Warming trends in the Florida Keys: Implications for queen conch (*Aliger gigas*) population persistence

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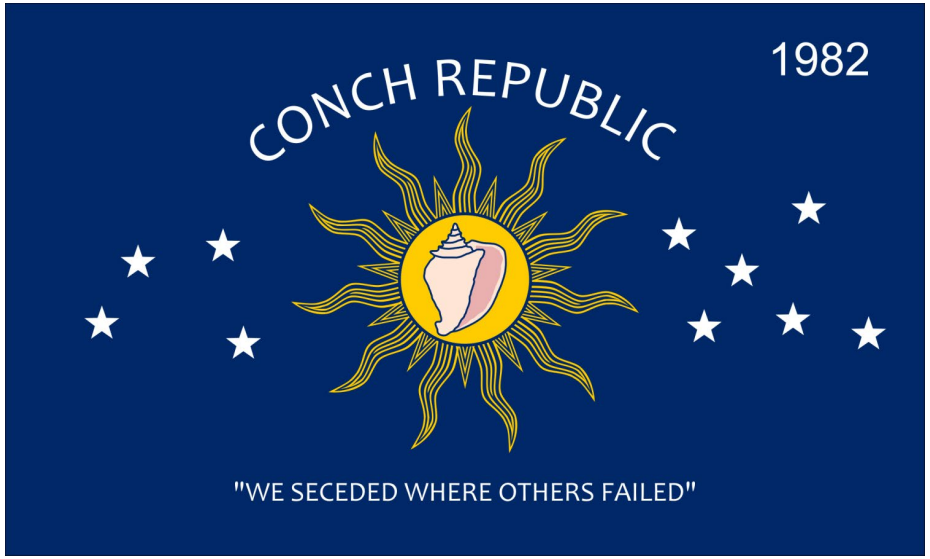
Background

- The queen conch population in the Florida Keys used to support commercial and recreational fisheries

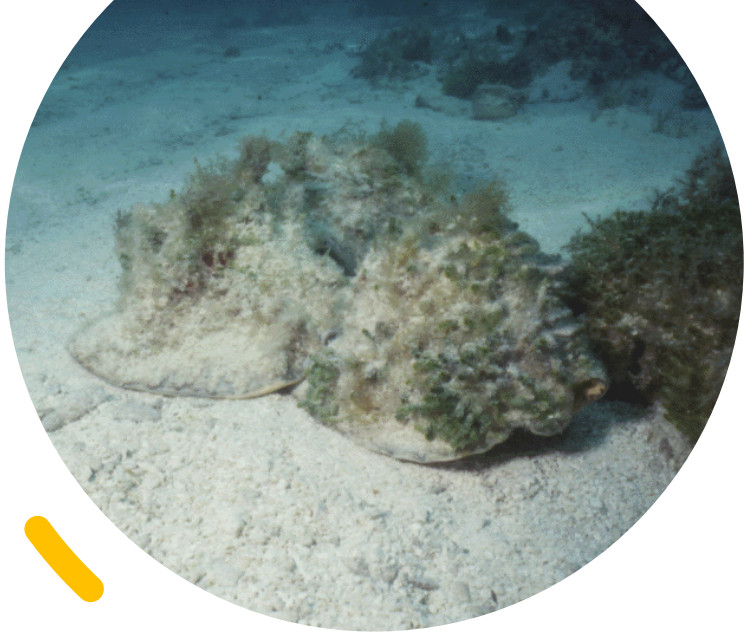
- 1985: Designated as a protected species in Florida (F.A.C. 68B-16.001)

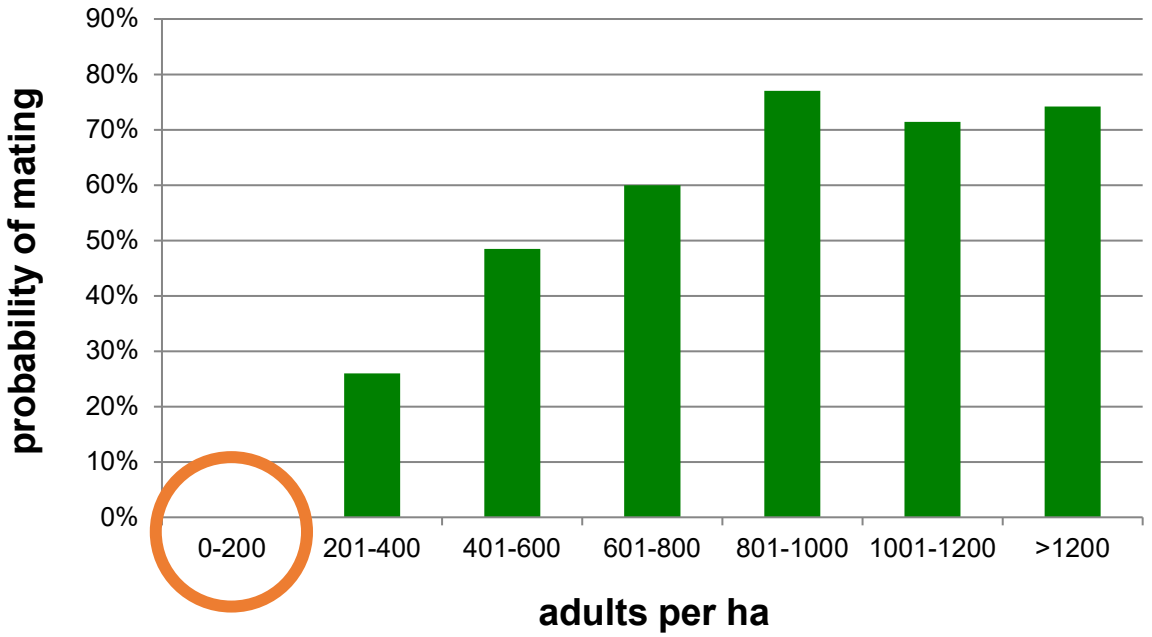
- 2024: NOAA-NMFS listed queen conch as **Threatened** under the U.S. Endangered Species Act



Background

- Recovery has been protracted due to numerous factors:
  - Density-dependent reproduction (Delgado and Glazer 2020)





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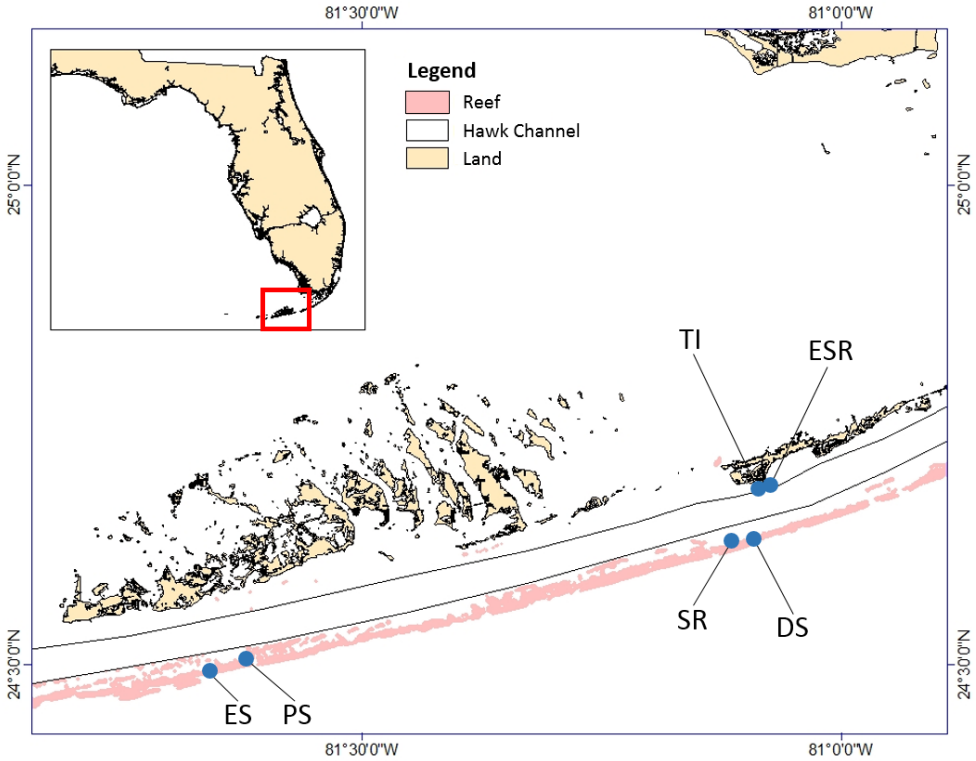
  - Shallow-water, nearshore queen conch in the Keys are not reproductively active (Delgado et al. 2004; Delgado et al. 2019)



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  - Density-dependent reproduction (Delgado and Glazer 2020)
  - Shallow-water, nearshore queen conch in the Keys are not reproductively active (Delgado et al. 2004; Delgado et al. 2019)
  - Limited larval recruitment from upstream sources (Delgado et al. 2008; Vaz et al. 2022)

Knowledge Gaps

- Identification of local larval sources and dispersal pathways is critical for the development of restoration strategies

- Moreover, these restoration strategies must be developed in the face of long-term environmental changes (i.e., ocean warming)

