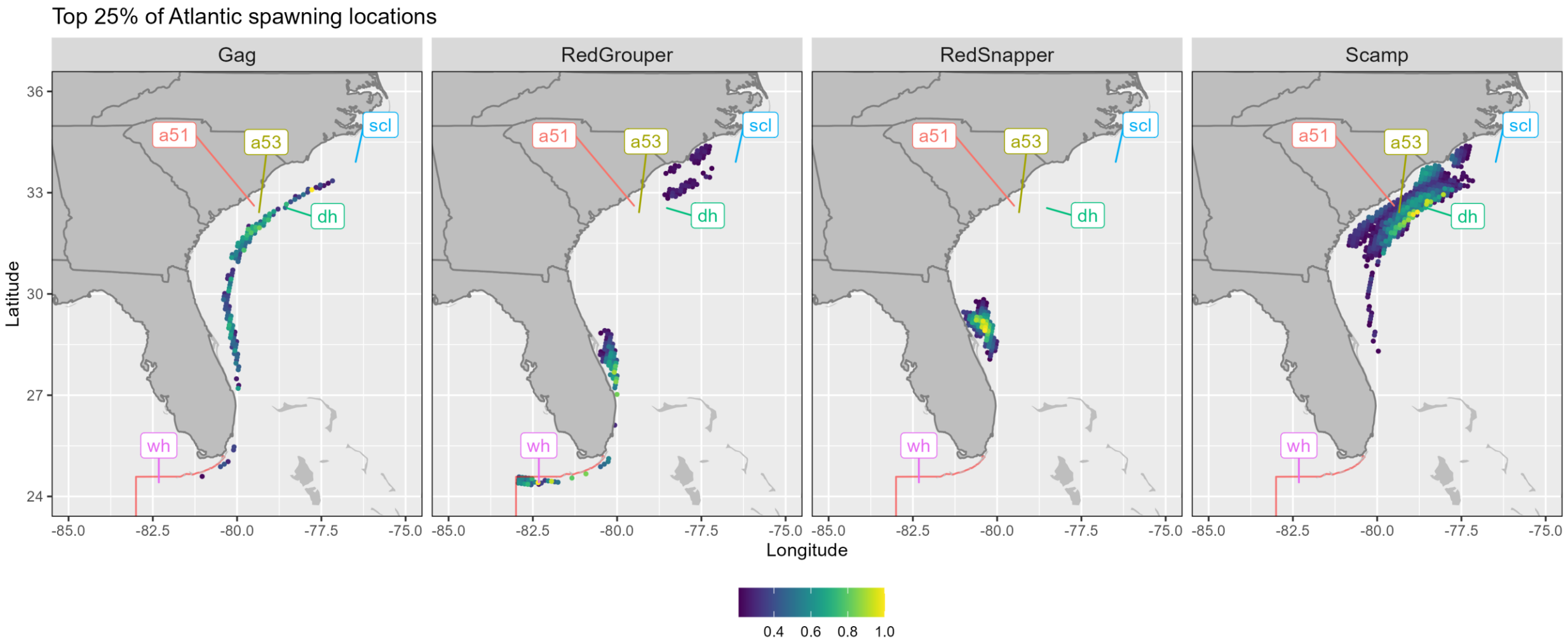

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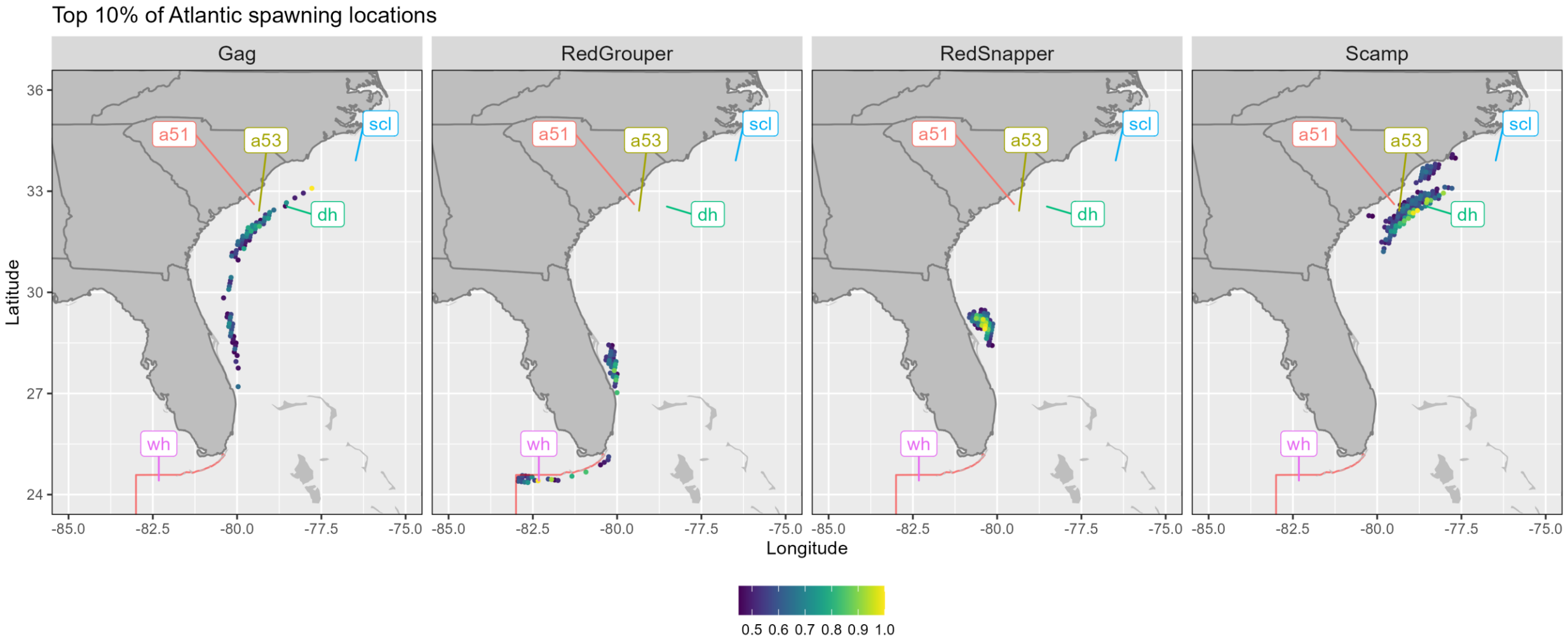

2) How do sSMZs Compare to Other Spawning Areas?

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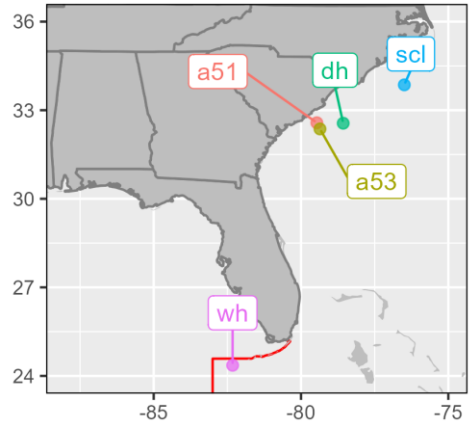
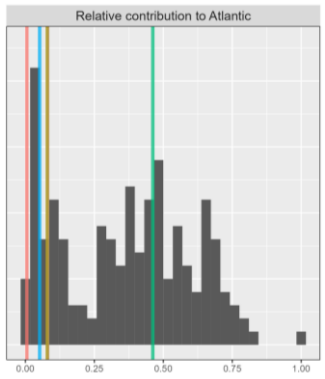
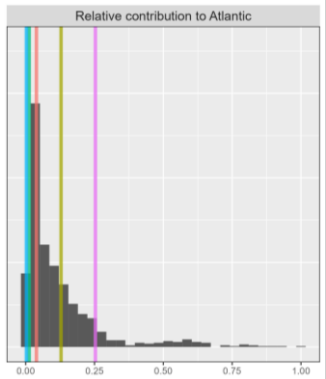
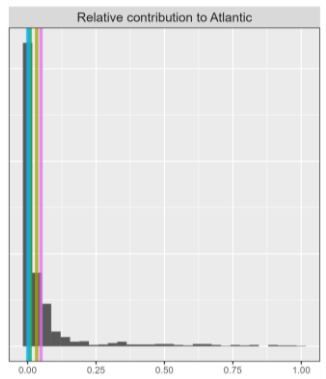
Percent of recruitment output from most productive spawning area

