Using GIS to locate hotspots for bluefin tuna

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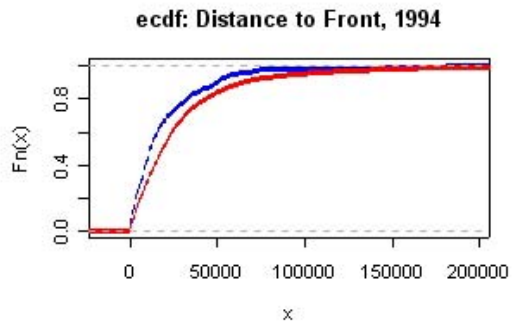
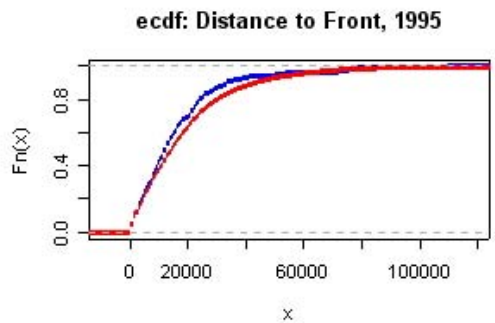
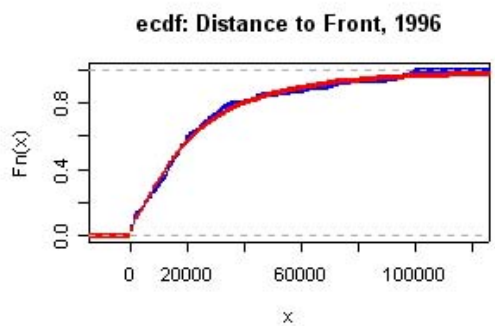
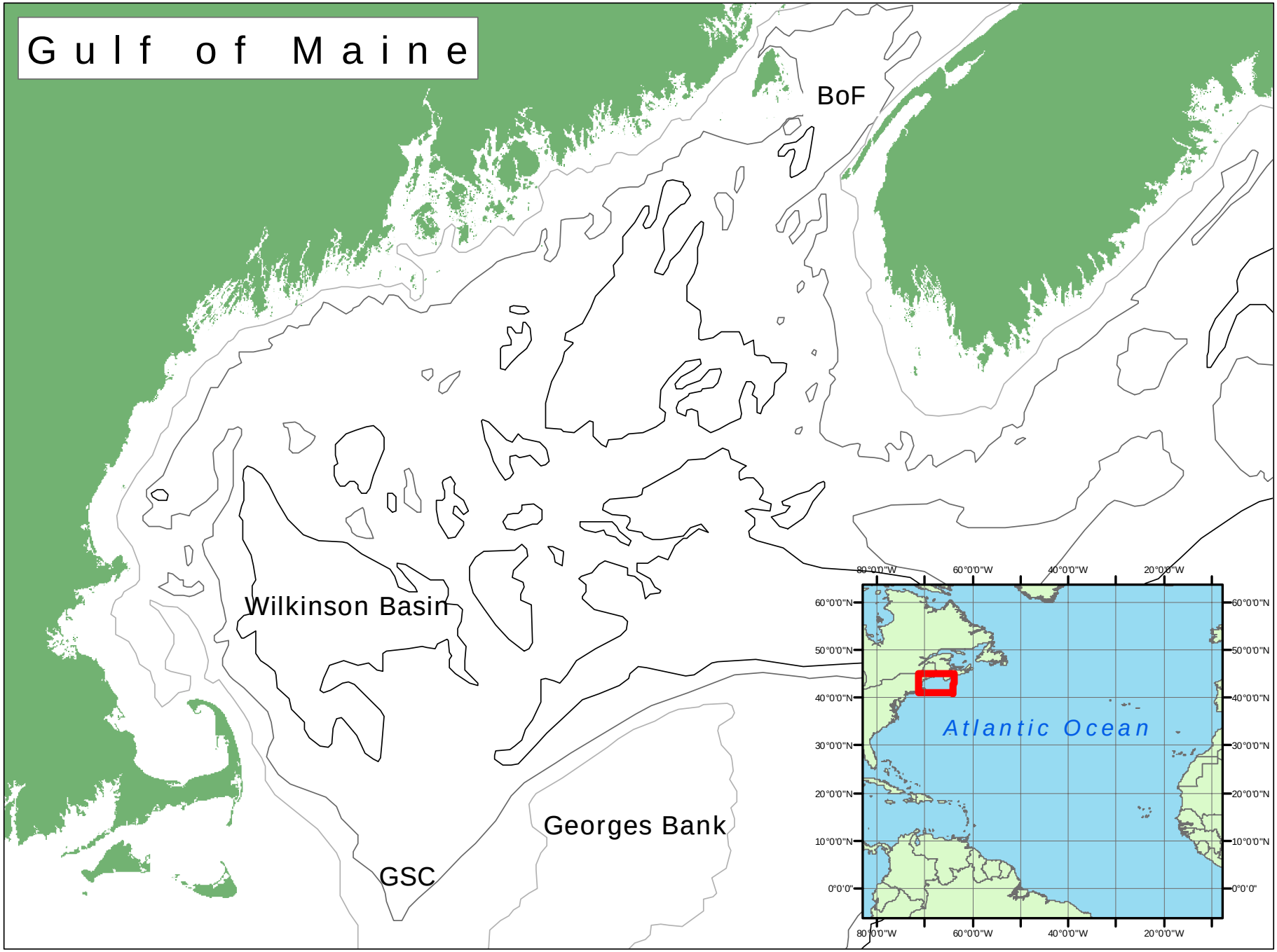
Bluefin and SST fronts

- We looked at 3 years of survey data, and found significant assoc. with SST fronts
- Yet the story was inconsistent at finer time scales
- SST emerged as a more important variable
- Schick et al., 2004, *Fish. Oceanogr.* 13:4 225-238