Objectives

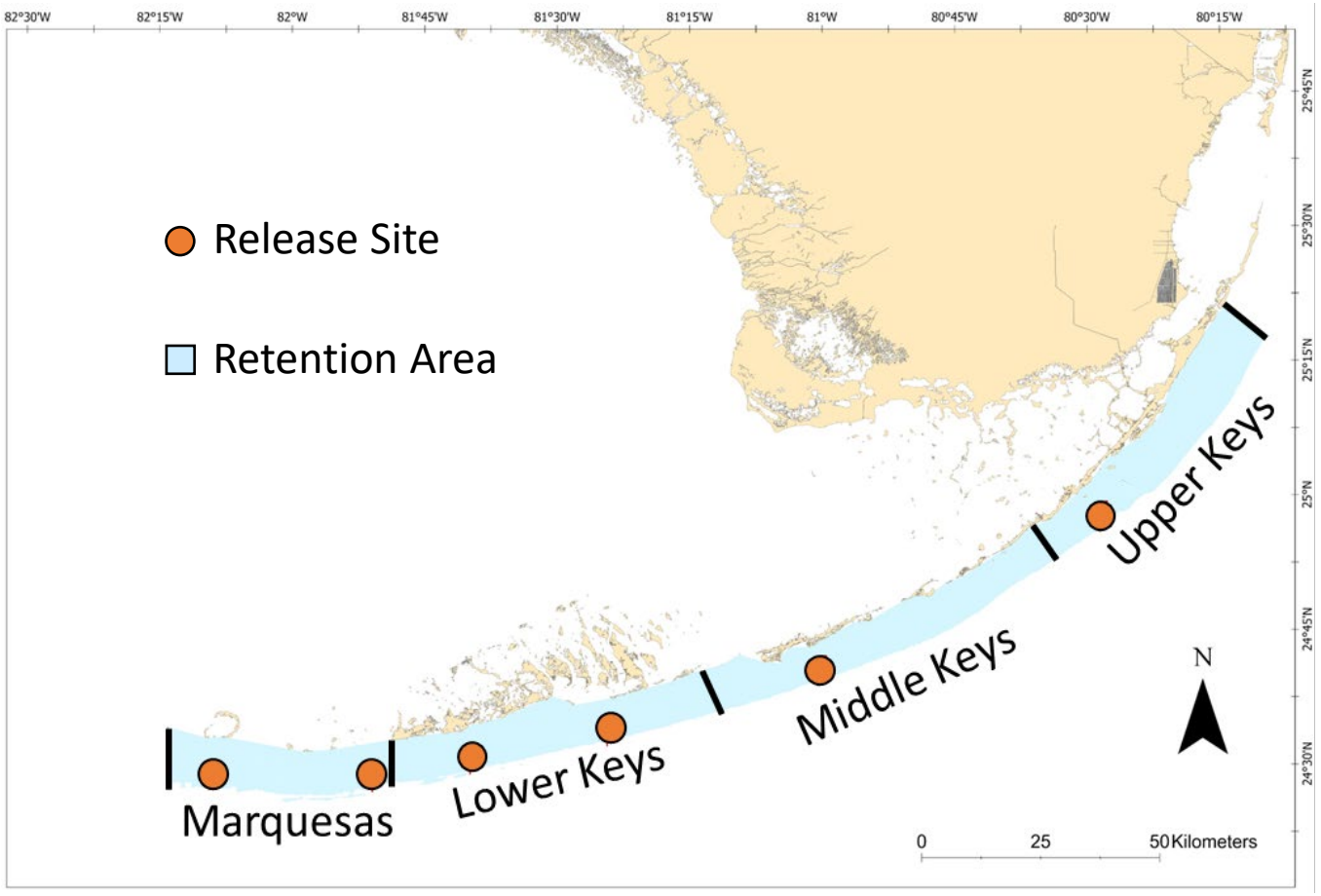
1. Analyze **larval source-sink dynamics** within the Florida Keys using simulated particle releases

2. Use juvenile density data from annual monitoring to **verify simulation results**

3. Evaluate **spatial-temporal sea surface temperature (SST) trends** in relation to the distribution of queen conch in the Florida Keys

Objective 1: Larval Source-Sink Dynamics

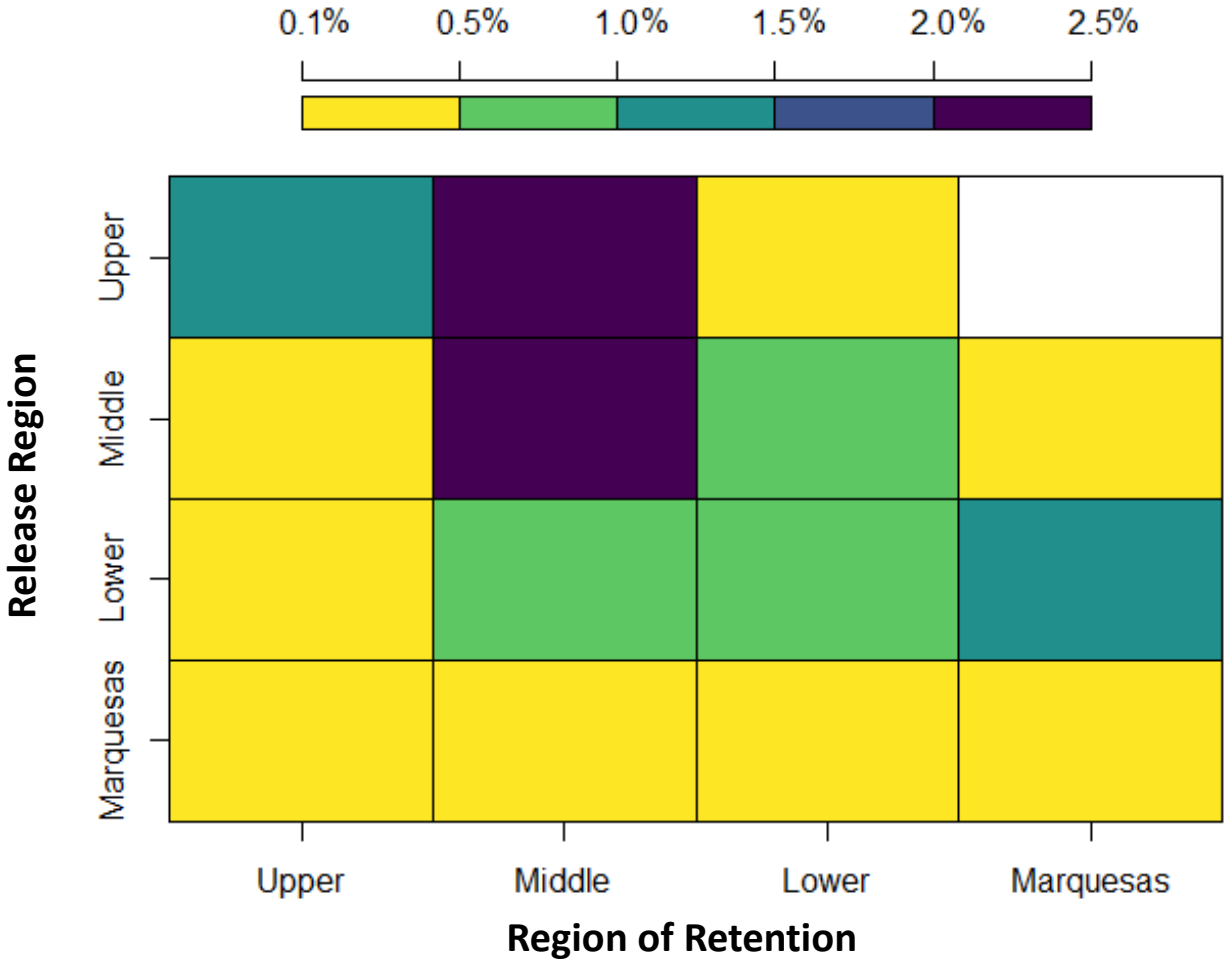
- FKEYS-HYCOM model (Kourafalou and Kang 2012) is the most detailed model available for the region
- Particles were released over six queen conch spawning aggregations each June from 2016 to 2020
- We then evaluated:
  - **Connectivity**
  - **Spatial-Temporal Patterns**



Objective 1: Larval Source-Sink Dynamics

Connectivity

- Regional connectivity matrix showing the % of particles transiting between each release region and the region of retention



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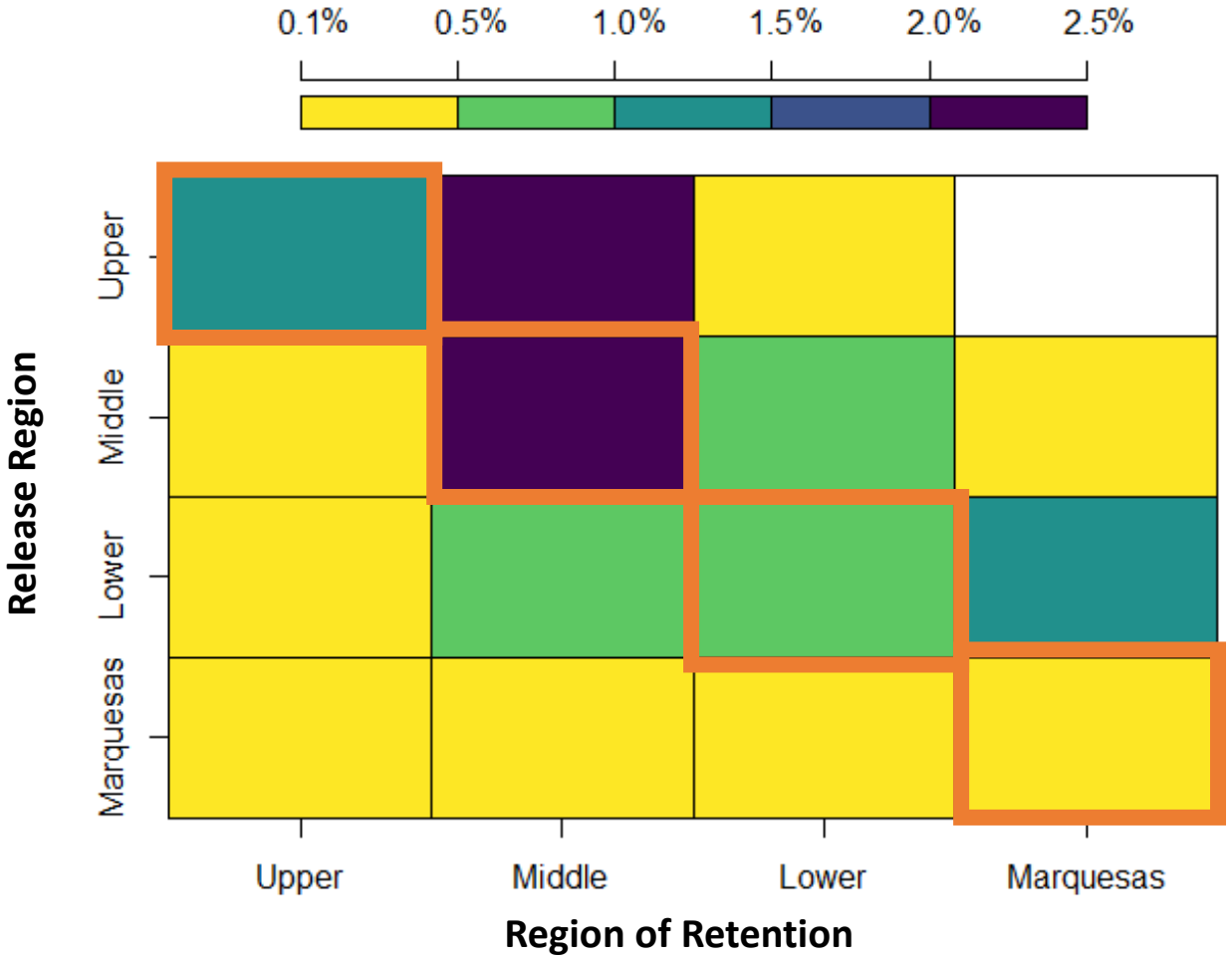