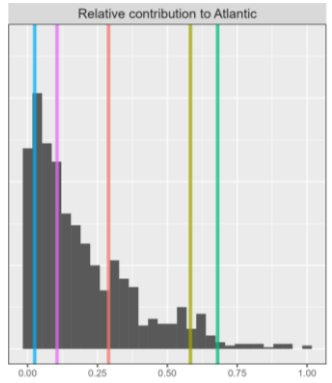
sSMZ	Gag	Red Grouper	Red Snapper	Scamp
Area 51	1	4	1	29
Area 53	8	13	3	58
Devil's Hole	46	1	1	68
South Cape Lookout	5	<0.5	<0.5	3
Warsaw Hole	8	25	5	1











2) How do sSMZs Compare to Other Spawning Areas?

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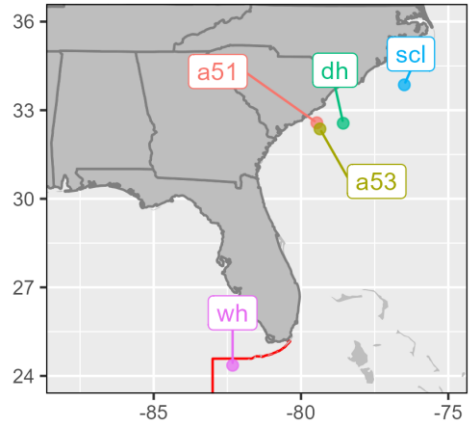
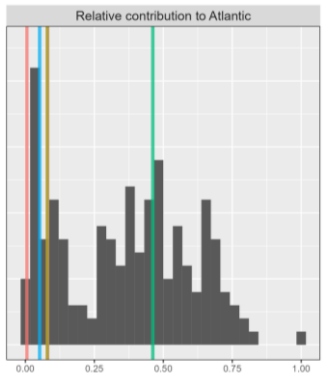
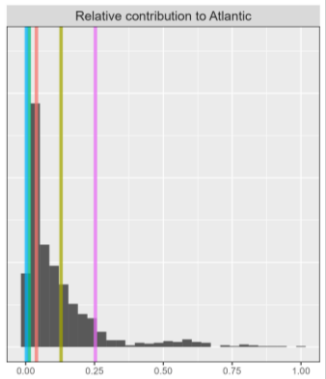
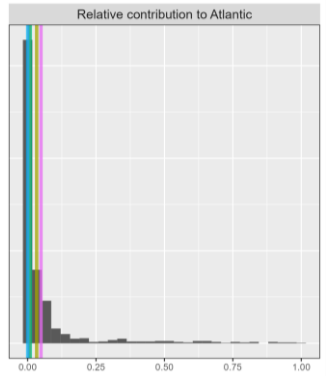
Percentile of each sSMZ location among all Atlantic spawning areas

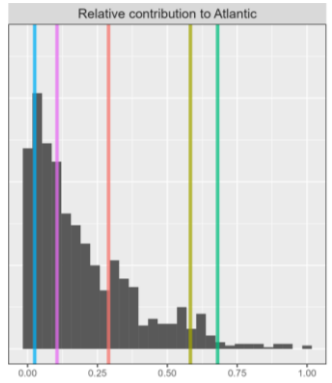
sSMZ	Gag	Red Grouper	Red Snapper	Scamp
Area 51	15	36	15	82
Area 53	52	64	32	95
Devil's Hole	90	19	17	98
South Cape Lookout	42	13	12	28
Warsaw Hole	52	79	41	58











2) How do sSMZs Compare to Other Spawning Areas?

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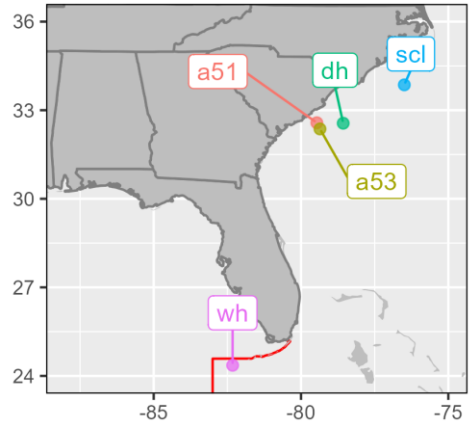
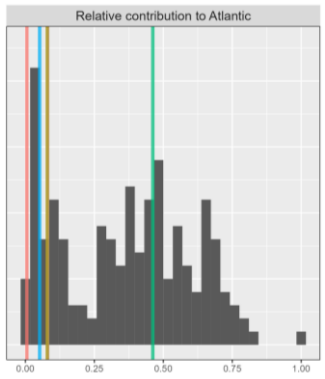
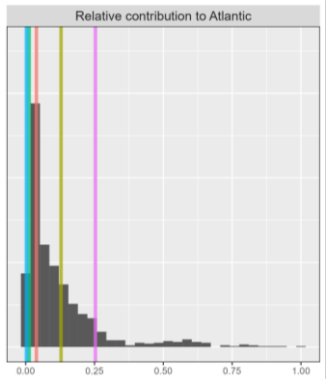
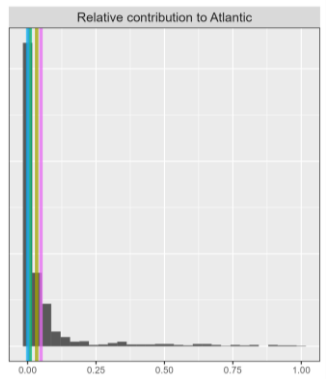
Percentile of each sSMZ location among all Atlantic spawning areas

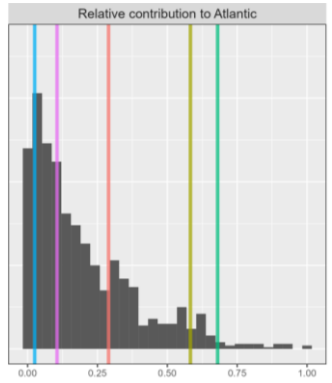
sSMZ	Gag	Red Grouper	Red Snapper	Scamp
Area 51	1/15	4/36	1/15	29/82
Area 53	8/52	13/64	3/32	58/95
Devil's Hole	46/90	1/19	1/17	68/98
South Cape Lookout	5/42	<1/13	<1/12	3/28
Warsaw Hole	8/52	25/79	5/41	1/58











2) How do sSMZs Compare to Other Spawning Areas?