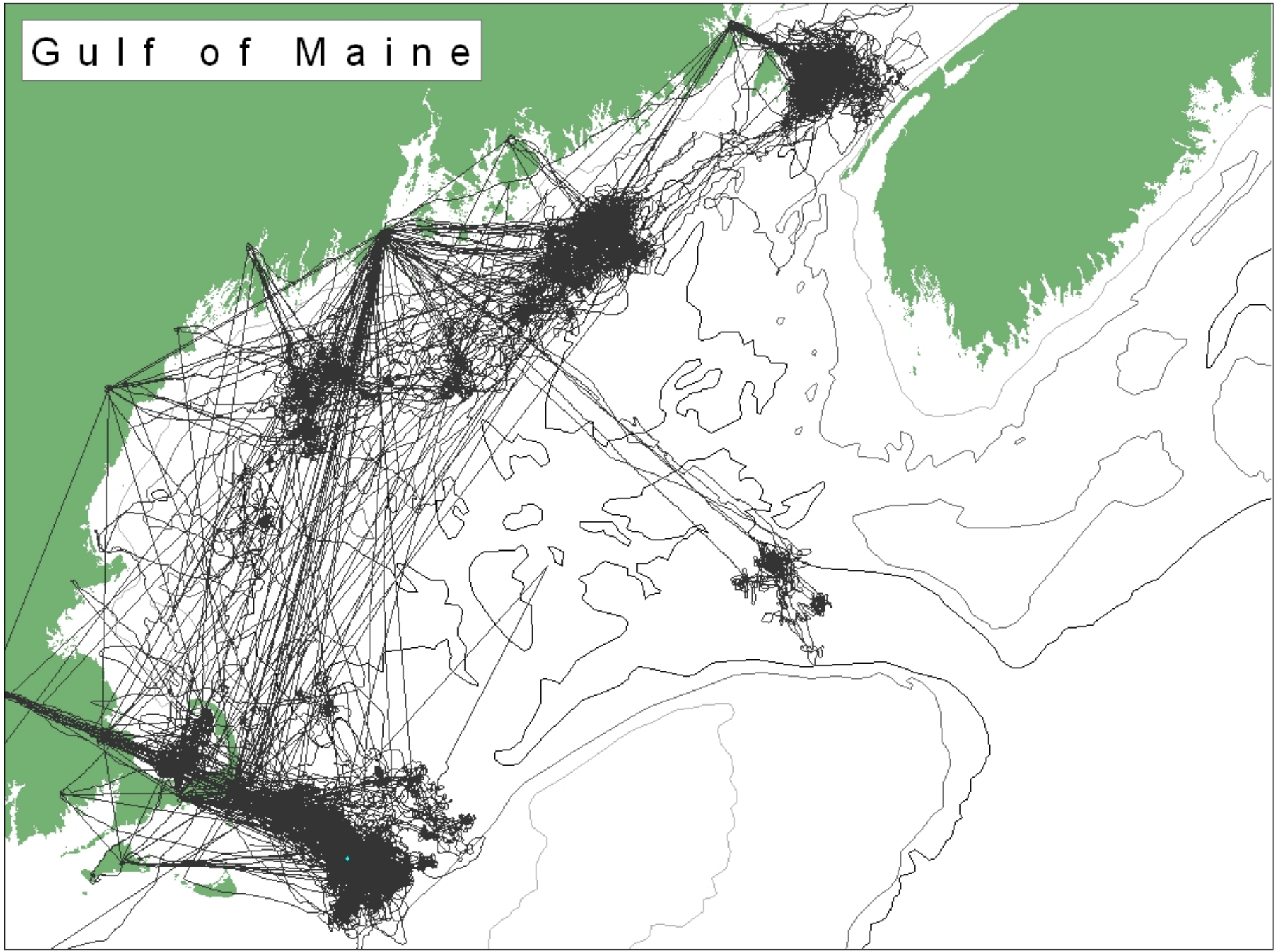


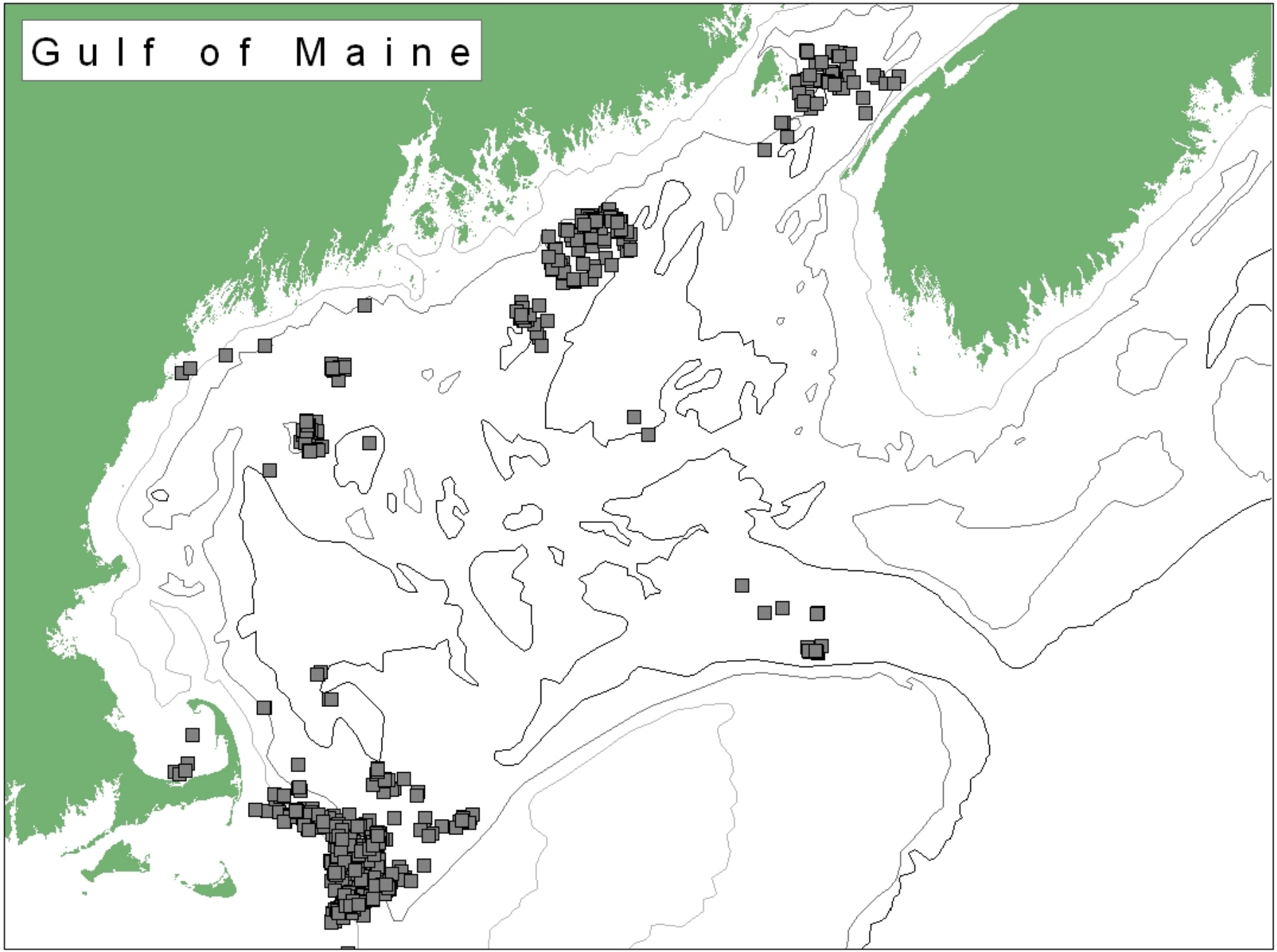



Gulf of Maine
BoF
Wilkinson Basin
Georges Bank
GSC
80°0'0"W
60°0'0"W
40°0'0"W
20°0'0"W
60°0'0"N
50°0'0"N
40°0'0"N
30°0'0"N
20°0'0"N
10°0'0"N
0°0'0"
Atlantic Ocean

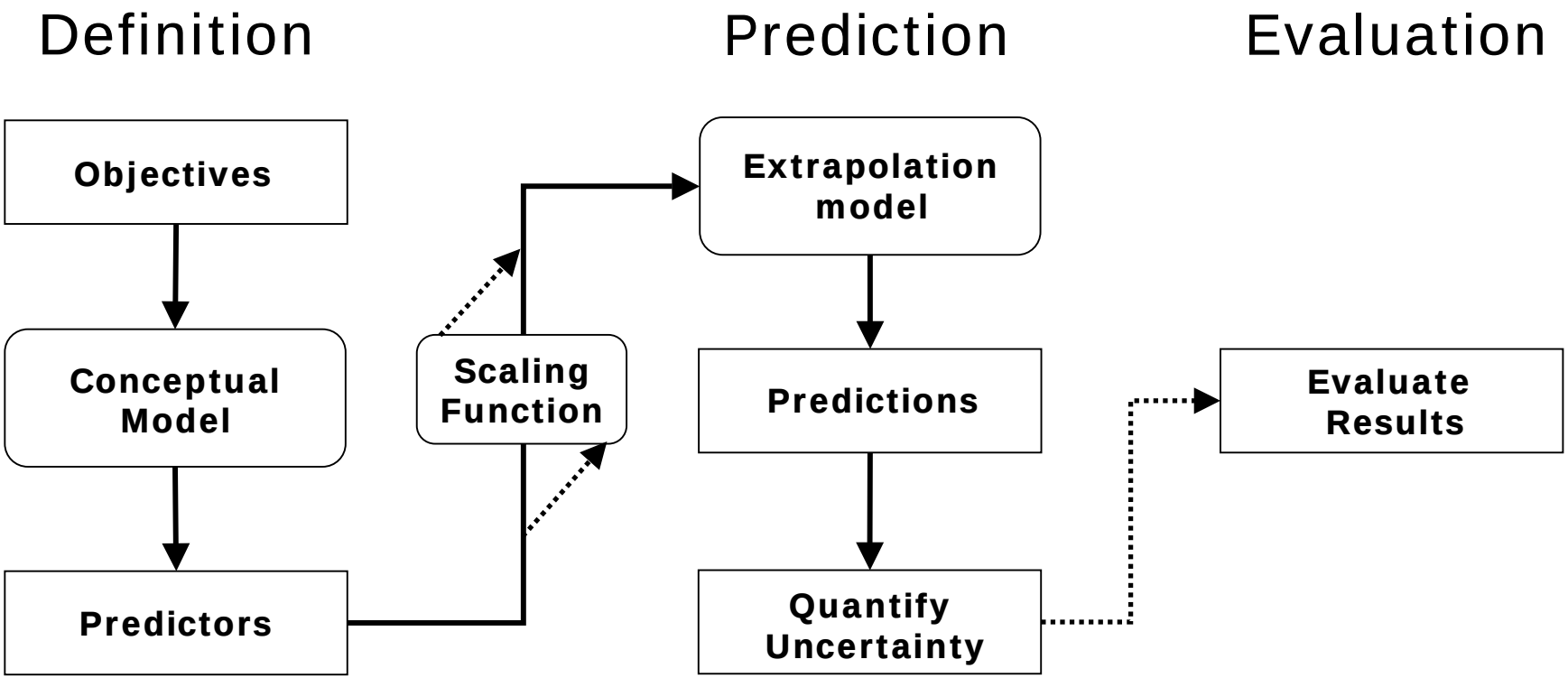
Bluefin Data

- Fishery linked random aerial surveys
- Presence-absence data from these over-flights
- Oceanographic variables sampled at each p/a data point


Gulf of Maine


Gulf of Maine

Spatial Extrapolation



Adapted from Miller et al., 2004, BioScience 54(4), 310-320

Definition

- Locate hotspots for bluefin tuna
  - Use statistical model & GIS to examine unsampled areas in GOM
  - Map out habitat cells on a daily timestep
  - Sum within and across years to explore persistence

Definition

- Data-driven statistical model

  `species ~ d.front + front.dens + temp + depth + slope`

- H_o: With GLM, fish are seen no closer to fronts than random

Definition

- Sea Surface Temperature
- Distance to a SST front
- Time-lagged density of SST fronts
- Bottom depth
- Bottom slope

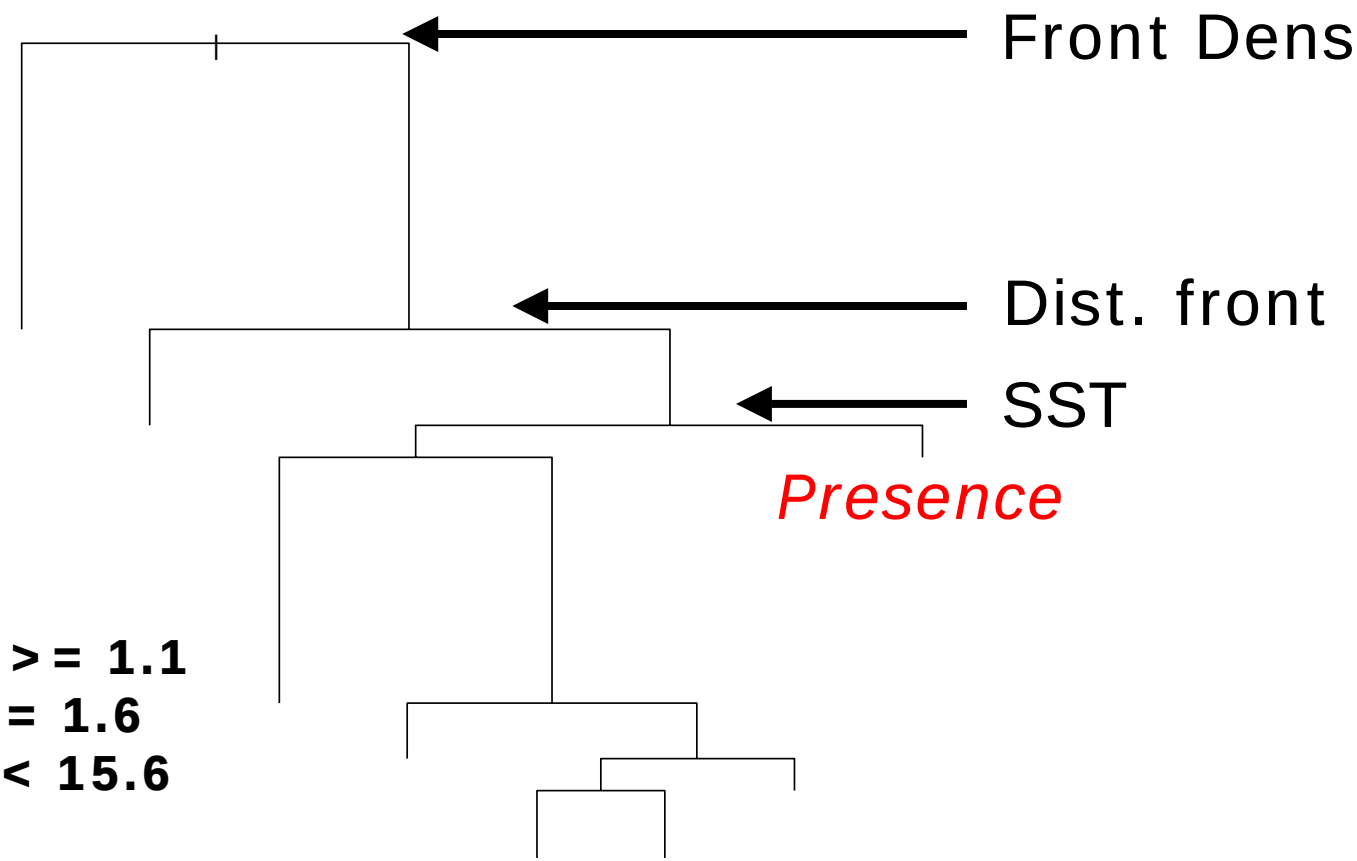
Prediction

- What is CART?
  - Recursive data partitioning algorithm
  - With class data, split variable is chosen such that it minimizes the deviance for the tree
  - Akin to a classification key
  - Results printed graphically