Objective 1: Larval Source-Sink Dynamics

Spatial-Temporal Patterns

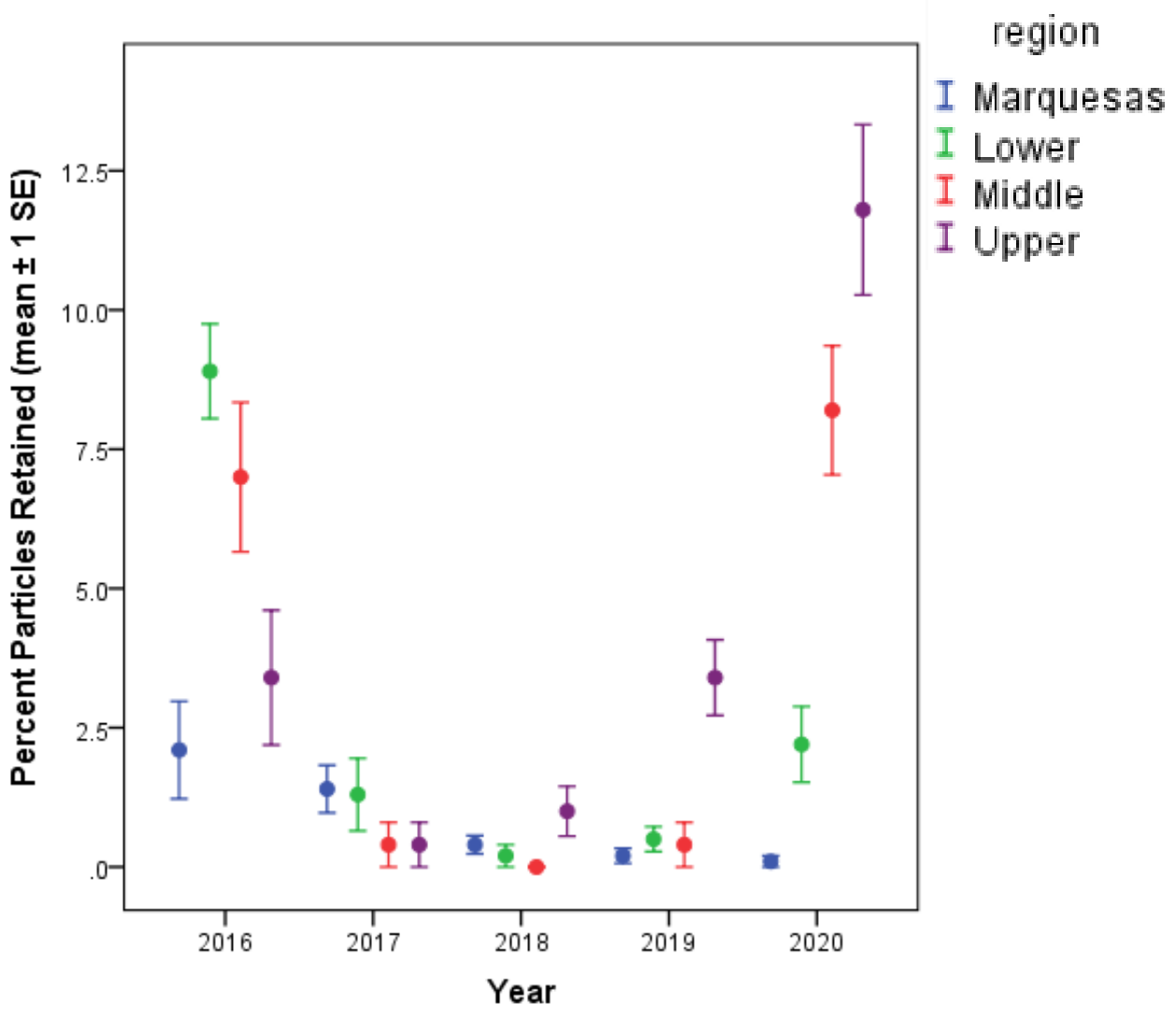
- The mean % of particles retained within the Keys by year and their region of origin

- General Linear Model:

$F_{\text{among regions [3, 12]}} = 1.190$, $P = 0.355$

$F_{\text{among years [4, 12]}} = 3.323$, $P = 0.047$*

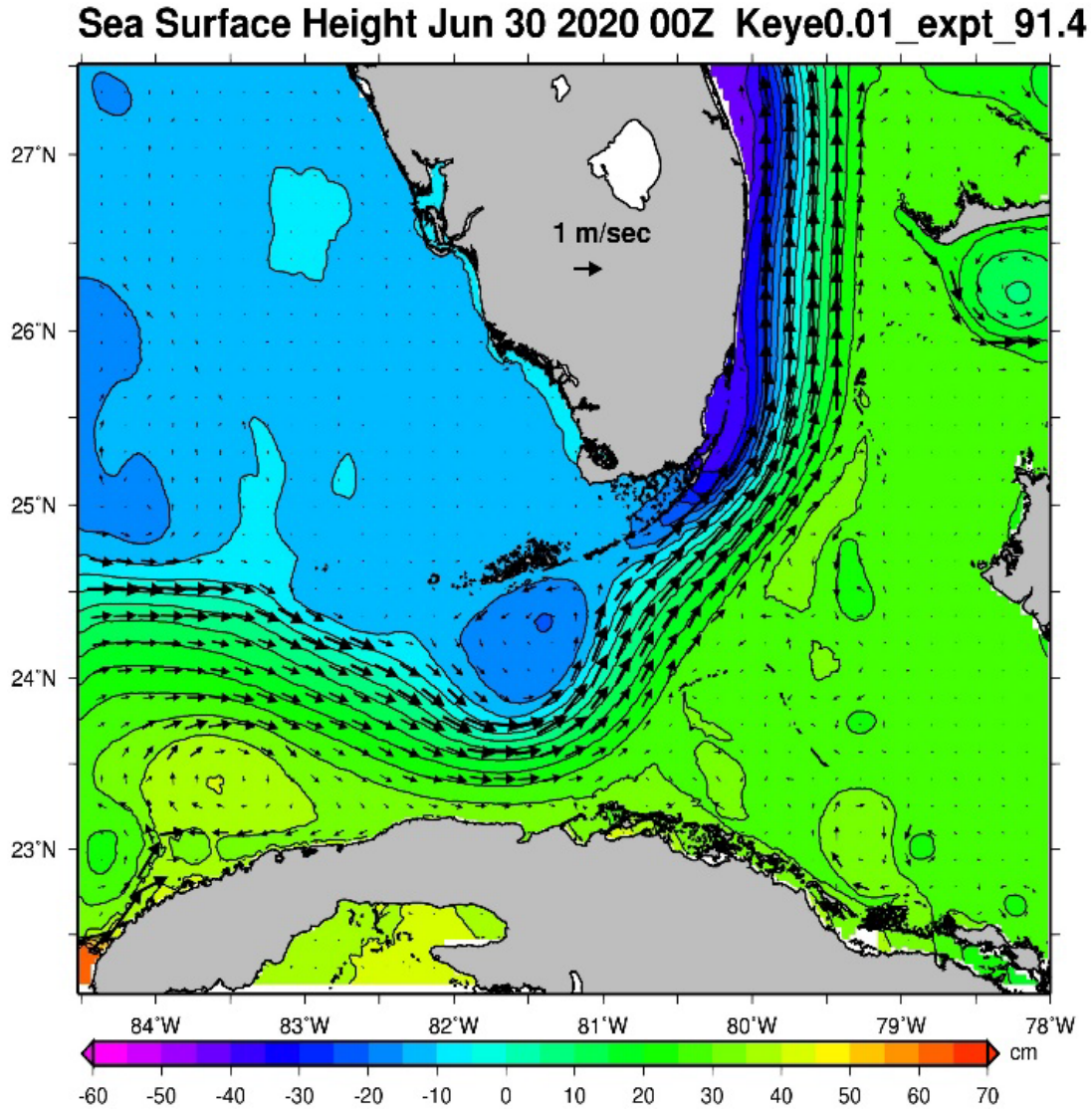
$F_{\text{interaction [12, 130]}} = 18.346$, $P < 0.001$*