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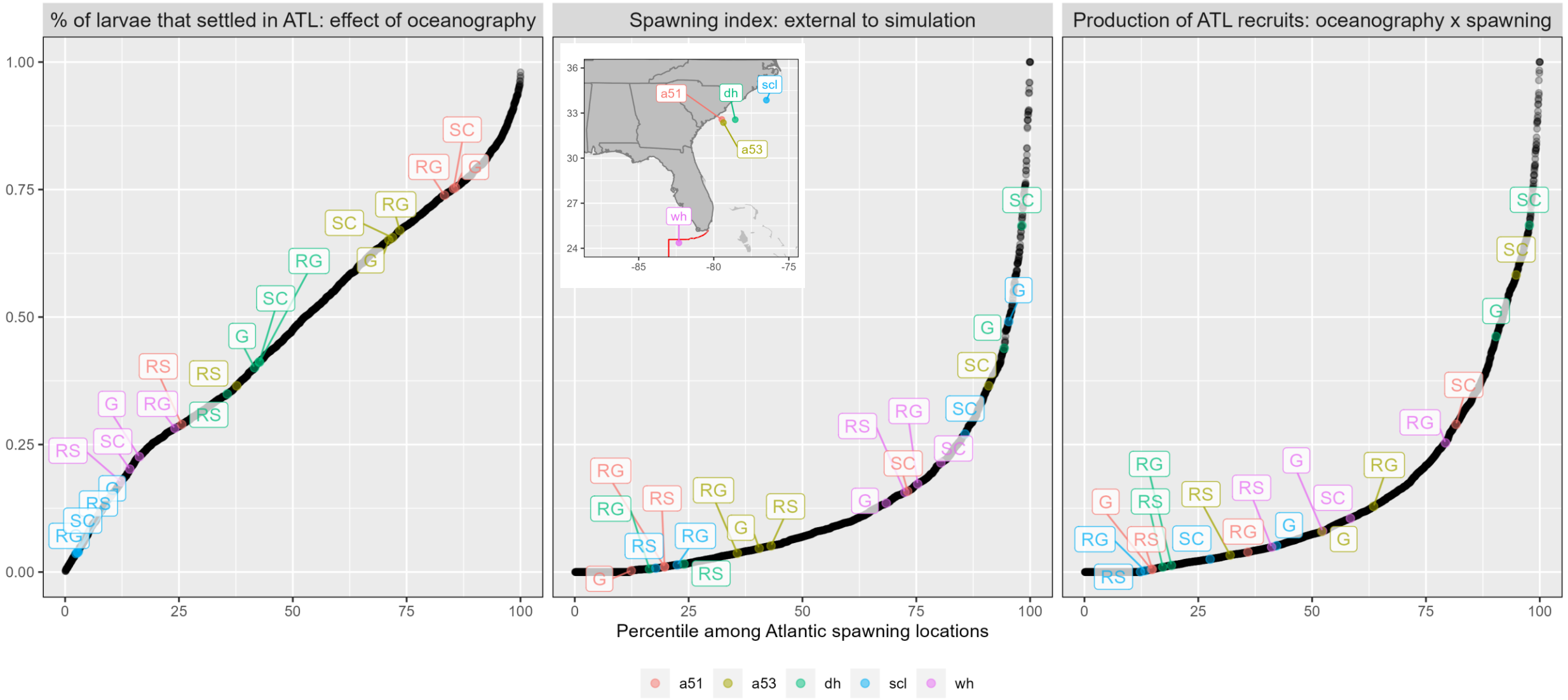
Oceanography x Spawning = Recruitment



Results

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3) **How much recruitment to the Atlantic comes from the sSMZs?**
   A. Expected contribution
   B. What if they were larger, or spawning was concentrated?
   C. What if they were in the perfect place for each species?

3) How much do sSMZs contribute to ATL recruitment?

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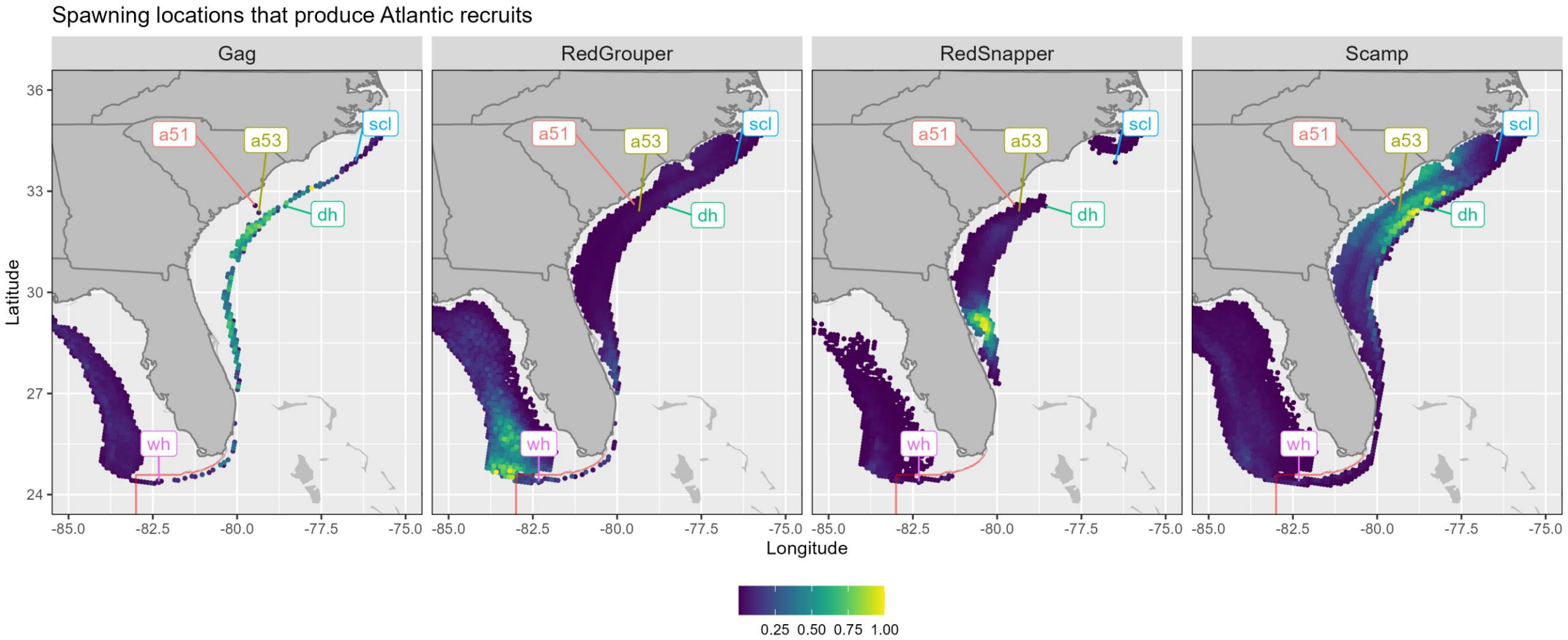

3) How much do sSMZs contribute to ATL recruitment?

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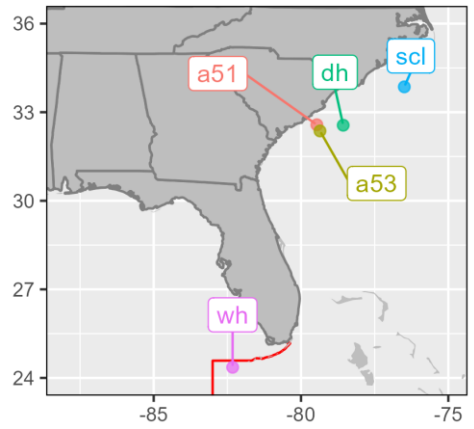
Percent of total Atlantic recruitment

Spawning area	Gag	Red Grouper	Red Snapper	Scamp
Gulf of Mexico	31	84	10	17
Atlantic	69	16	90	83
sSMZs combined	<0.1	<0.01	0.01	<0.1