See De'ath & Fabricious, 2000, Ecology 81(11): 3178 - 3192

Fitted Classification Tree

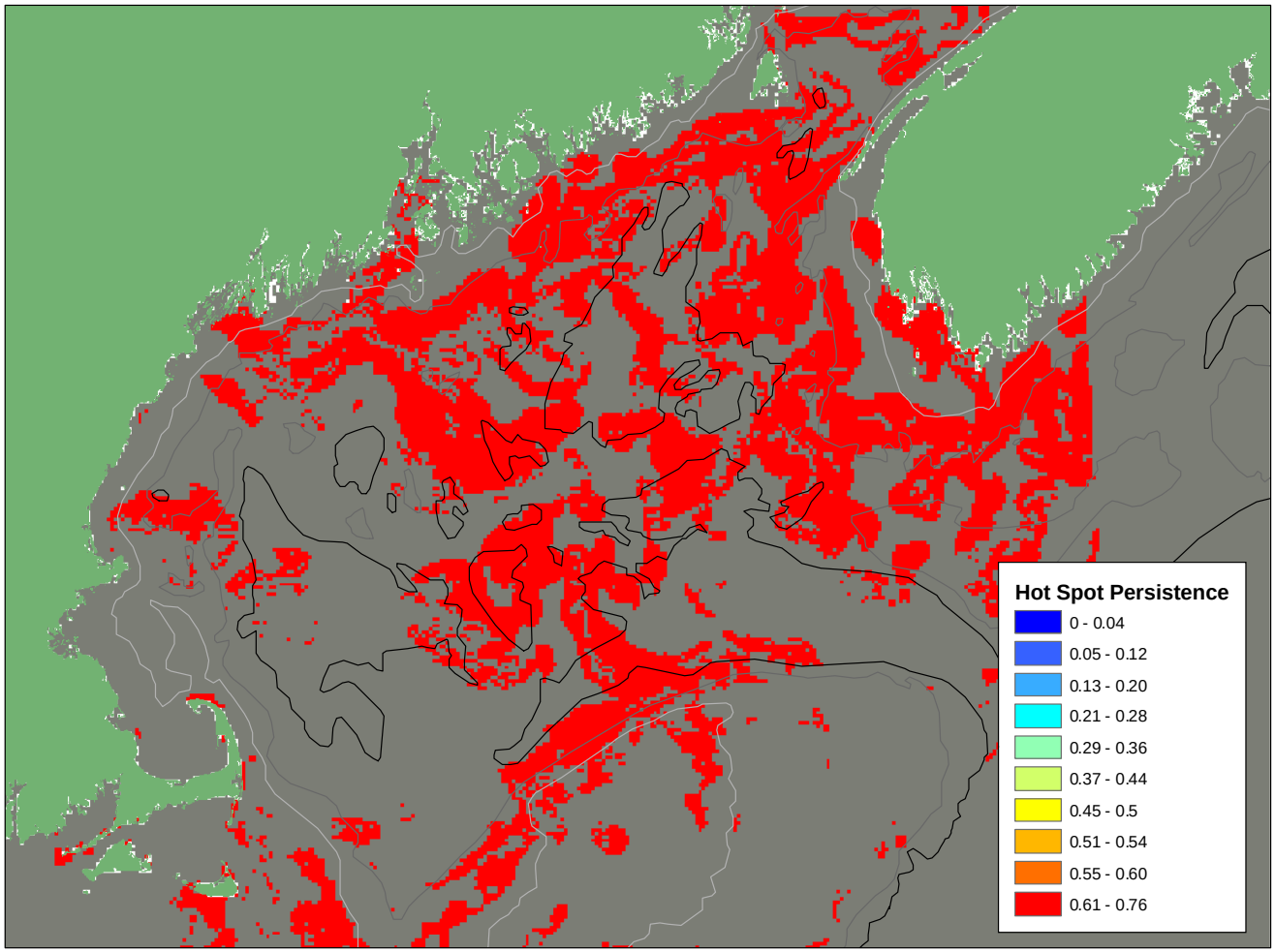
July 30th 1995, All variables: Raw Data



1) root
3) front.dens >= 1.1
7) d.front >= 1.6
15) temp < 15.6

Spatial Extrapolation: Prediction

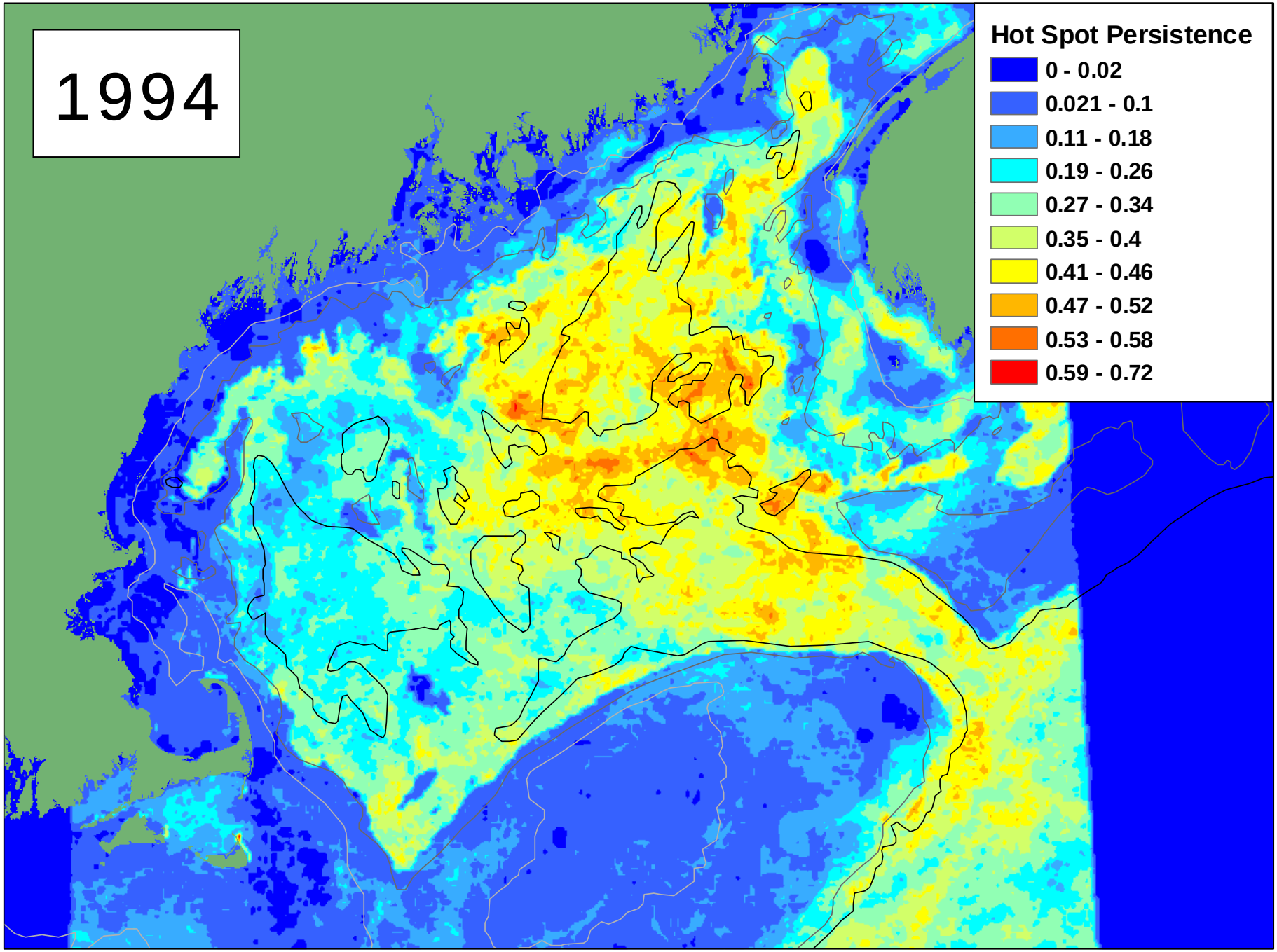
Objectives	Conceptual	Predictors	Scaling	Extrapolation	**Predictions**	Uncertainty	Evaluate

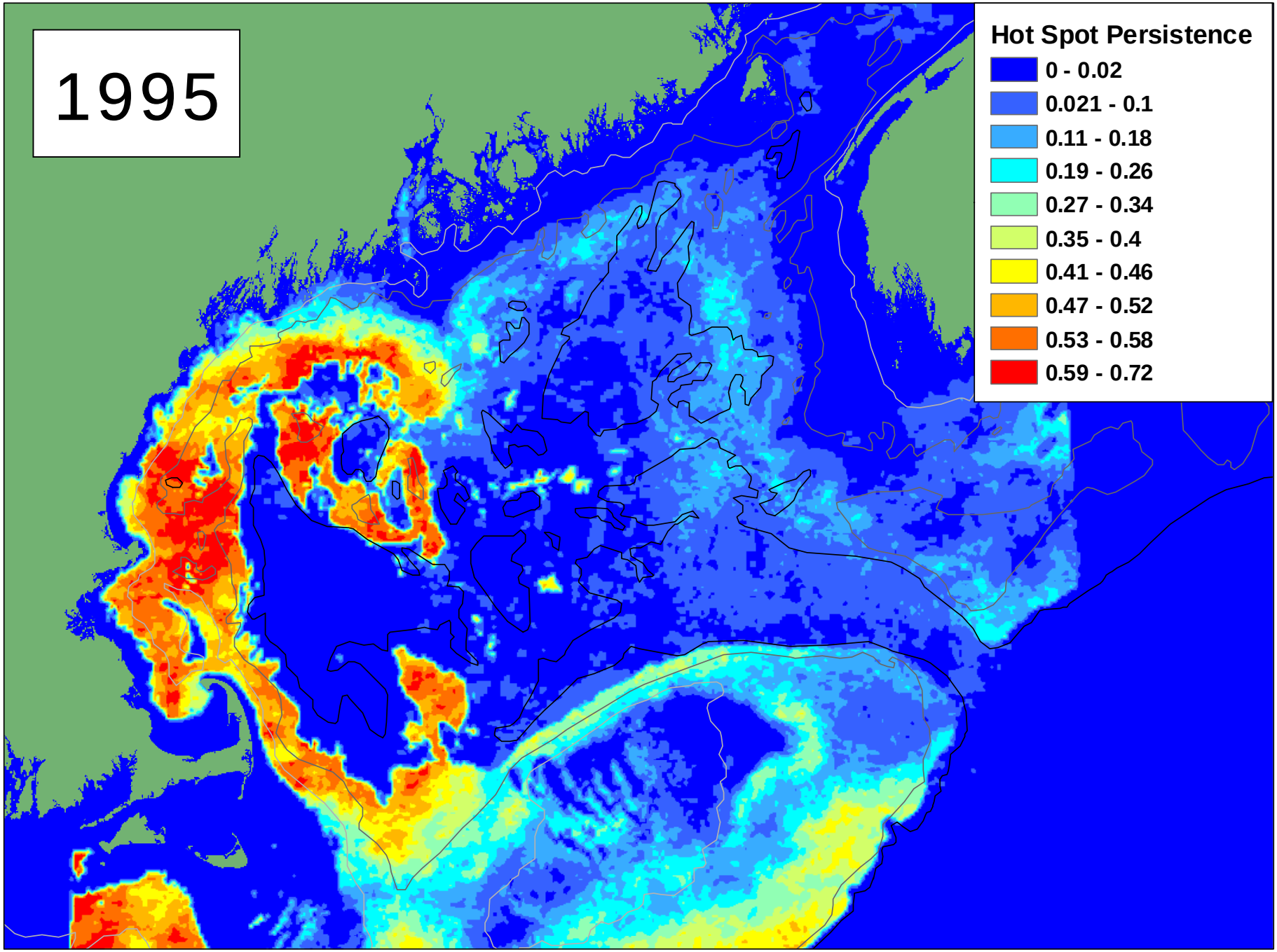


Spatial Extrapolation: Prediction

Objectives	Conceptual	Predictors	Scaling	Extrapolation	Predictions	Uncertainty	Evaluate

- To develop an index of persistence:
  - Summed the daily grids
  - Divided by the number of days
  - Classify that into bins
  - Results...?