Objective 1: Larval Source-Sink Dynamics

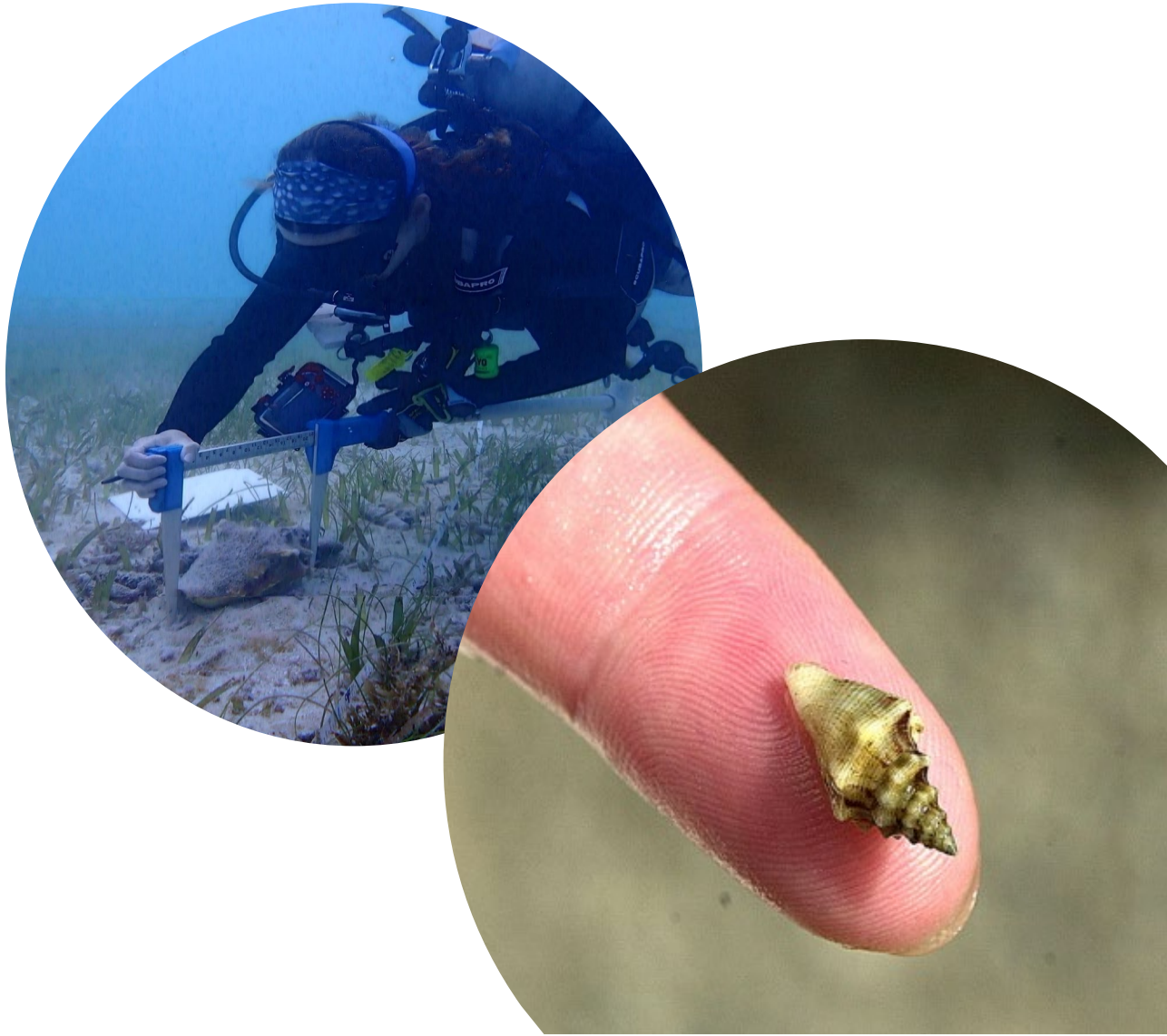
Spatial-Temporal Patterns

- The spatial-temporal patterns seen in the FKEYS-HYCOM simulations are due to the fluctuating position of the Florida Current and its associated eddy field



Objective 2: Field Verification of Model Results

- Annual monitoring: surveyed aggregations throughout the Keys in the summer
- Juveniles were counted and measured
- Newly settled conch are extremely small and do not show up on our surveys
- Density (**≤ 12 cm**) was calculated for each year

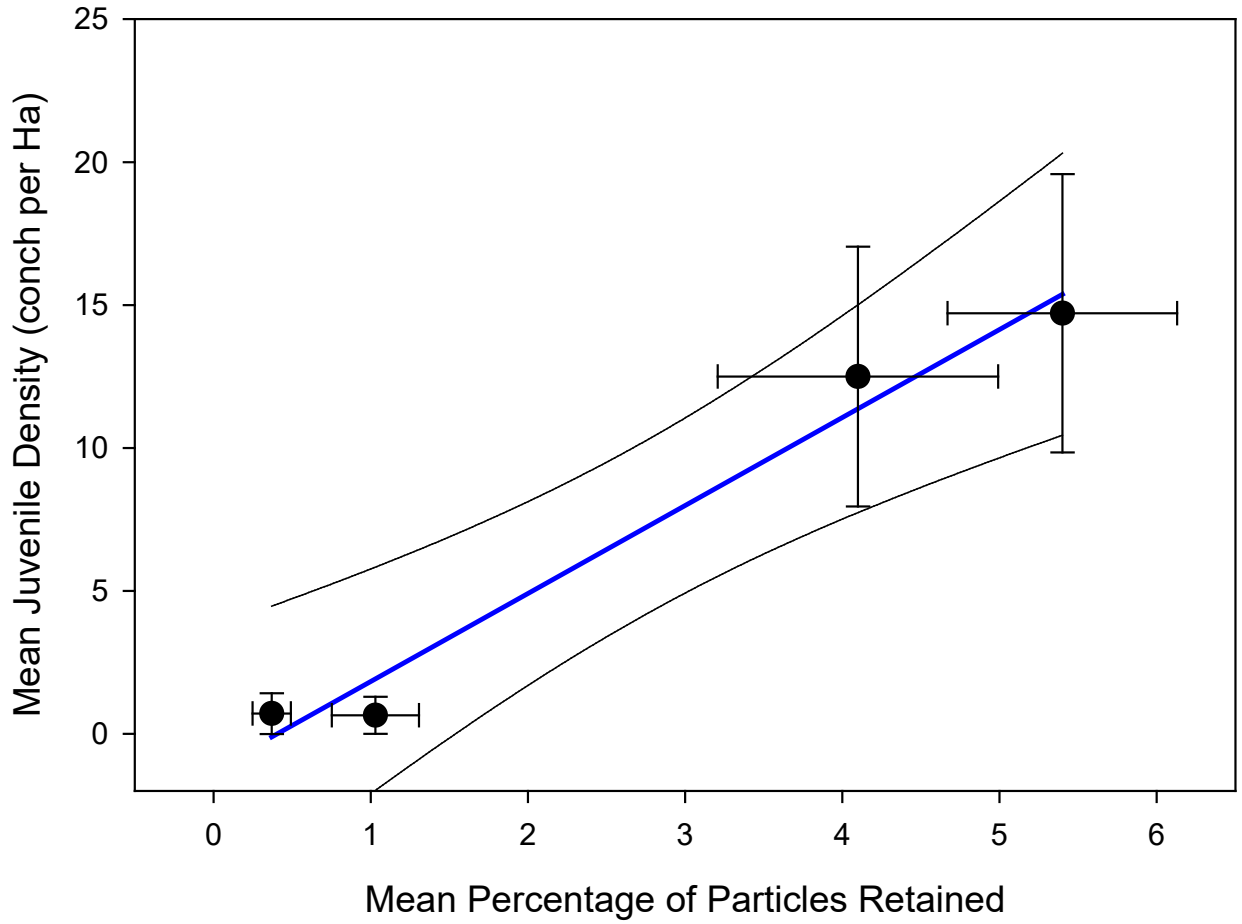


Objective 2: Field Verification of Model Results

Juvenile Density (≤ 12 cm)

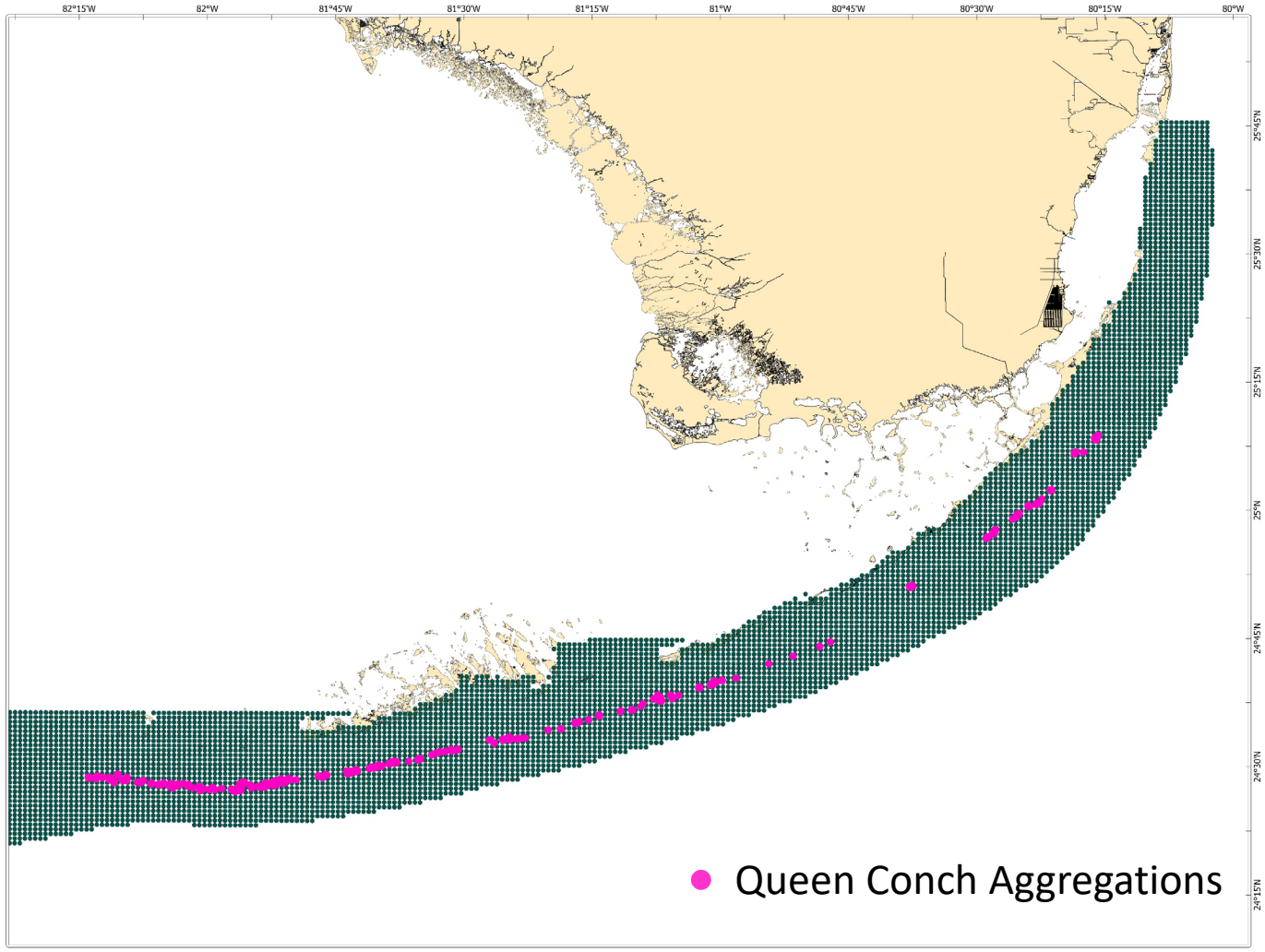
- Juvenile density was correlated with modeled particle retention from the previous year (one-year time lag)