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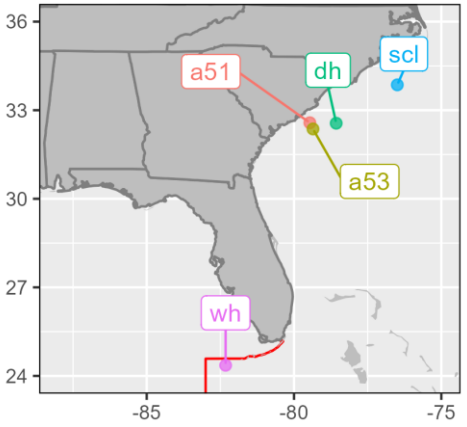

% from each sSMZ

	A51	A53	DH	SCL	WH
Gag	1	12	68	8	12
Red Grouper	9	30	3	1	58
Red Snapper	6	34	10	1	50
Scamp	17	35	40	2	6

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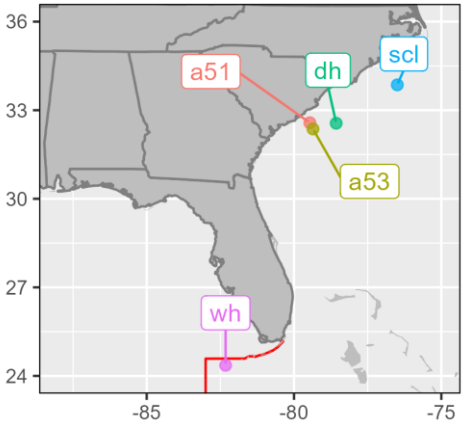
We predict relative spawning in 10km x10km grid cells.



These estimates assume that spawning is uniformly distributed throughout each grid cell.

Total = 45.9	A51	A53	DH	SCL	WH
Area (sqkm)	7.8	7.8	7.9	13.2	9.3

If sSMZs were larger, or spawning is concentrated

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% Atlantic recruits from all sSMZs combined

	Gag	Red Grouper	Red Snapper	Scamp
Current sSMZs	0.06	0.006	0.01	0.05
If 100 sqkm each	0.71	0.07	0.13	0.65

If we assume that all of the spawning in a grid cell occurs within the sSMZ,

or, alternatively, that the five sSMZs are hypothetically expanded to encompass their entire grid cell (100 sqkm).

Total area of 500 sqkm
10 x total area of current sSMZs

Neither is likely correct, but they can serve as reasonable bounds

Conclusions

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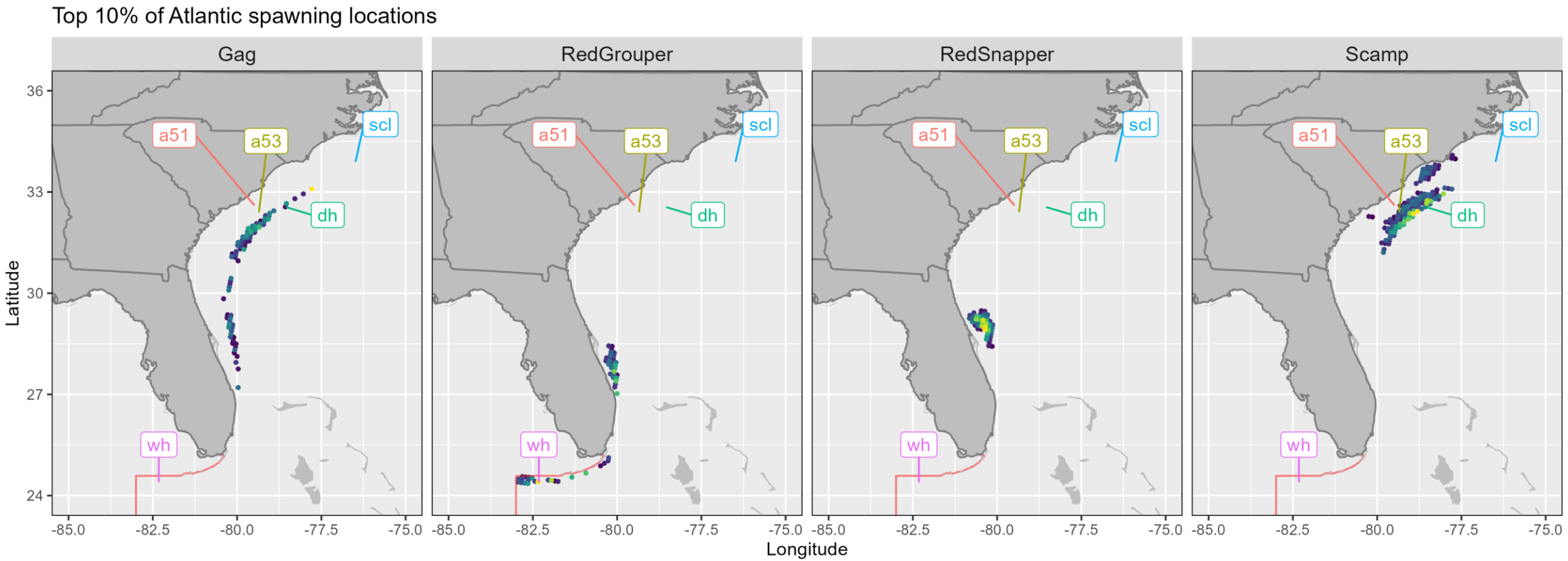

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Gulf of Maine Research Institute

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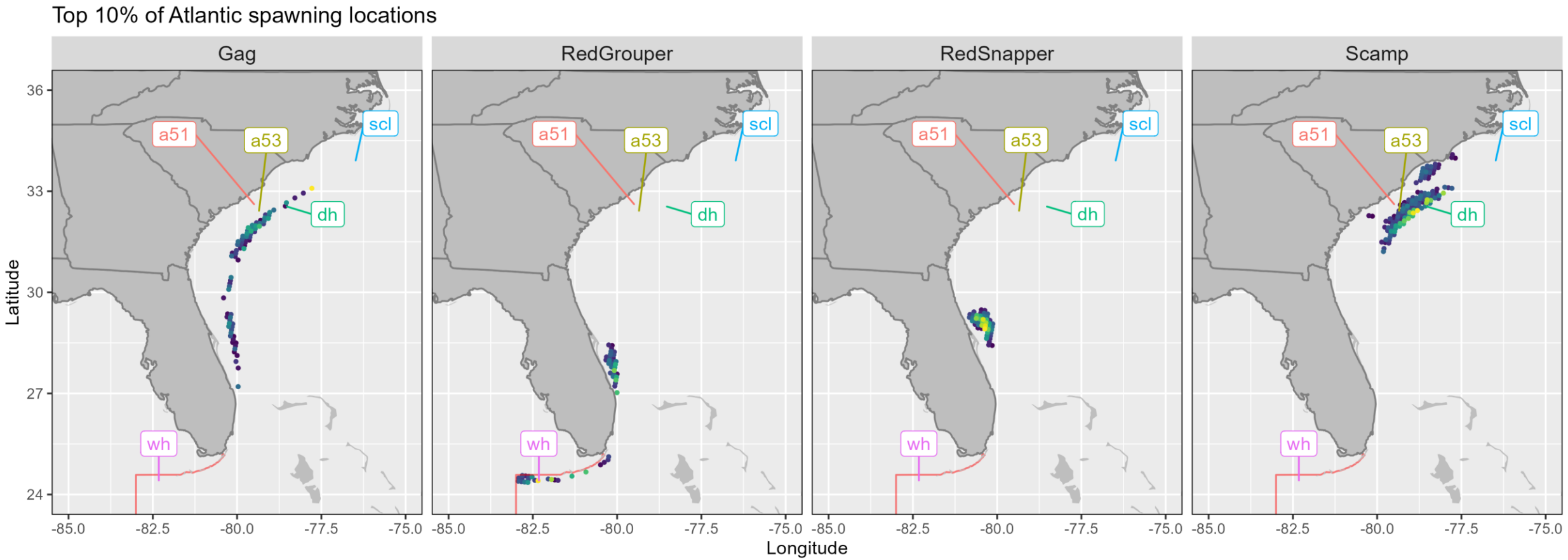