1994
Hot Spot Persistence
0 - 0.02
0.021 - 0.1
0.11 - 0.18
0.19 - 0.26
0.27 - 0.34
0.35 - 0.4
0.41 - 0.46
0.47 - 0.52
0.53 - 0.58
0.59 - 0.72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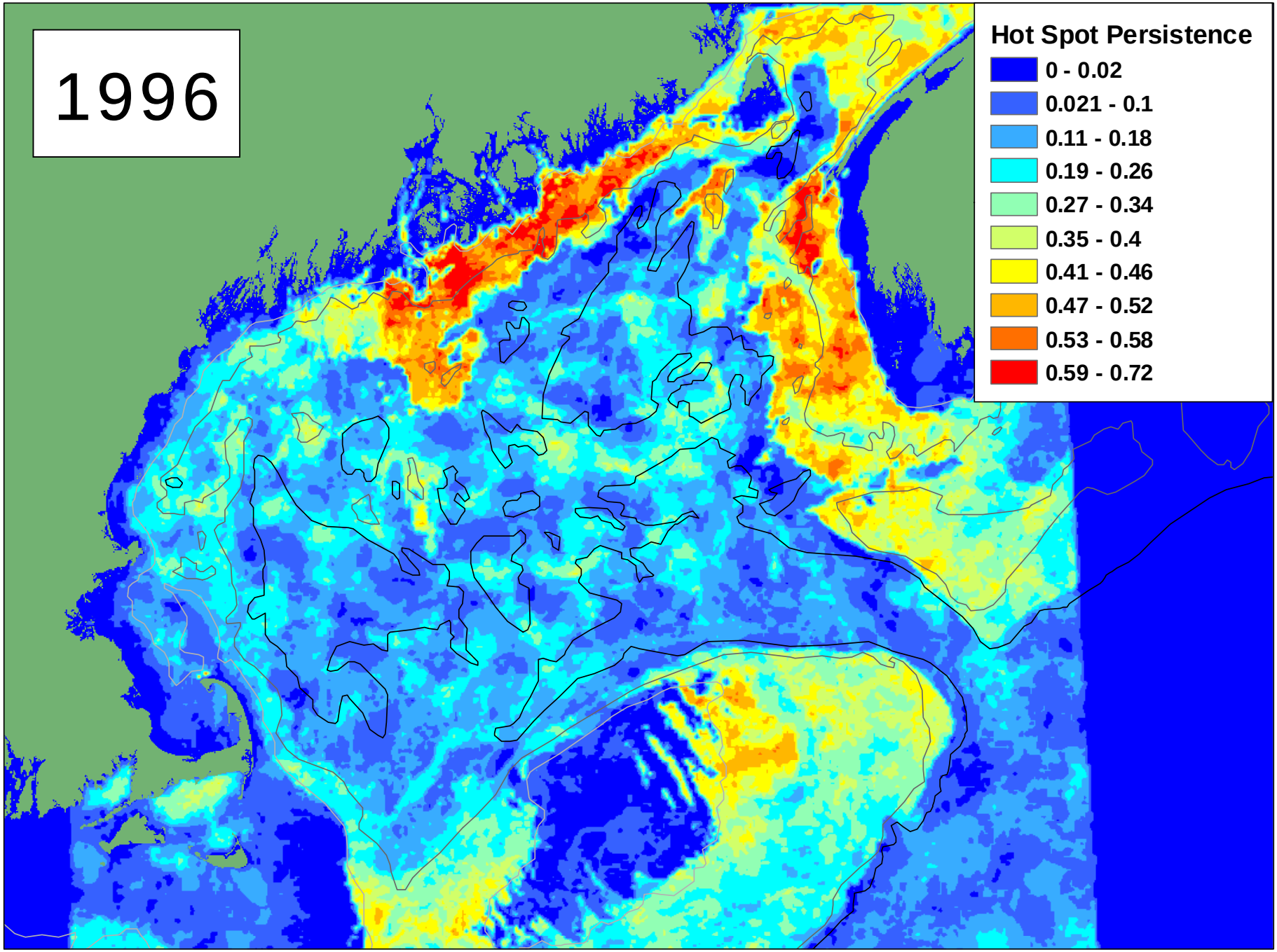
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Hot Spot Persistence
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0.11 - 0.18
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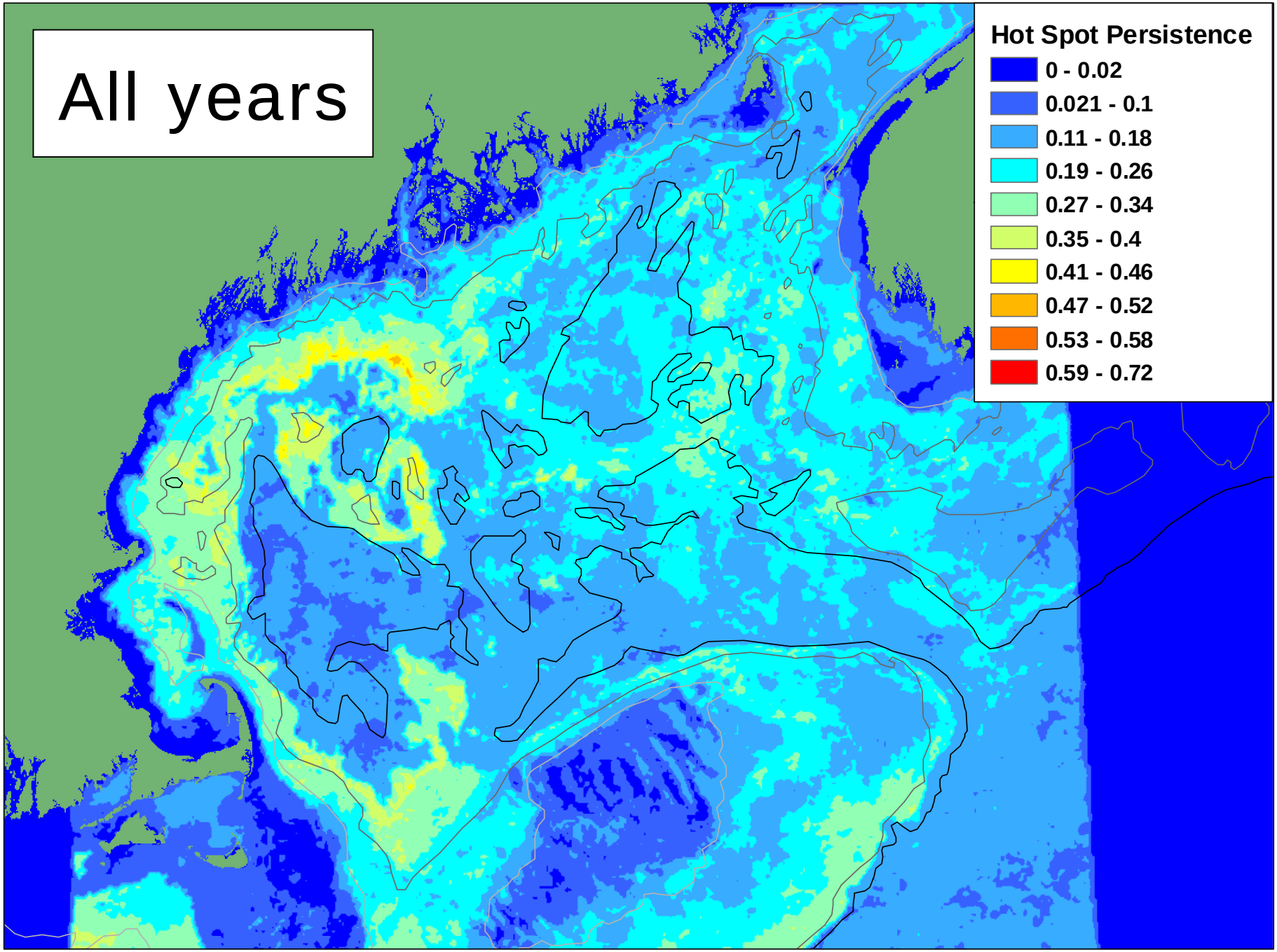
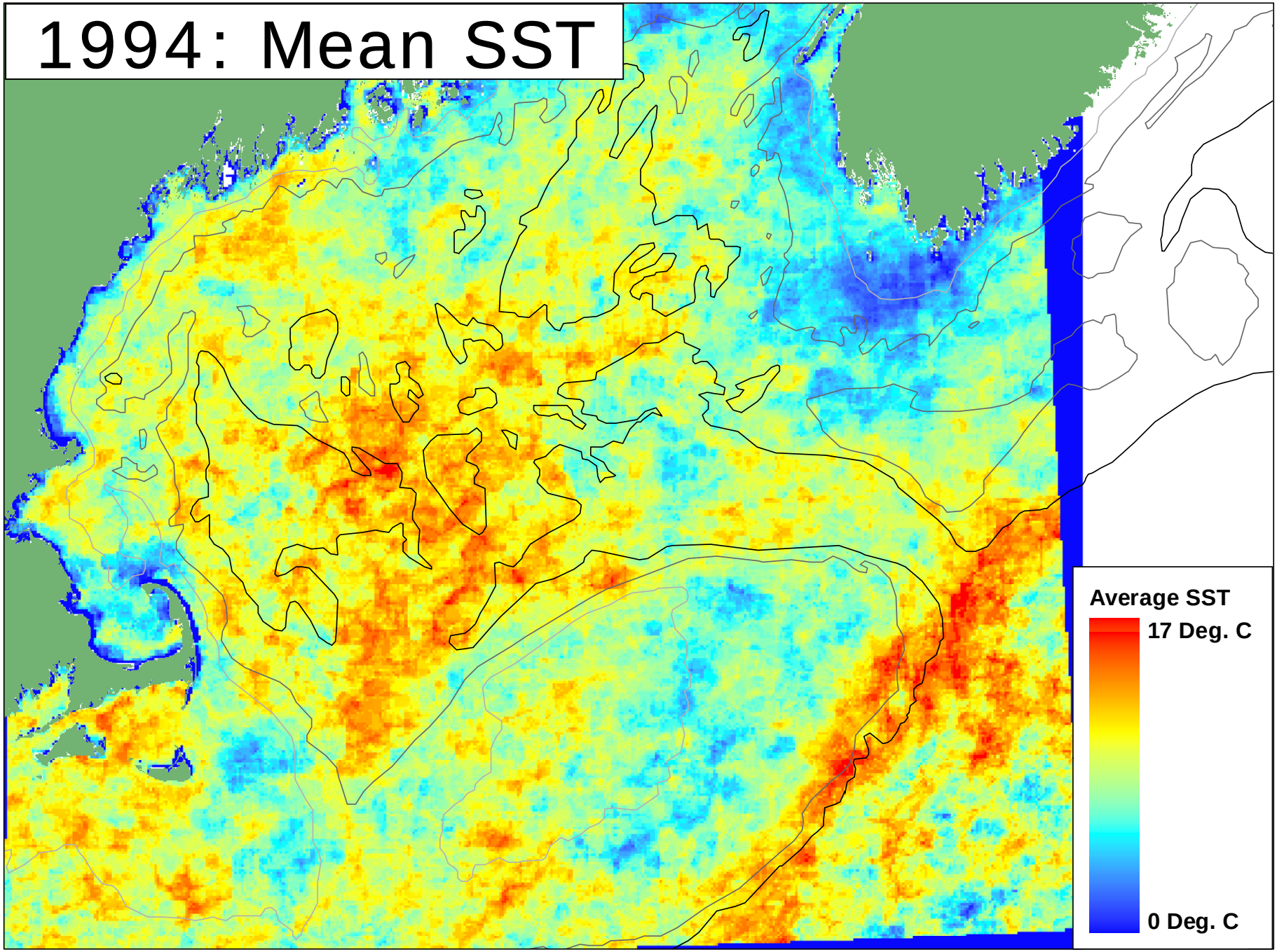
0.41 - 0.46
0.47 - 0.52
0.53 - 0.58
0.59 - 0.72