  Pearson: $R^2 = 0.988$, $P = 0.012$



Objective 3: Spatial-Temporal SST Trends

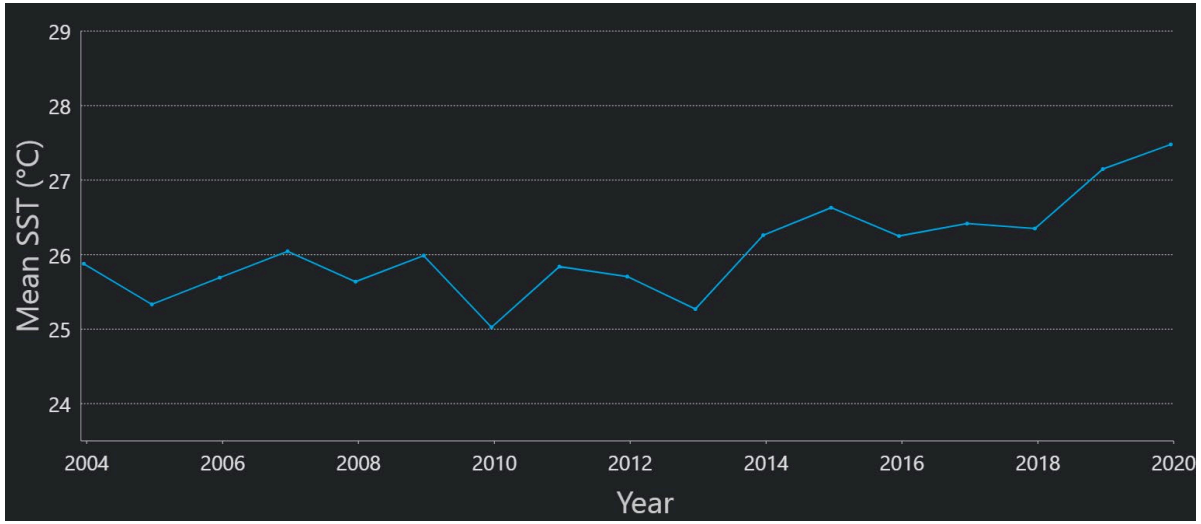
- Spawning aggregations occur in some of the shallowest areas along the reef tract
- 33% of all adult queen conch in the Keys are clustered in spawning aggregations
- Extracted daily SST data from 2004 to 2020 from the FKEYS-HYCOM model
  - **Mean SST**
  - **% of readings > 30°C**



Objective 3: Spatial-Temporal SST Trends

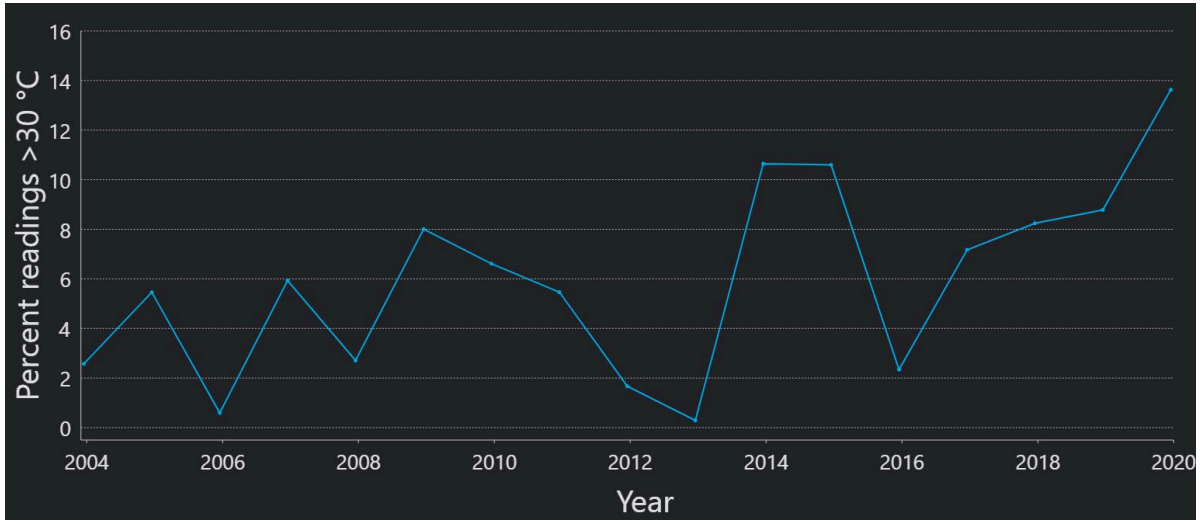
- **Mean SST** showed a significant increasing trend

  Mann-Kendall = 2.92, P = 0.003



- **% of readings > 30°C** showed a significant increasing trend

  Mann-Kendall = 2.18, P = 0.029



Objective 3: Spatial-Temporal SST Trends

- Emerging Hot-Spot Analysis in ArcGIS Pro 2.8 to evaluate trends through space and time
- Identifies intricate patterns
  - **Red** generally **increasing** trend
  - **Blue** generally **decreasing** trend

Symbol	Pattern Name	Definition
	No Pattern Detected	Does not fall into any of the hot or cold spot patterns defined below.
	New Hot Spot	Statistically significant hot spot for the final time step only.
	Consecutive Hot Spot	Single uninterrupted run of statistically significant hot spot bins in the final time-step intervals.
	Intensifying Hot Spot	Clustering of high counts in each time step is increasing overall and that increase is statistically significant.
	Persistent Hot Spot	A location that has been a statistically significant hot spot for ninety percent of the time-step intervals.
	Diminishing Hot Spot	Clustering of high counts in each time step is decreasing overall and that decrease is statistically significant.
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	Historical Cold Spot	The most recent time period is not cold, but at least ninety percent of the time-step intervals have been statistically significant cold spots.

Objective 3: % > 30°C

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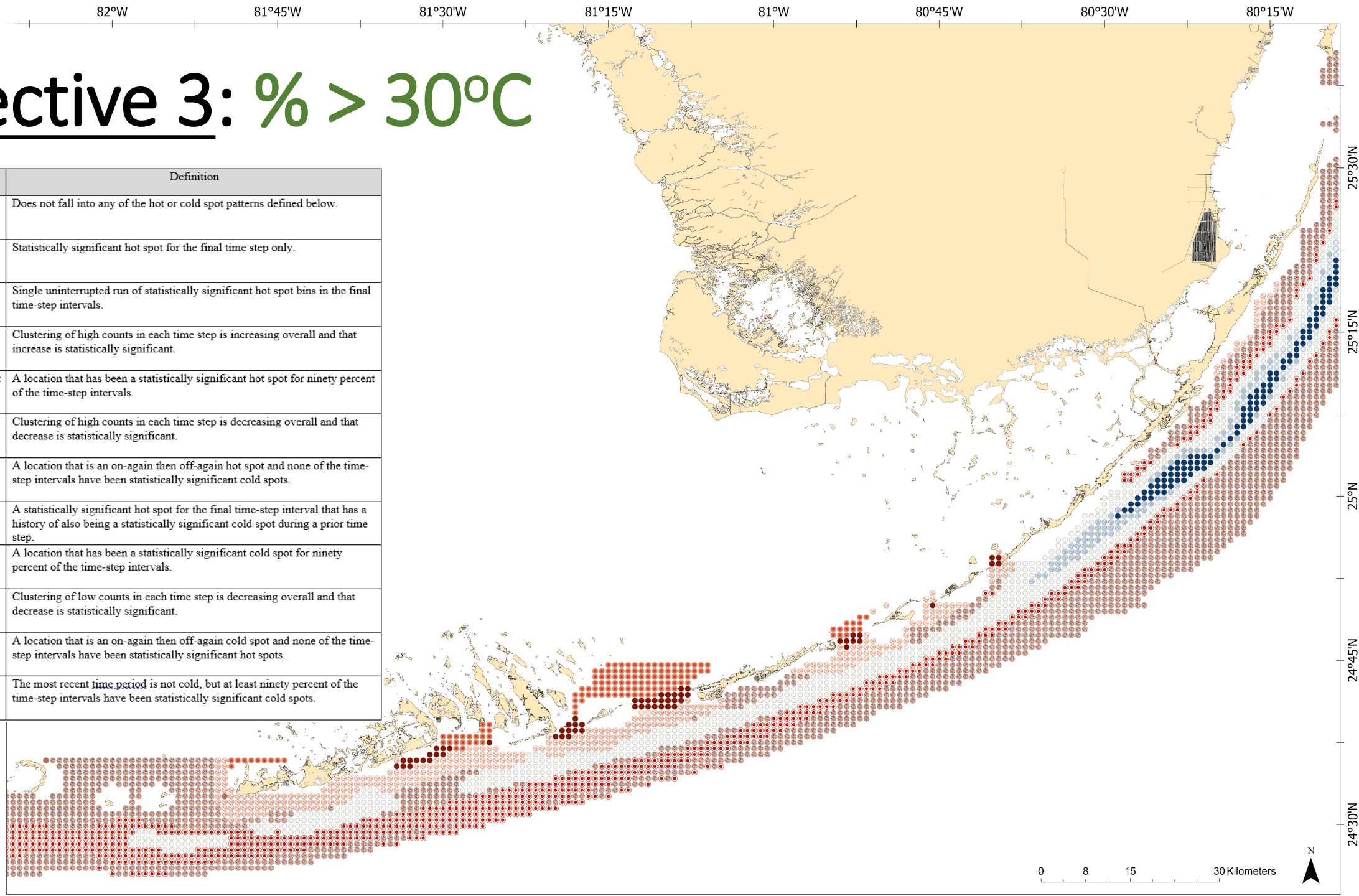