Conclusions

Gulf of Maine Research Institute

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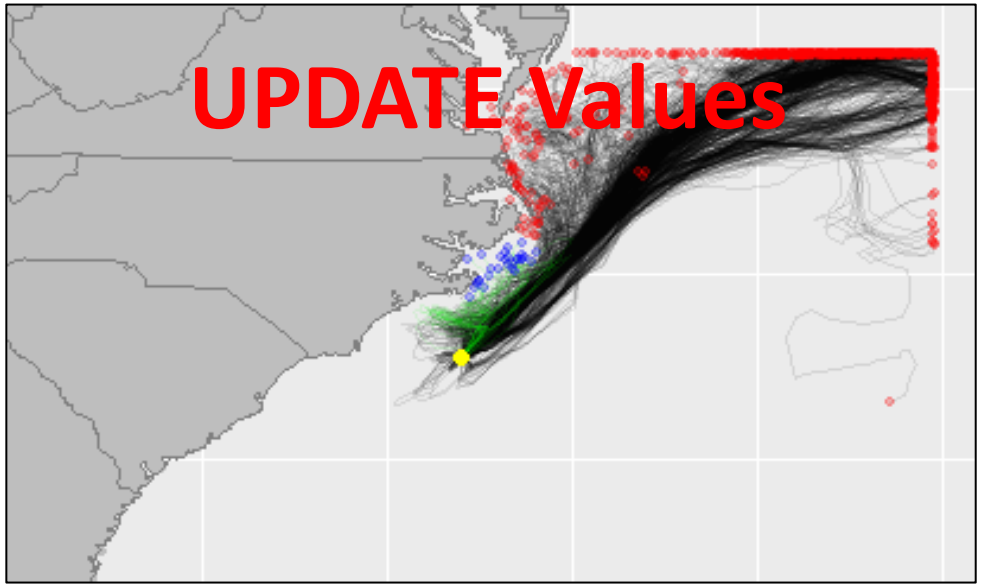
- Those areas with high spawning are not always the areas that provide the highest recruitment. Probability of settlement success (oceanography) is critical.



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- The small footprint of each sSMZ makes it difficult to facilitate meaningful recruitment.

Uncertainties

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- Biological configurations
  - Settlement criteria
  - Vertical distribution of larvae in the water column
  - Spatial distribution of spawning

- Ocean circulation models differ

- Everything I have shown is a mean estimate from simulating several years.
  - We are currently working to assess the inter-annual variability in these relationships.
  - i.e., if we look at the maximum annual recruitment from a particular spawning location, instead of the mean, does it tell a different story?

Acknowledgements

- Collaborators: N Klibansky, NA Farmer, TS Switzer, SK Lowerre-Barbieri, GT Kellison, R He, M Le Hénaff, M Reichert

- Data providers: J Blondeau, M Campbell, C Gardner, K Thompson, L Lombardi-Carlson, T Smart, D Wyanski, T Gerard, G Zapfe, T MacDonald

Questions?

Roger Brothers – rbrothers@gmri.org

Additional figures for reference

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Gag Results

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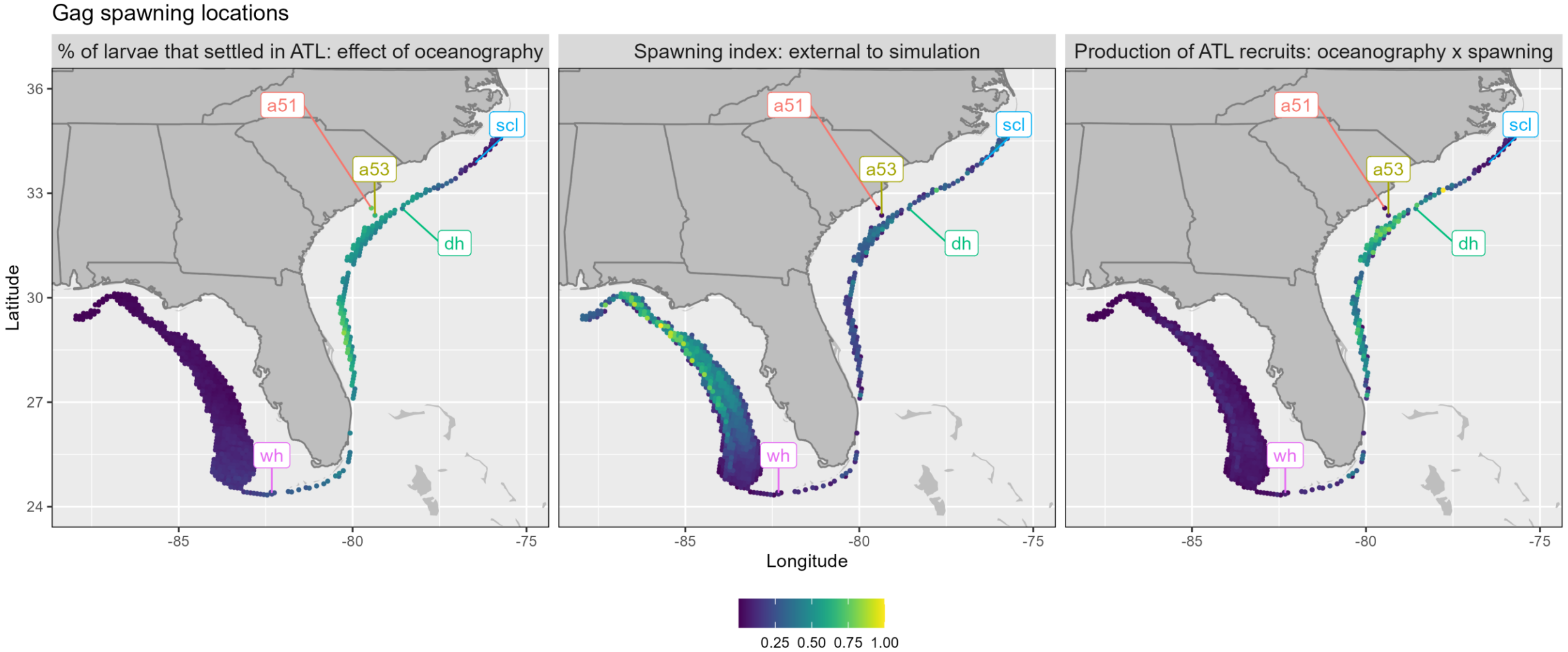
Oceanography x Spawning = Recruitment