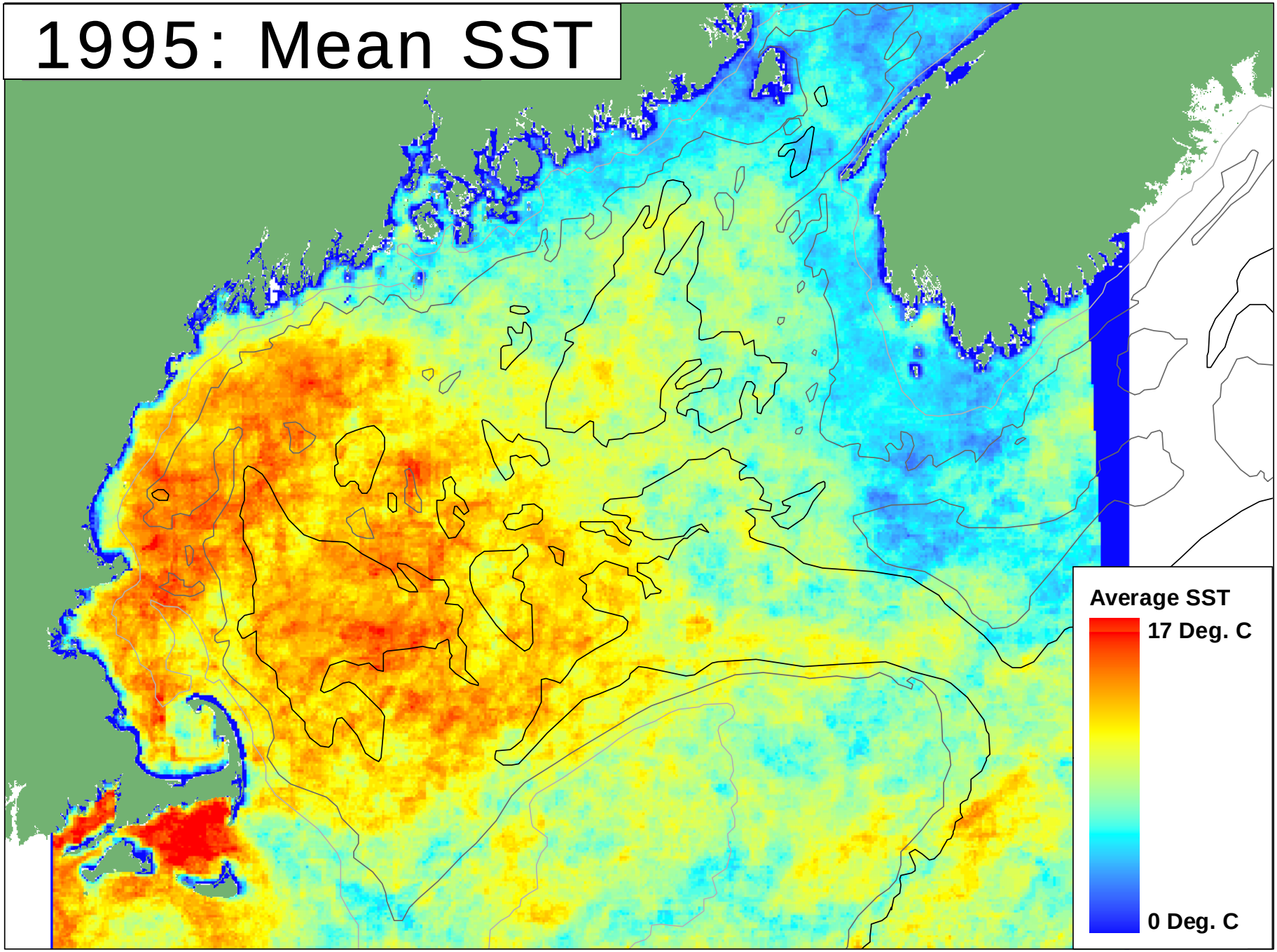

All years
Hot Spot Persistence
0 - 0.02
0.021 - 0.1
0.11 - 0.18
0.19 - 0.26
0.27 - 0.34
0.35 - 0.4
0.41 - 0.46
0.47 - 0.52
0.53 - 0.58
0.59 - 0.72

Evaluation

Objectives	Conceptual	Predictors	Scaling	Extrapolation	Predictions	Uncertainty	Evaluate

- Measure Uncertainty
  - Total = (aleatory + epistemic)
  - Aleatory: randomness
  - Epistemic: incomplete knowledge
- What's driving the shift in distribution?
- Test against independent data


1994: Mean SST
Average SST
17 Deg. C
0 Deg. C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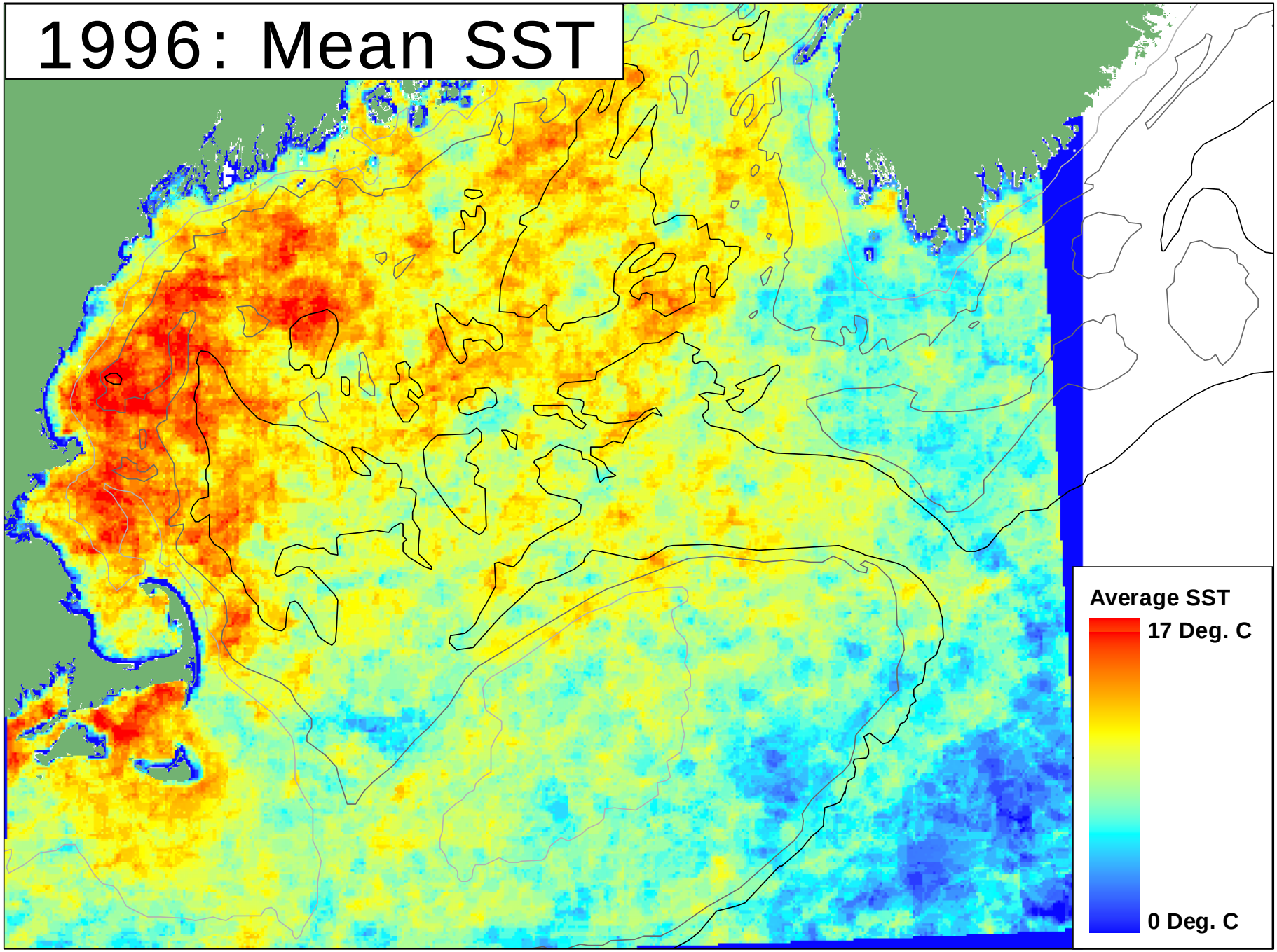
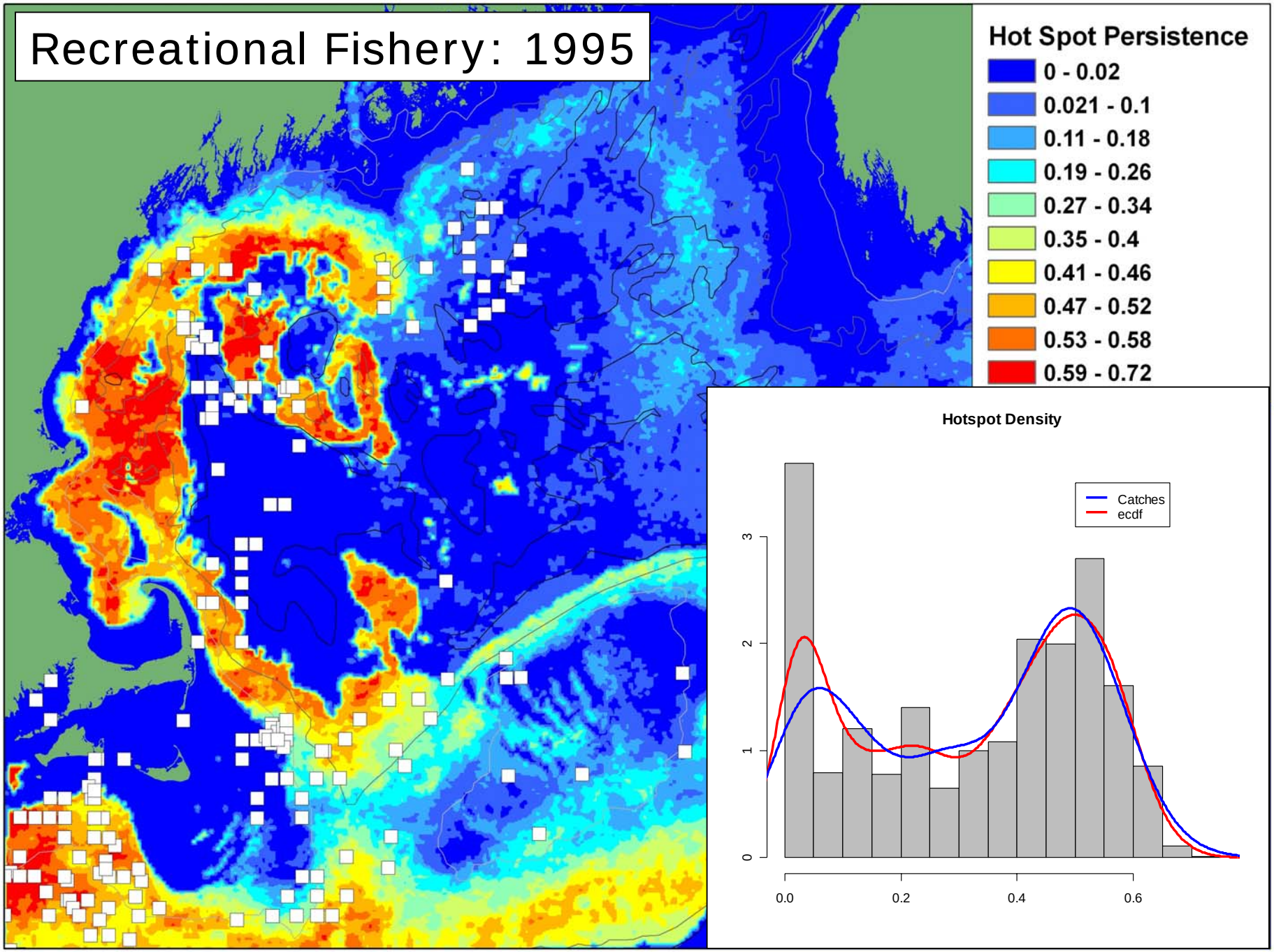