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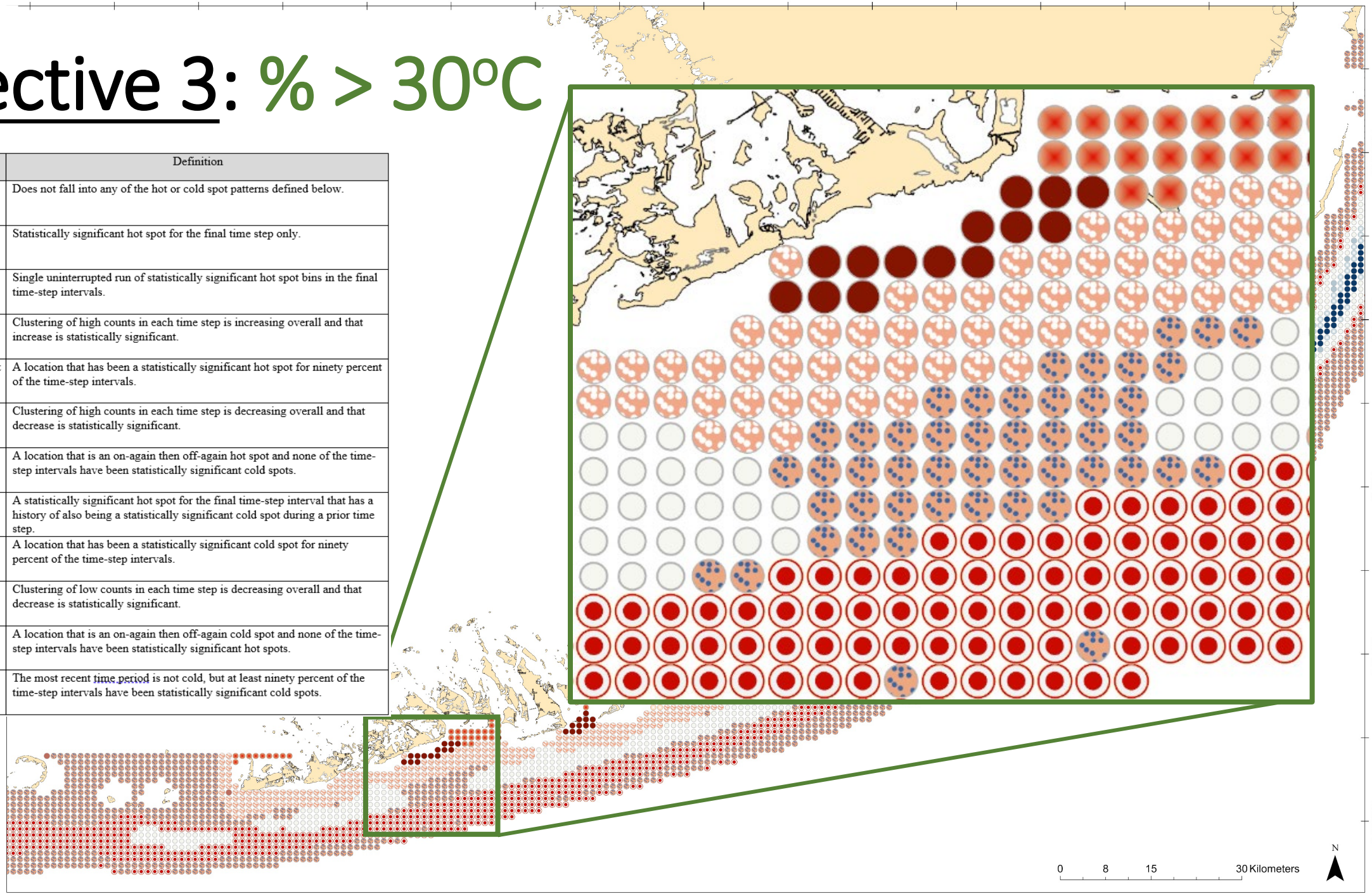
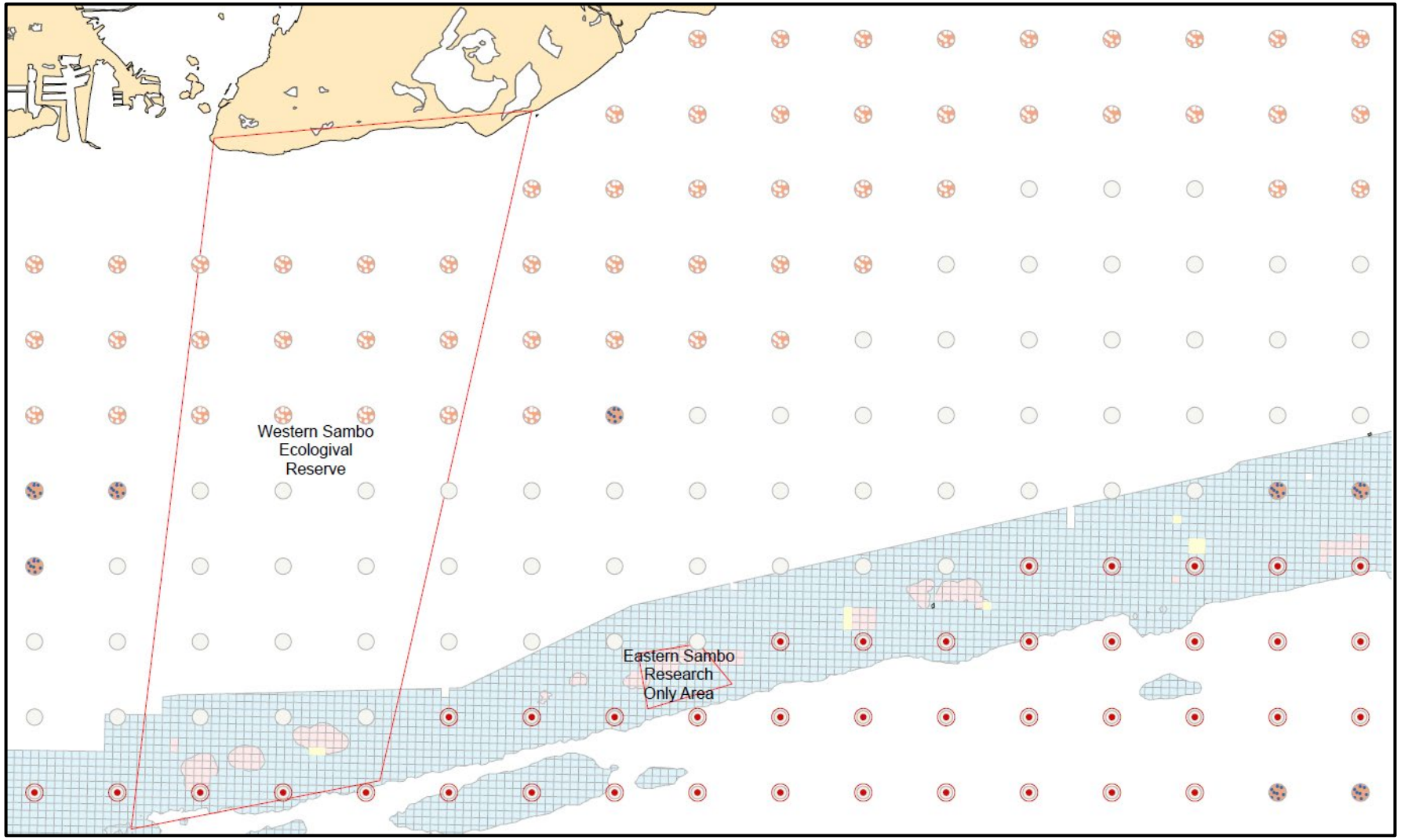


Objective 3: % > 30°C

- 58% of the areal extent of conch spawning aggregations overlap with new hot spots



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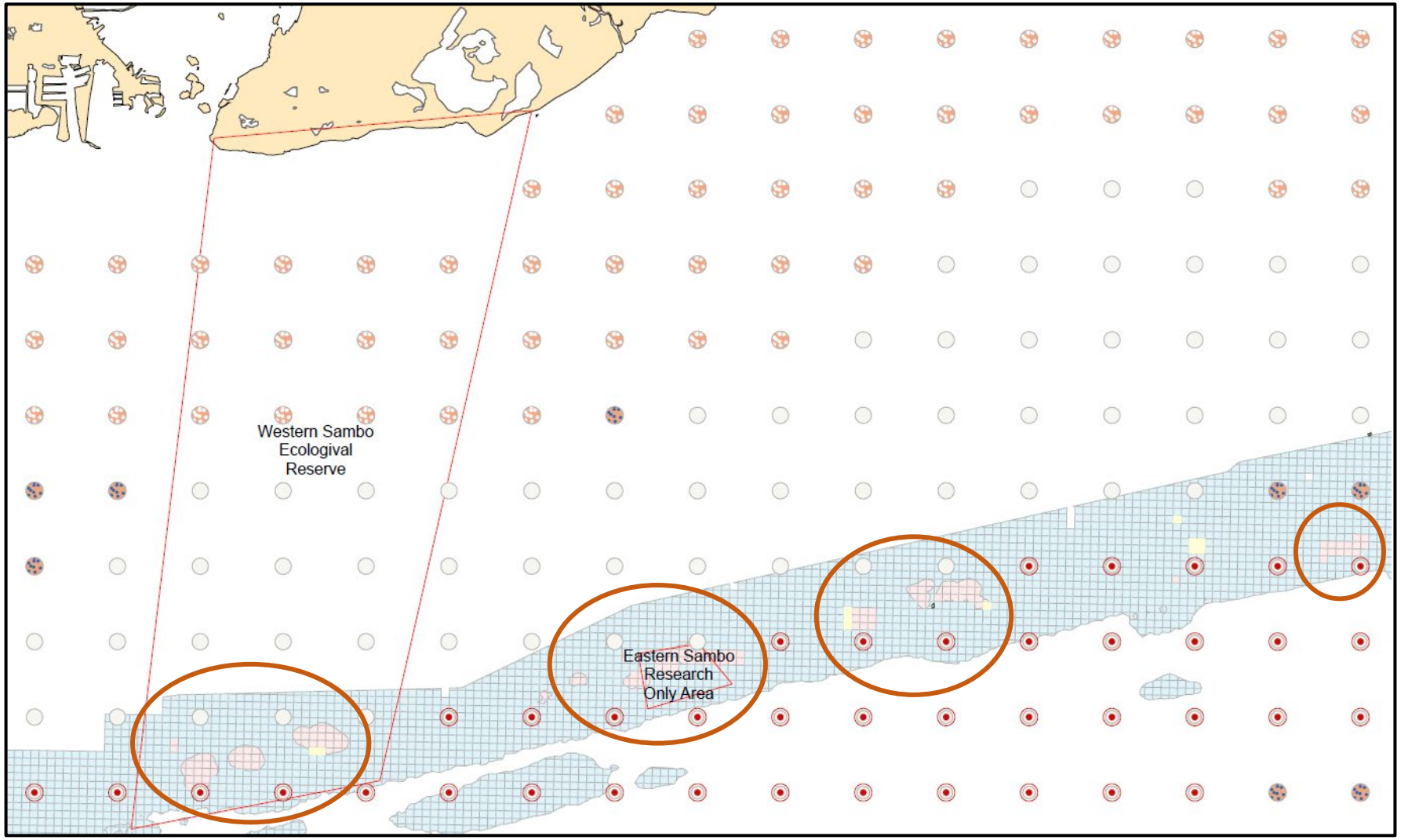