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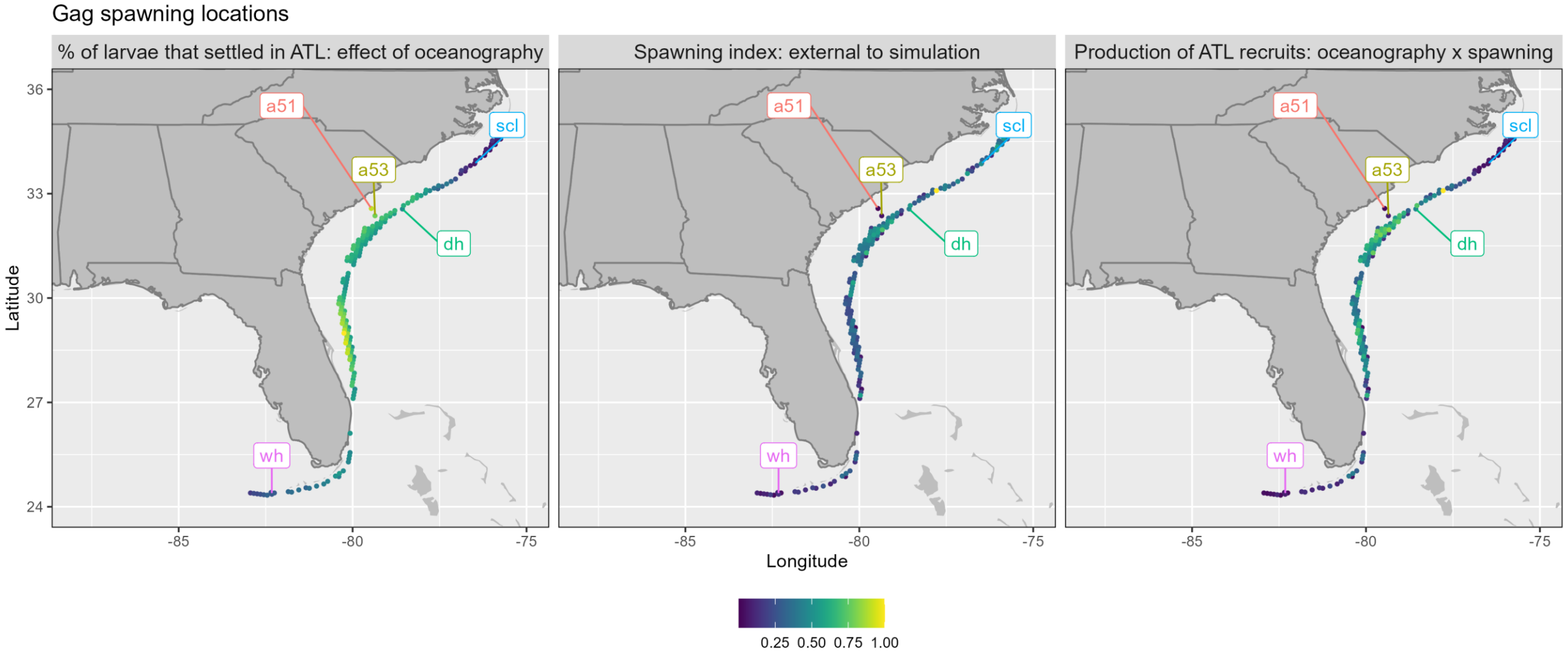

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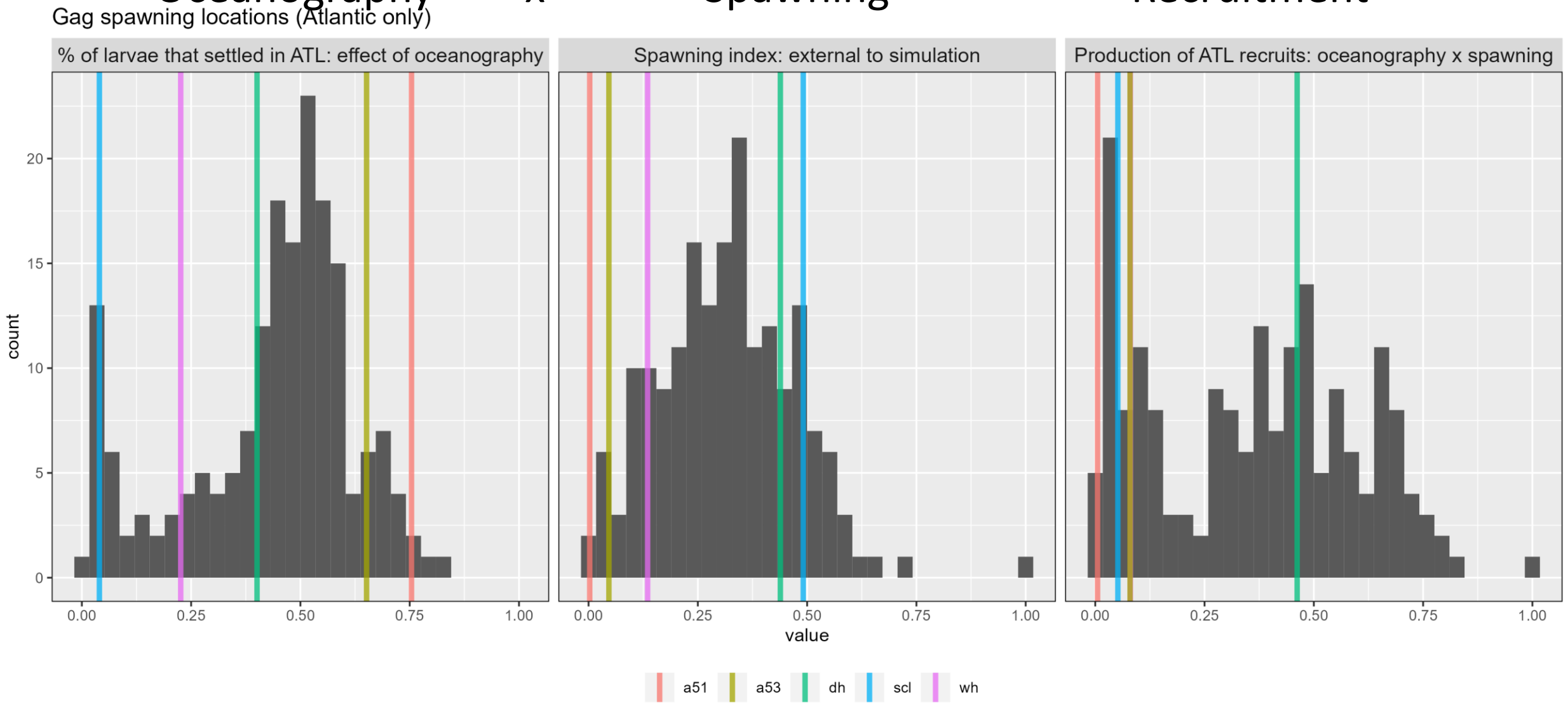

Red Grouper Results

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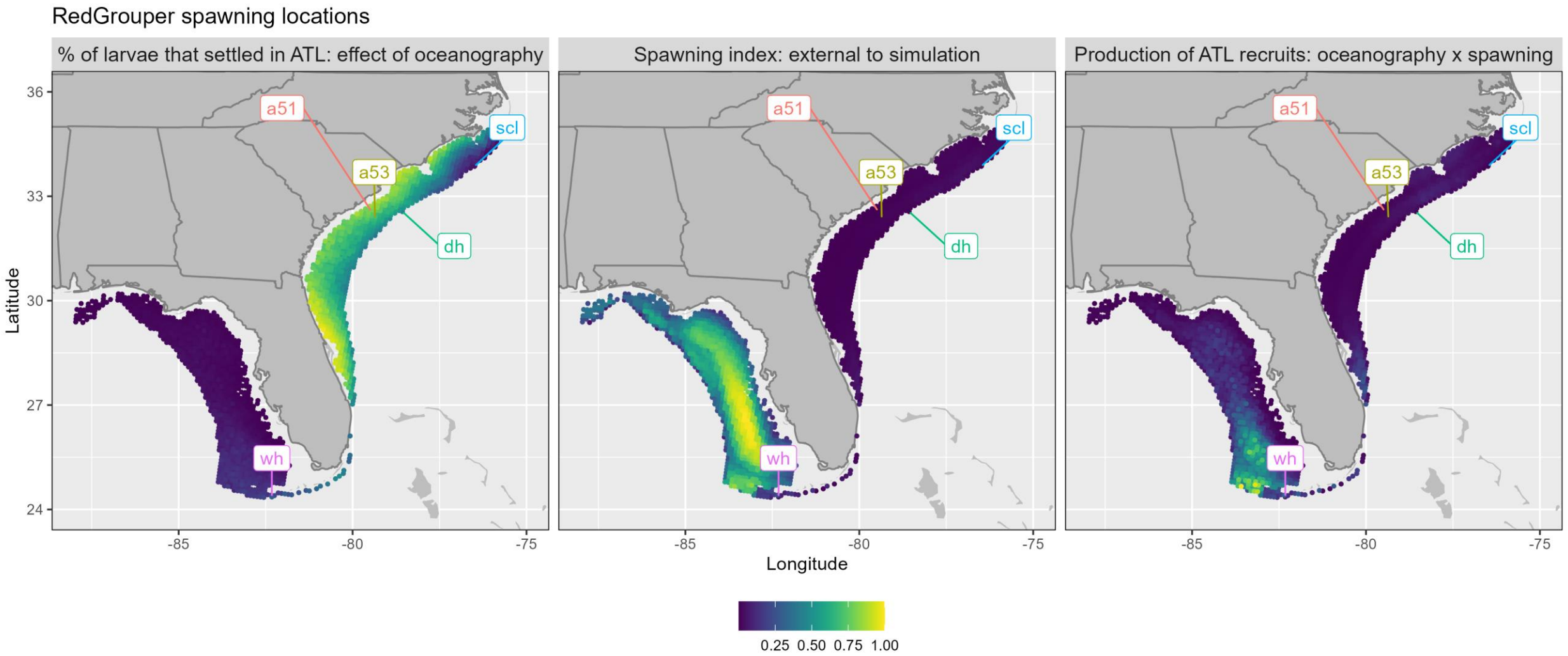