1996: Mean SST
Average SST
17 Deg. C
0 Deg. C


Recreational Fishery: 1995
Hot Spot Persistence
0 - 0.02
0.021 - 0.1
0.11 - 0.18
0.19 - 0.26
0.27 - 0.34
0.35 - 0.4
0.41 - 0.46
0.47 - 0.52
0.53 - 0.58
0.59 - 0.72
Hotspot Density
Catches
ecdf
0
1
2
3
0.0
0.2
0.4
0.6

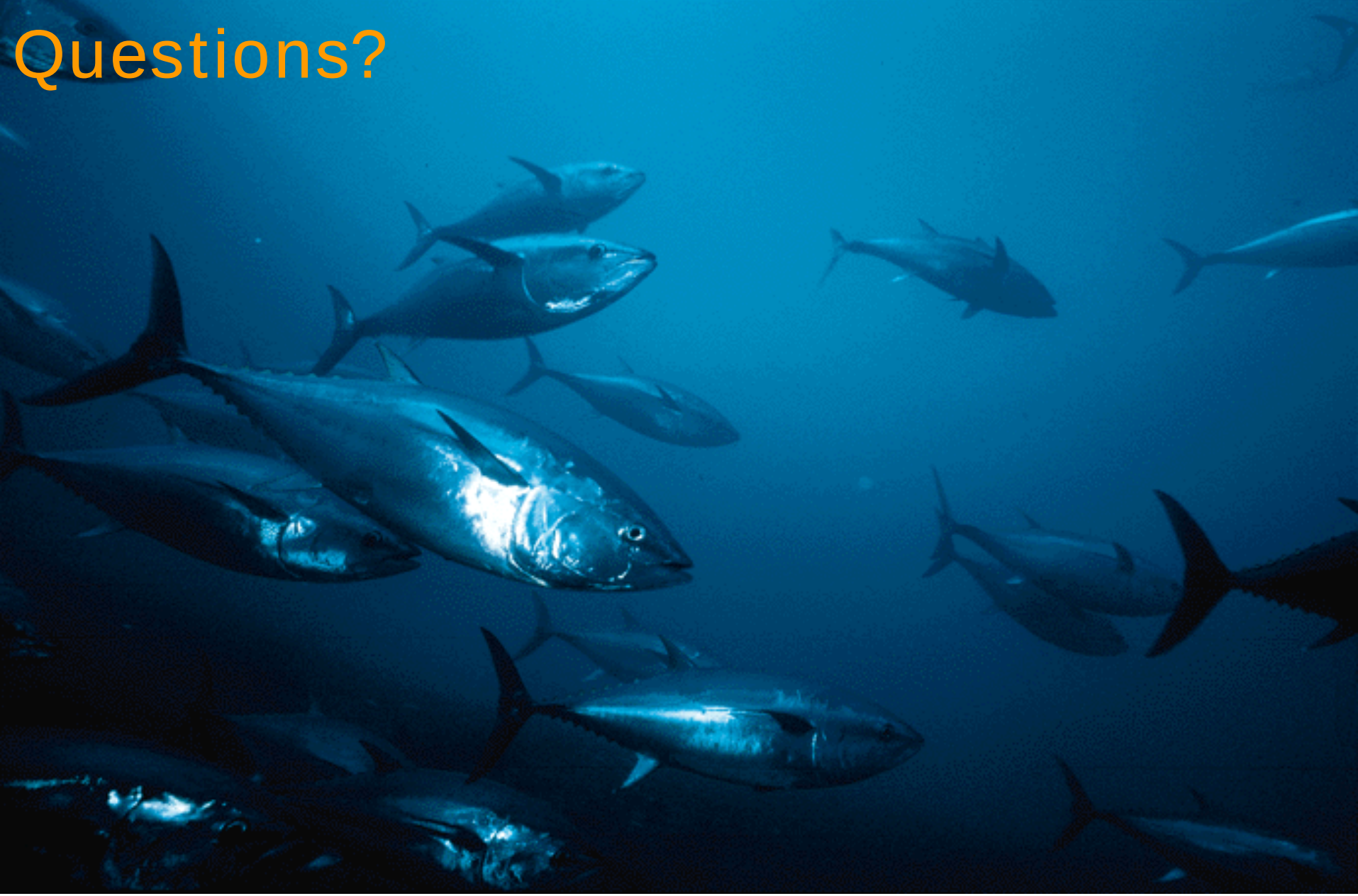
Discussion

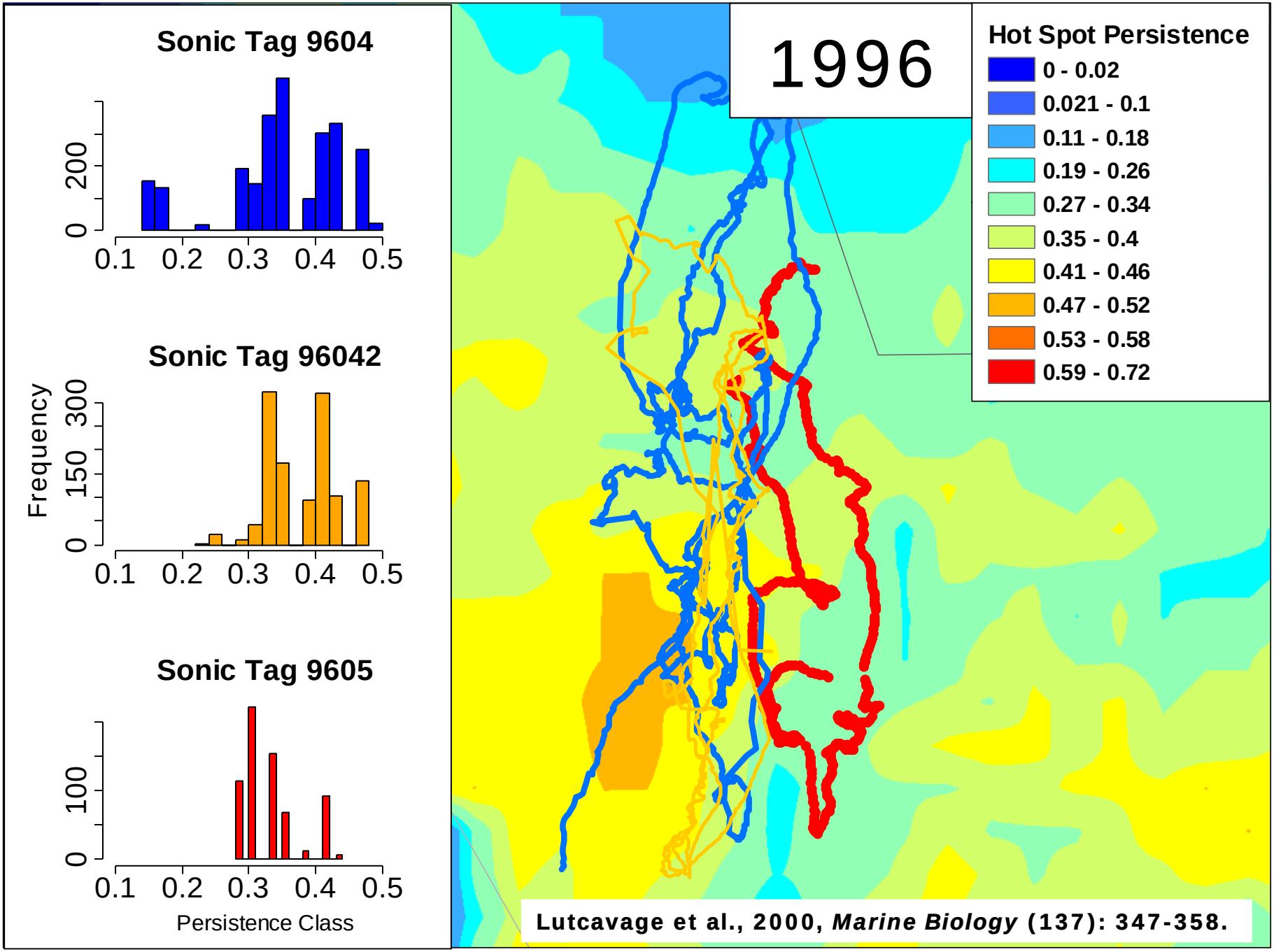
- What is a hotspot?
  - Do they differ at different life history stages?
  - Do they differ w/r/t to behavior?
- Organism driven vs. env. driven?
  - Do hot spots generically exist in GOM
  - Or are they organism specific?

Take home Message

- Hotspots do exist in GOM, and are used by bft
- Hotspots are spatially and temporally variable
- Though a small portion of GOM is persistently “hot”…
- …Likely that hotspots present a clearer signal at yearly time steps
- Next steps:
  - 1. Use commercial catch data
  - 2. explore landscape pattern w/r/t hotspots (does use change w/diff. spatial structure?)
  - 3. scaling
  - 4. Incorporate more oceanographic variables
  - 5. data predictors (prey)

Questions?