Summary

1. Simulations suggest that all areas of the Keys can act as larval sources, but the main source of larvae will differ from year to year

2. Larval retention appears to be boom or bust

3. Juvenile monitoring data corroborates the temporal patterns seen in the simulations

4. New hot spots have emerged over the offshore spawning aggregations

Take Aways

1. Due to the stochastic nature of larval recruitment, all regions need to be preserved to achieve high levels of recruitment

2. With continued warming, queen conch in spawning aggregations could become negatively affected like those nearshore

3. Their reproductive season is correlated to ocean temperature, so changes may affect timing and length of their reproduction, therefore influencing when larvae may interact with eddy formation


The Conch Republic
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THE FLORIDA KEYS & KEY WEST
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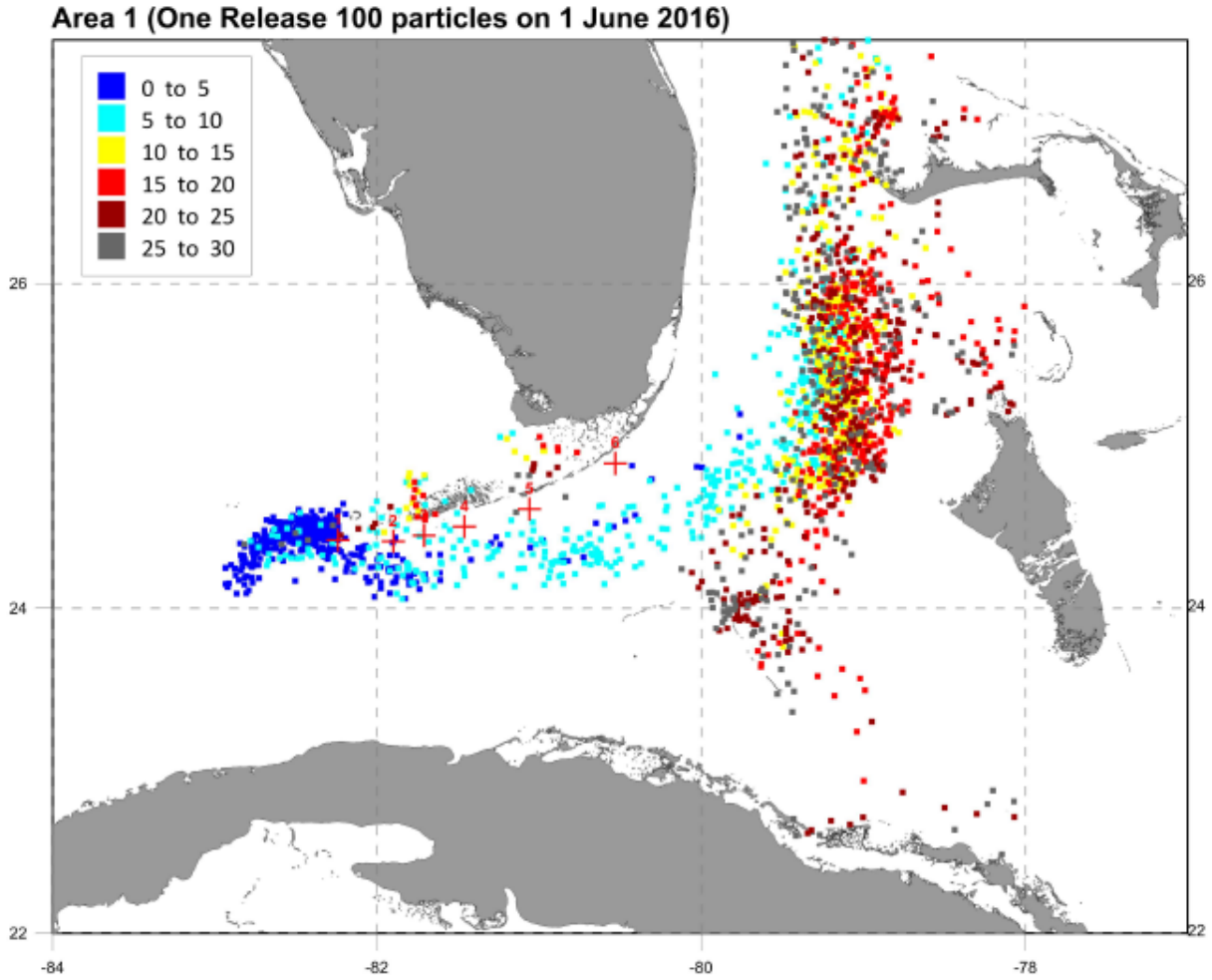
Methods: Larval Source-Sink Dynamics

- 100 particles released in the model's surface layer on each of the first five days of June for the years 2016 to 2020, inclusive

- Peak egg laying (Delgado and Glazer 2020) and early-stage larvae (Stoner et al. 1997; FWC unpublished data) occurs in June



Methods: Field Verification of FKEYS-HYCOM Simulations

- Queen conch aggregations (N = 139) cover approximately 851 Ha Keys-wide

- Aggregations divided into 100 m x 100 m cells (N = 1,071)

- Surveyed randomly selected cells within queen conch aggregations throughout the Keys from Mar. through Oct.

  2017: N = 85

  2018: N = 77

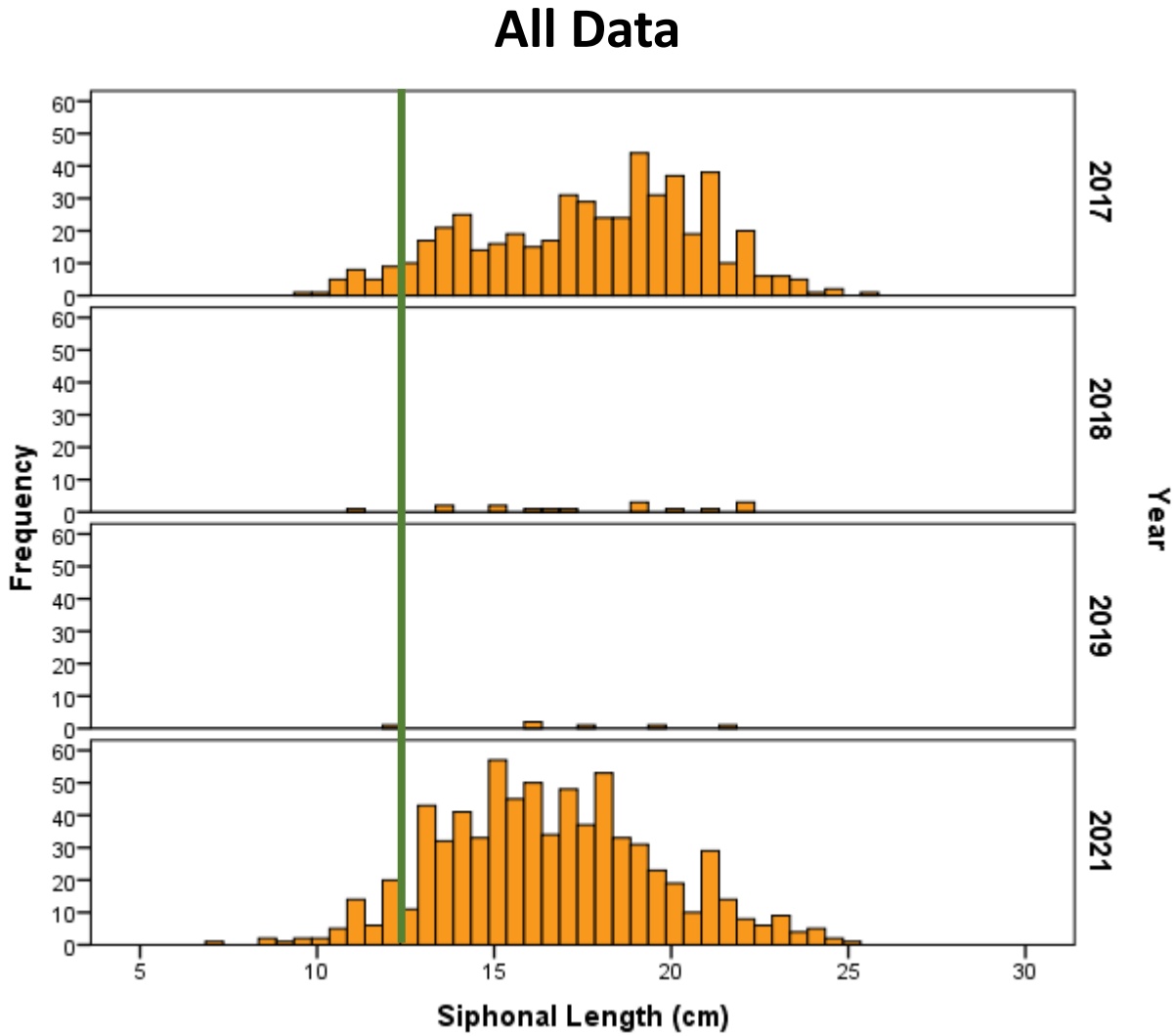
  2019: N = 70

  2020: no surveys due to Covid restrictions

  2021: N = 160

Methods: Field Verification of FKEYS-HYCOM Simulations

- Four 25 m x 2 m transects within each cell; one in each cardinal direction
- Total survey area = 200 m^2
- Juveniles were enumerated and siphonal lengths measured to the nearest 0.1 cm
- Density (**≤ 12 cm**) was calculated for each year