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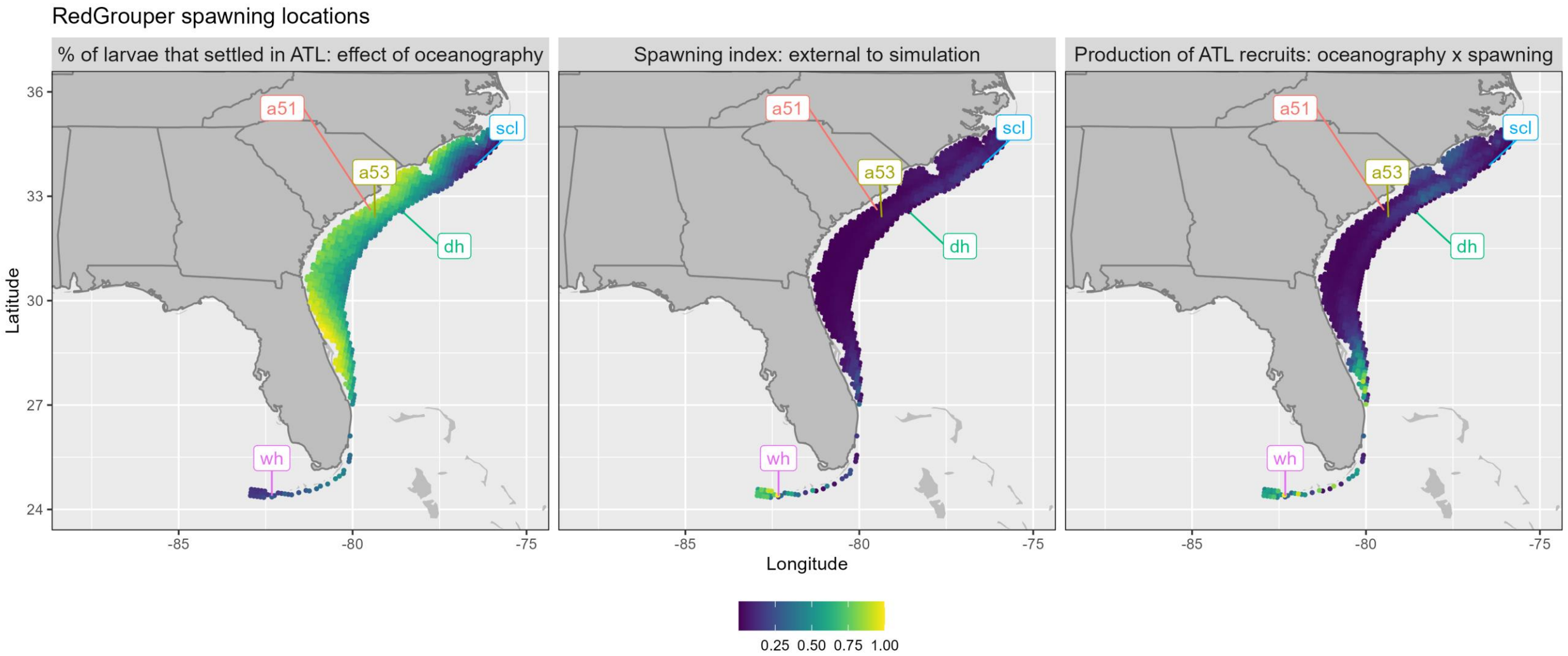

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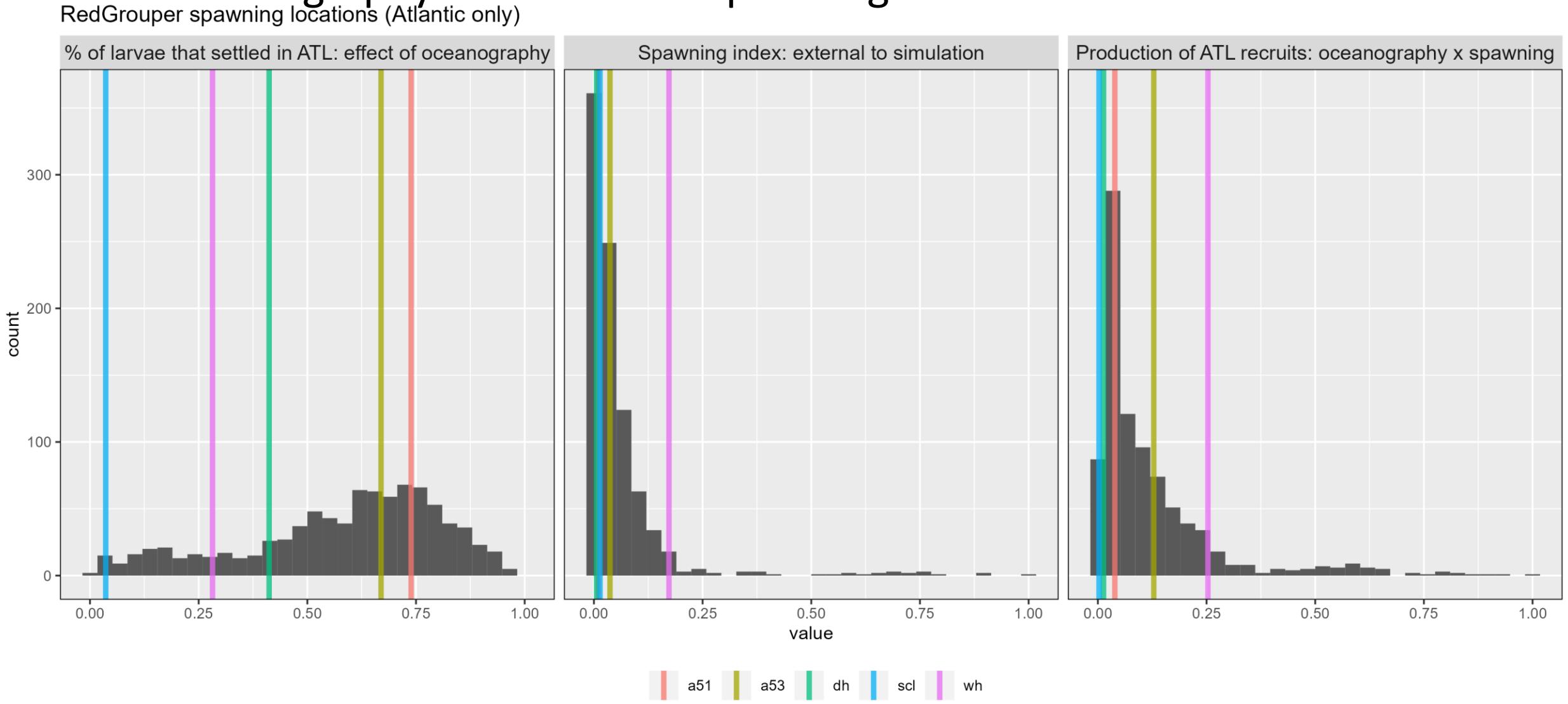