Sonic Tag 9604
0
200
0.1
0.2
0.3
0.4
0.5
Sonic Tag 96042
Frequency
0
150
300
0.1
0.2
0.3
0.4
0.5
Sonic Tag 9605
0
100
0.1
0.2
0.3
0.4
0.5
Persistence Class
1996
Hot Spot Persistence
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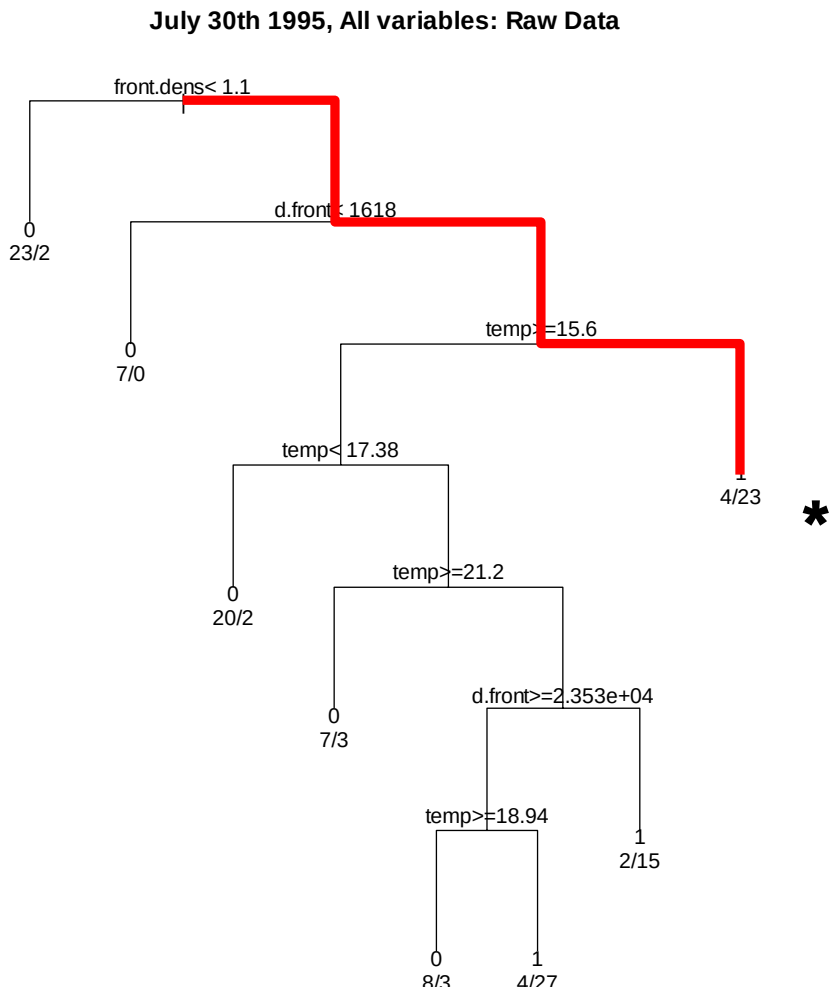
Lutcavage et al., 2000, *Marine Biology* (137): 347-358.

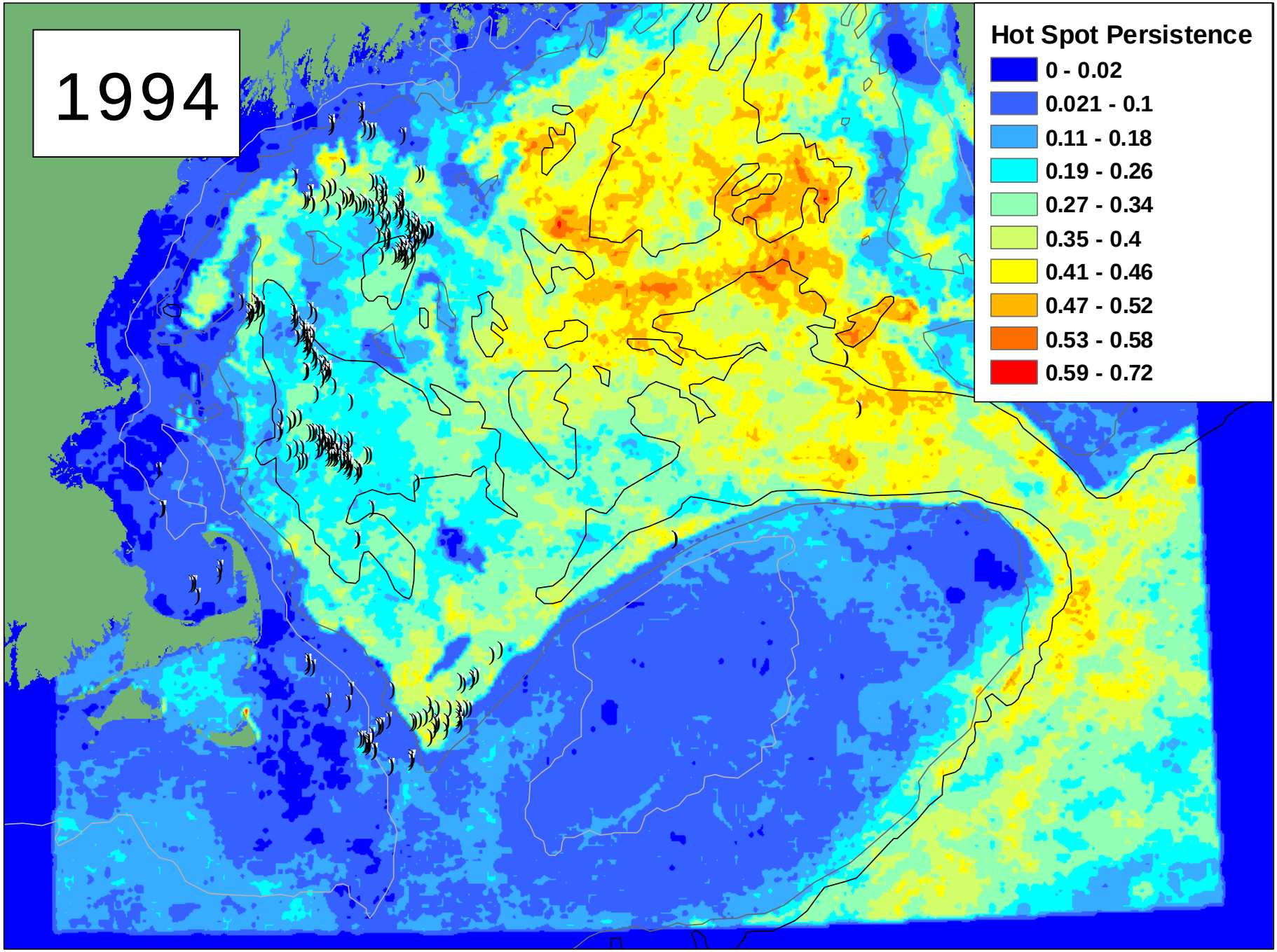
Tree to GIS output


```
> print(jul3095.raw.tree)
n= 150

node), split, n, loss, yval, (yprob)
      * denotes terminal node

  1) root 150 75 0 (0.5 0.5)
    3) front.dens>=1.1 125 52 1 (0.42 0.52)
      7) d.front>=1618 118 45 1 (0.38 0.62)
       15) temp< 15.6   27  4 1 (0.15 0.85) *
```