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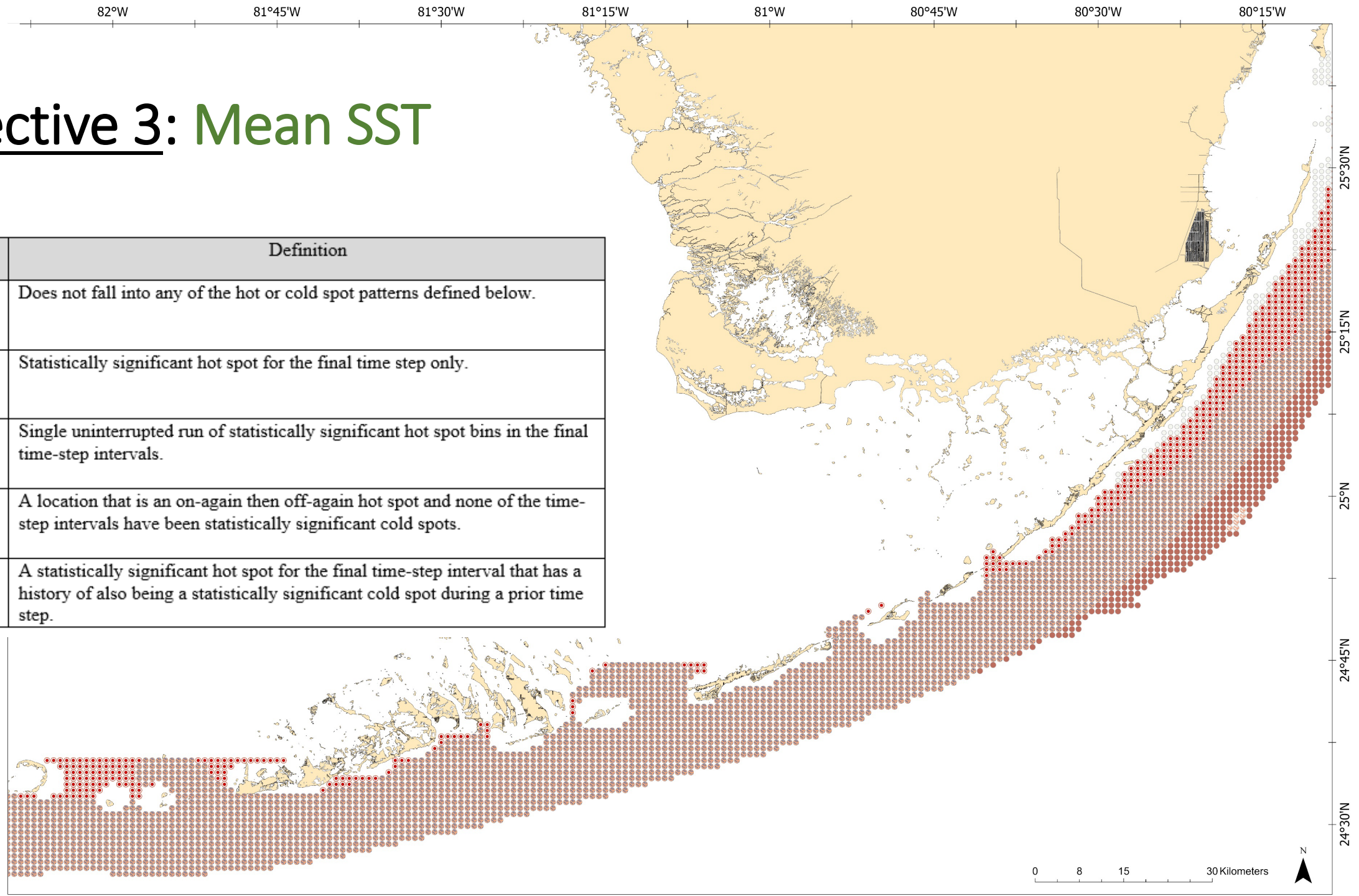
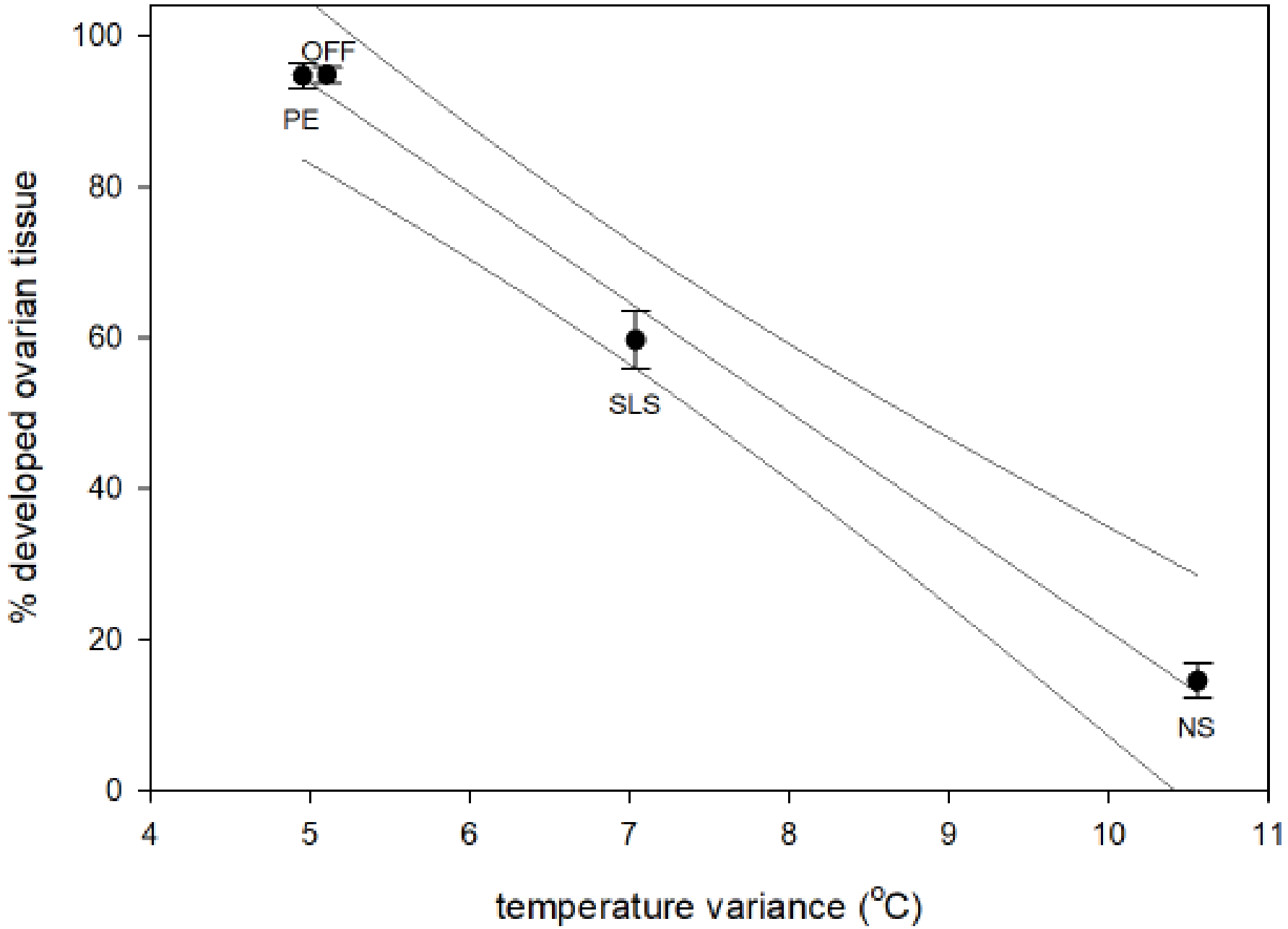
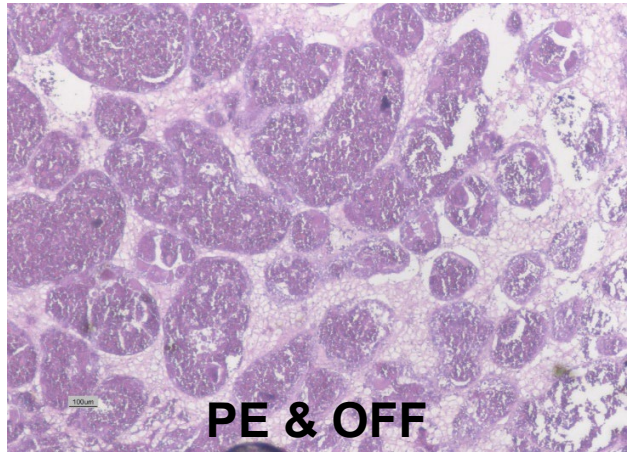
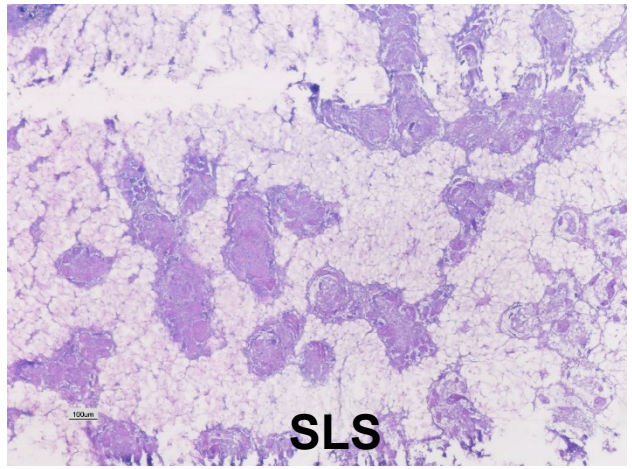
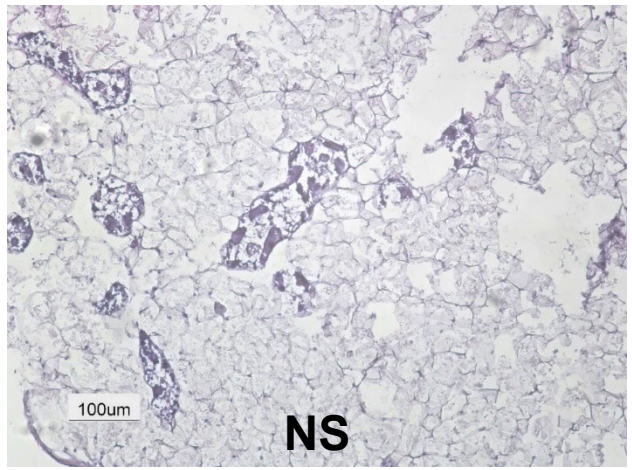


Site	Mean (°C)	Variance (°C)	Readings <24°C	Readings >30°C
SLS	25.7	7.0	**29.7%**	3.6%
PE	27.0	5.0	9.0%	9.9%
OFF	27.3	5.1	7.5%	13.2%
NS	26.9	**10.6**	18.8%	**22.7%**


100
80
60
40
20
0
% developed ovarian tissue
OFF
PE
SLS
NS
4
5
6
7
8
9
10
11
temperature variance (°C)


PE & OFF


SLS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