Red Snapper Results

Gulf of Maine Research Institute

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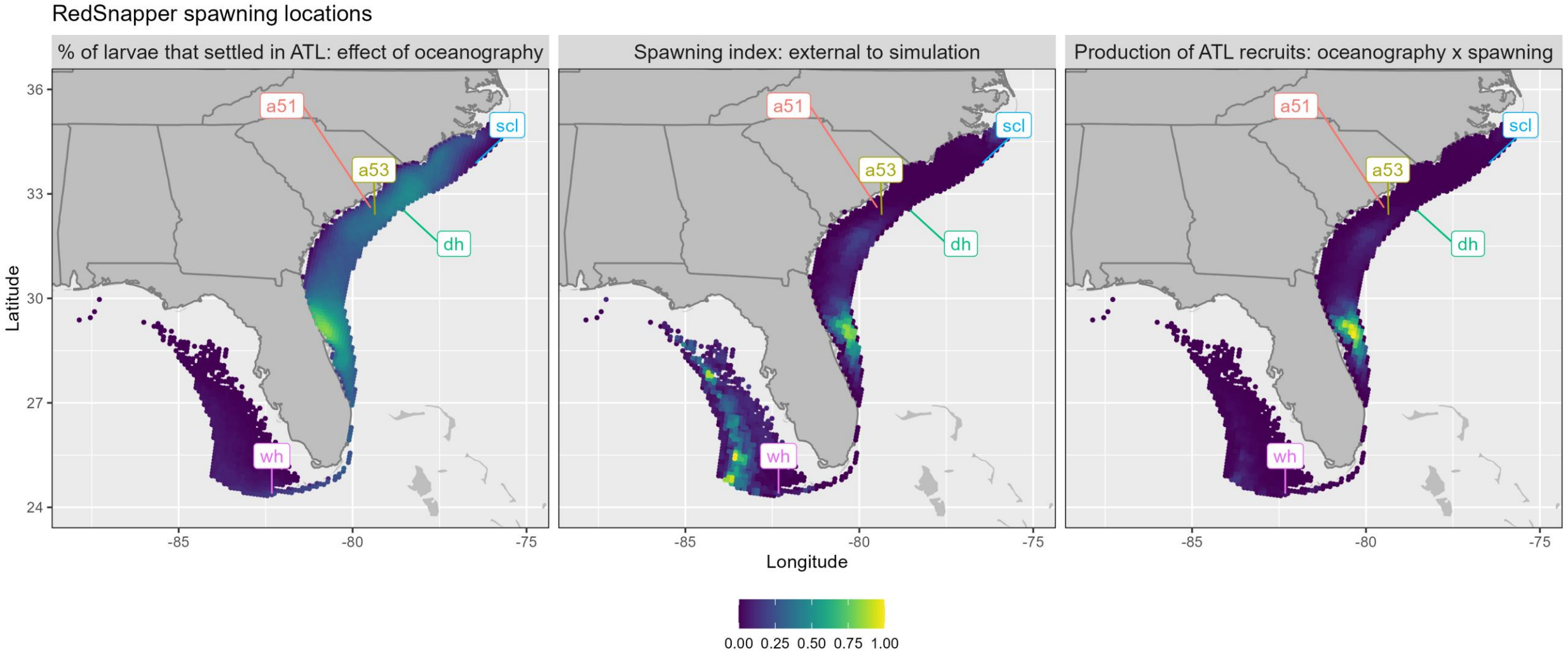

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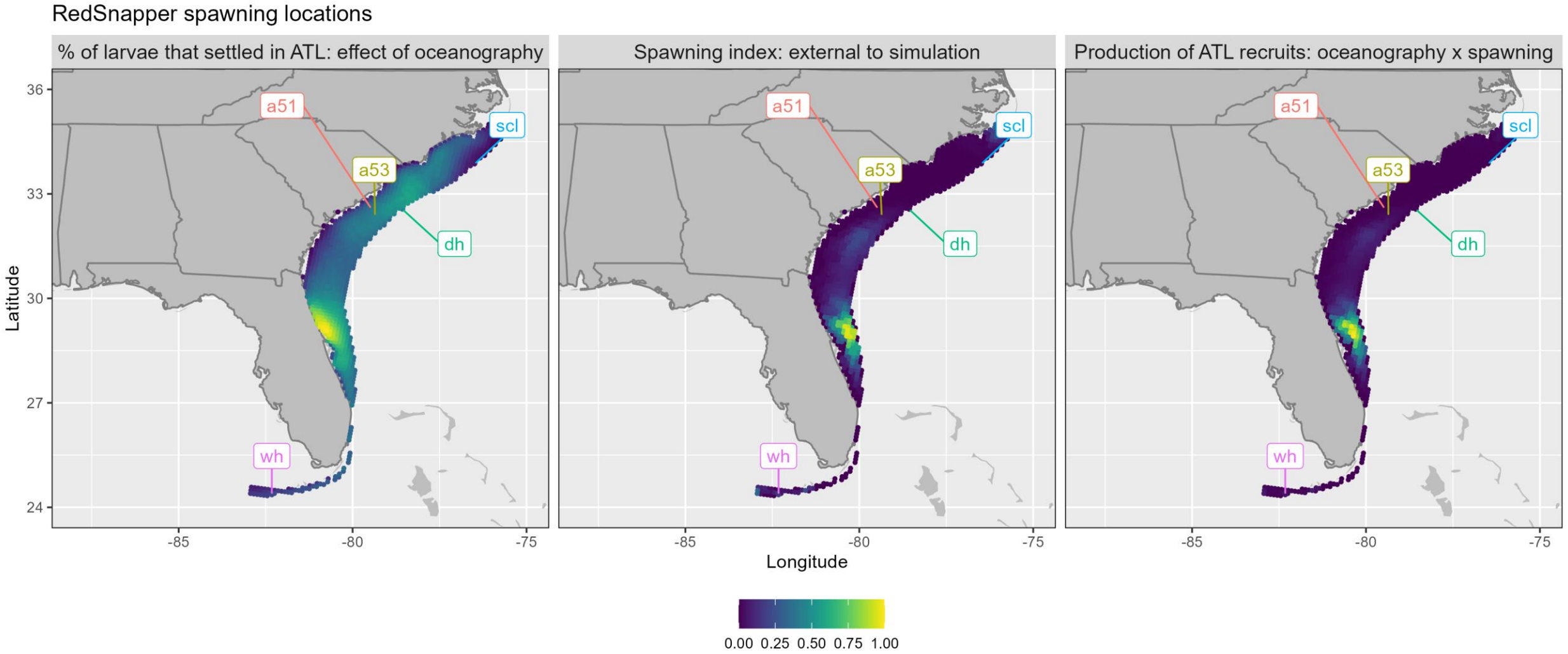

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