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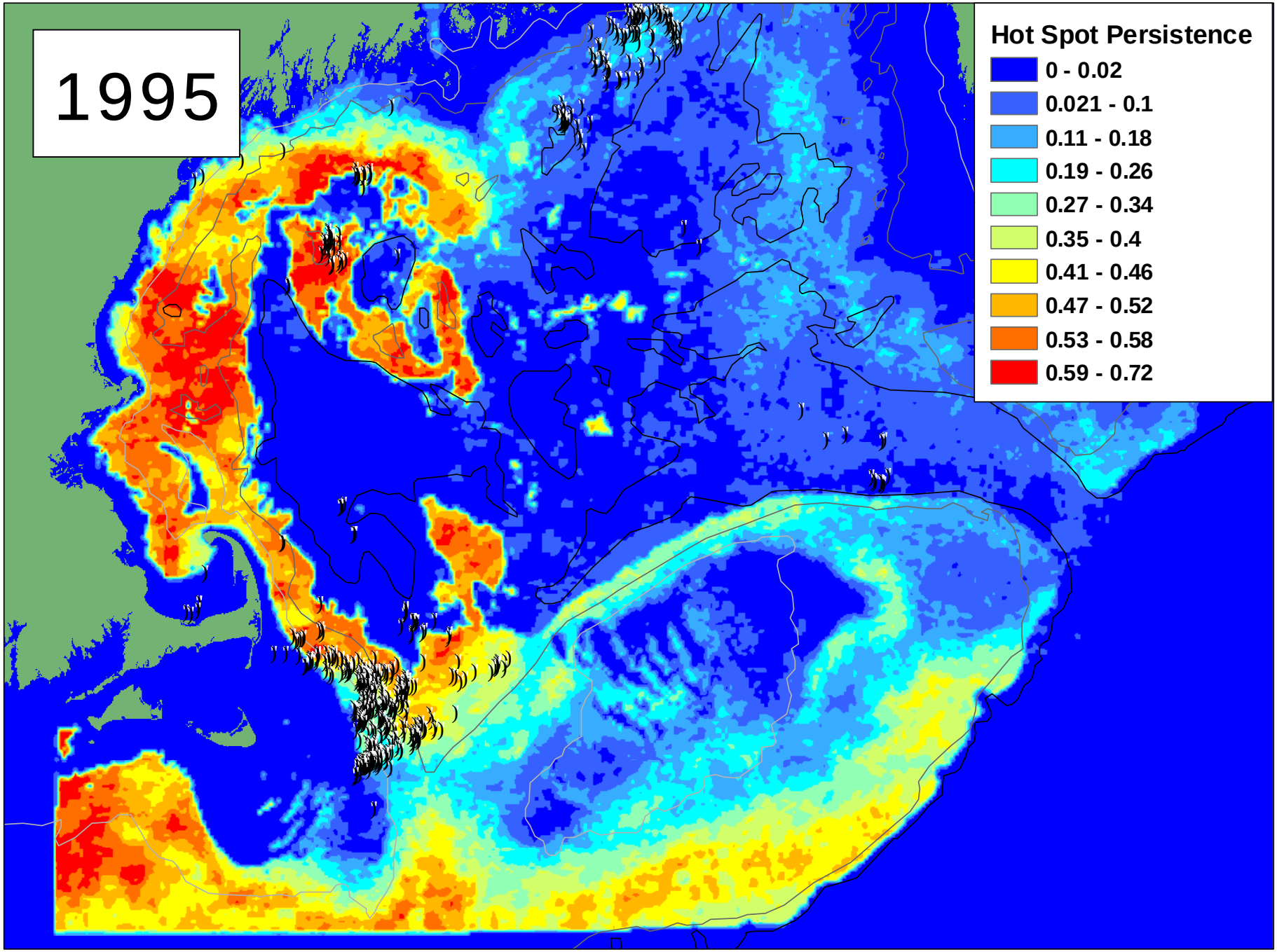
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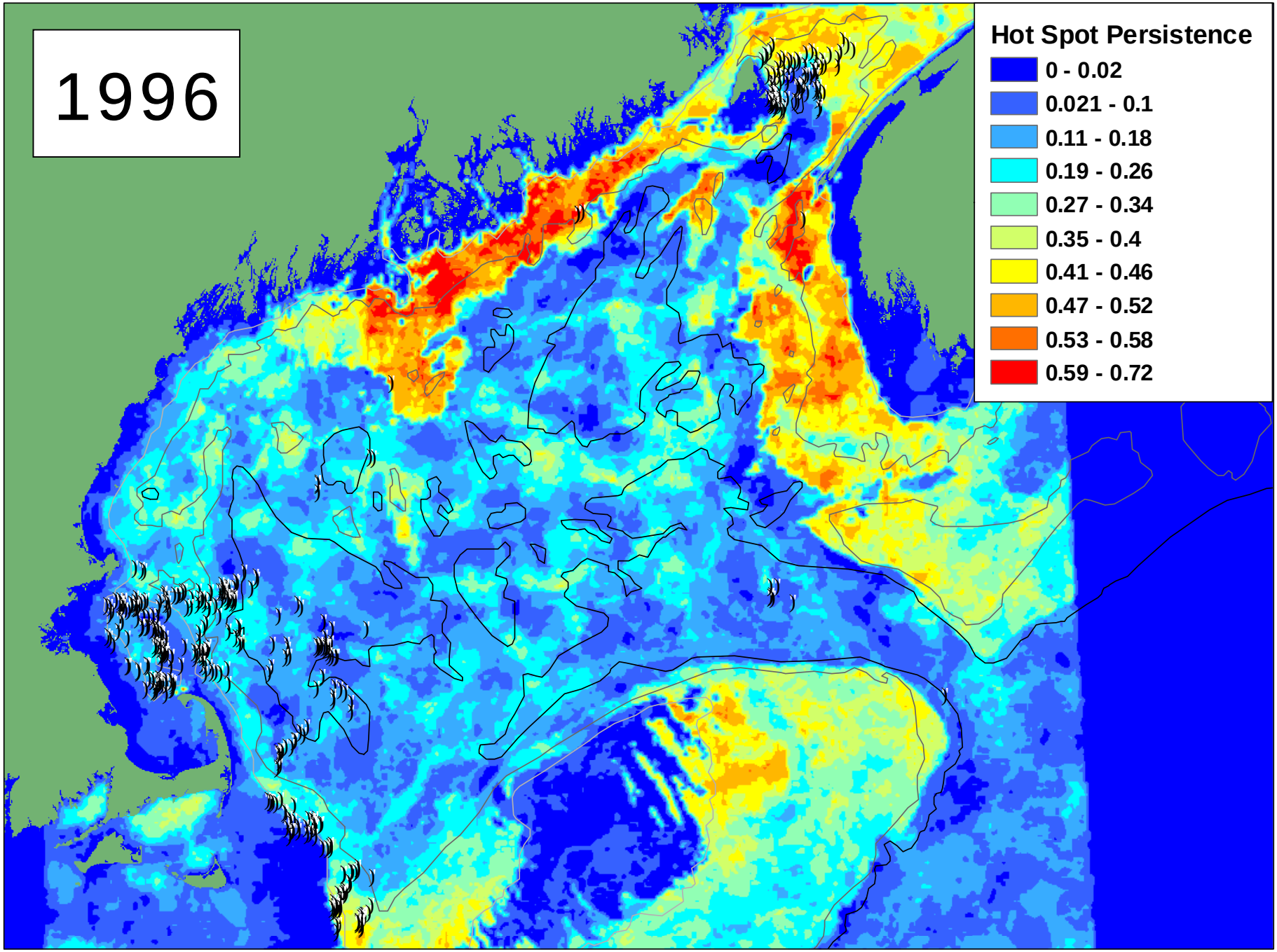
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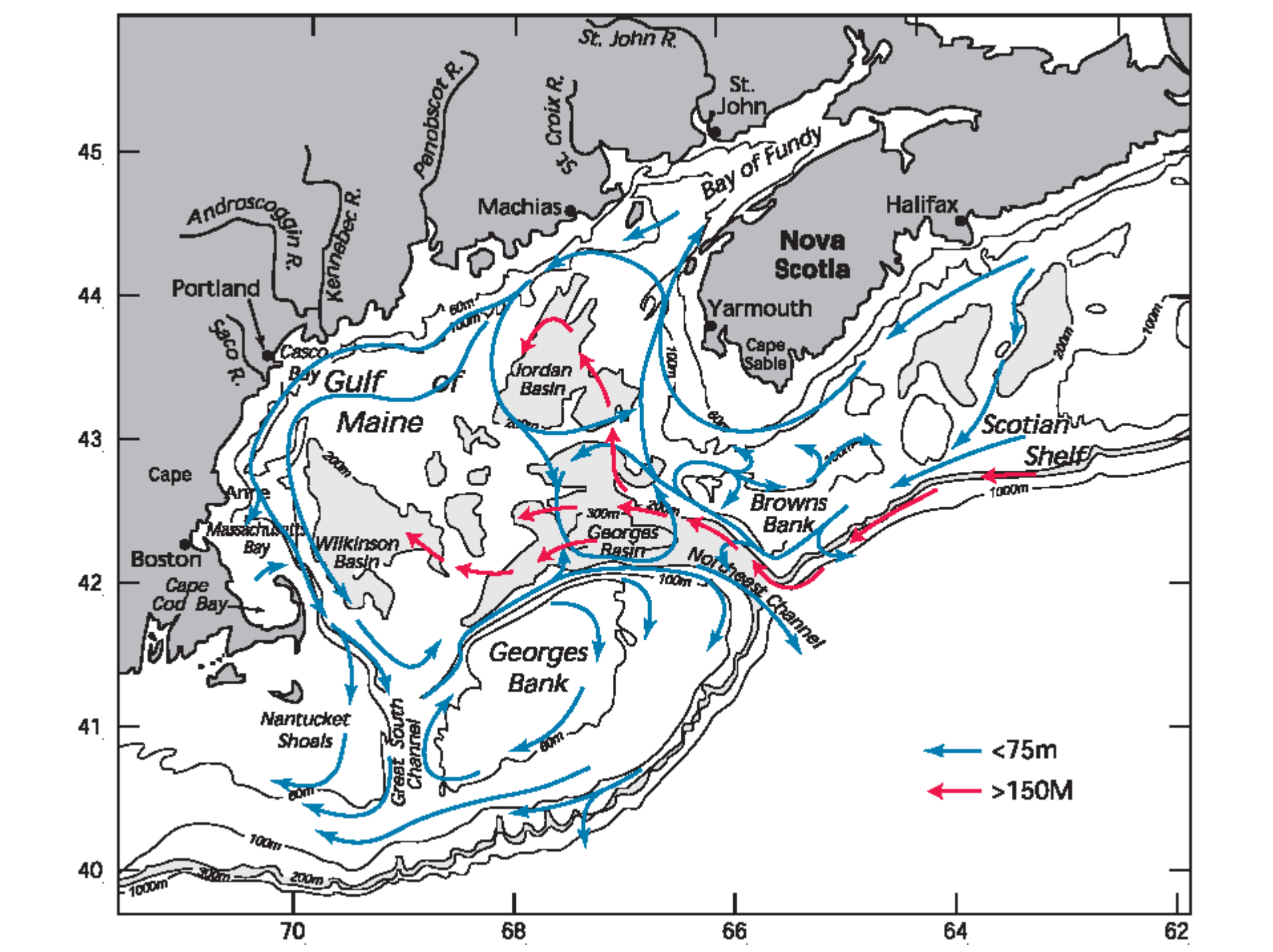
Prediction

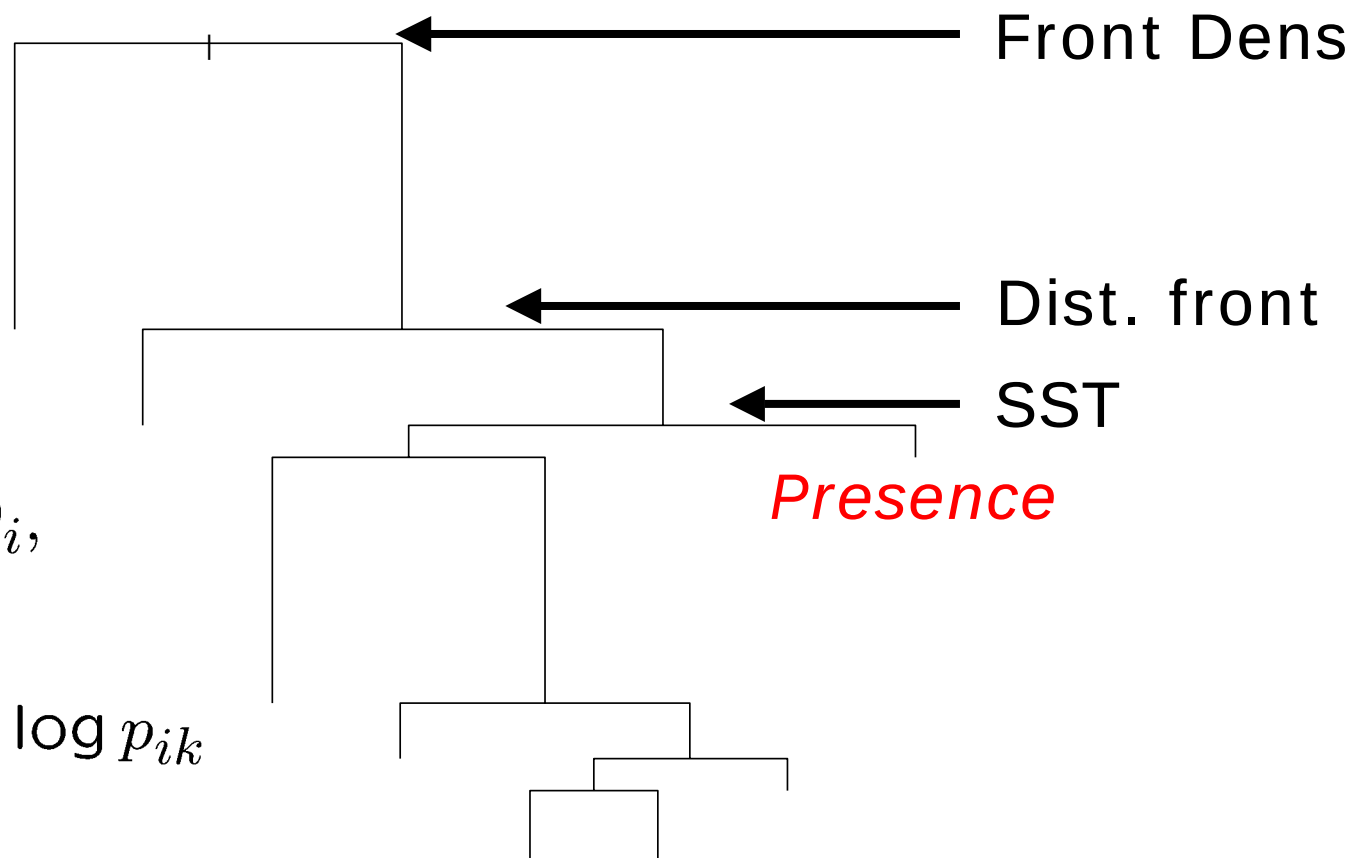
Objectives	Conceptual	Predictors	Scaling	Extrapolation	Predictions	Uncertainty	Evaluate

- CART +/-'s
  - + Non-parametric
  - + Handle mult. data types
  - + Auto. stepwise selection
  - + Easy to diagnose and interpret
  - + Locates interactions between predictors
  - – Searches for thresholds
  - – Orthogonal partitions not always optimal
  - – Decreasing power ~ n
  - – Overfits the data, but…


St. John R.
Penobscot R.
St. Croix R.
St. John
Androscoggin R.
Kennebec R.
Machias
Bay of Fundy
Halifax
Nova Scotia
Portland
Yarmouth
Saco R.
Casco Bay
Gulf of Maine
Jordan Basin
Cape Sable
Scotian Shelf
Cape Ann
Massachusetts Bay
Wilkinson Basin
Georges Basin
Browns Bank
Boston
Cape Cod Bay
Northeast Channel
Georges Bank
Nantucket Shoals
Great South Channel
<75m
>150M
60m
100m
200m
300m
1000m
45
44
43
42
41
40
70
68
66
64
62

Fitted Classification Tree

July 30th 1995, All variables: Raw Data



$$D = \sum_i D_i,$$

$$D_i = -2 \sum_k n_{ik} \log p_{ik}$$

Prediction

Objectives	Conceptual	Predictors	Scaling	Extrapolation	**Predictions**	Uncertainty	Evaluate

- GIS
- docell scripting to locate prescribed combinations of predictors
- Fit model on a daily time step