

# Review and analysis of Atlantic herring spawning on Georges Bank

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New England  
Fishery Management Council

# Presentation outline

- Scope of review
- A model for assessing spawning areas based on '*consensus*'
- Review of herring biology, spawning and management (coming)
- Consideration of existing maps and datasets:
  - DMR/MDMF dockside monitoring
  - Trawl surveys
  - Larval distribution
  - Egg EFH
  - Historical spawning areas
  - Diet database
- Building a consensus
- Industry interviews
- Research recommendations

# Scope of Review and Timeline

- Request for proposals was made public in March
  - Summarize status of herring including historical and updated data about spawning
  - Provide maps showing historical and current spawning locations and herring egg begs
  - Summarize fishery data that may have relevant information regarding location, season, condition and trends in herring spawning
  - Review draft discussion with PDT in summer of 2019
  - Present discussion document to Herring Committee (September 2019)
  - Finalize document (October 2019)
- GMRI was awarded contract on May 9<sup>th</sup>
- GMRI has since reviewed and analyzed data sets
- Written document still pending



# A model for inferring spawning areas from diverse sources

ICES Journal of  
Marine Science



ICES Journal of Marine Science (2017), 74(6), 1587–1601. doi:10.1093/icesjms/fsx031

## Original Article

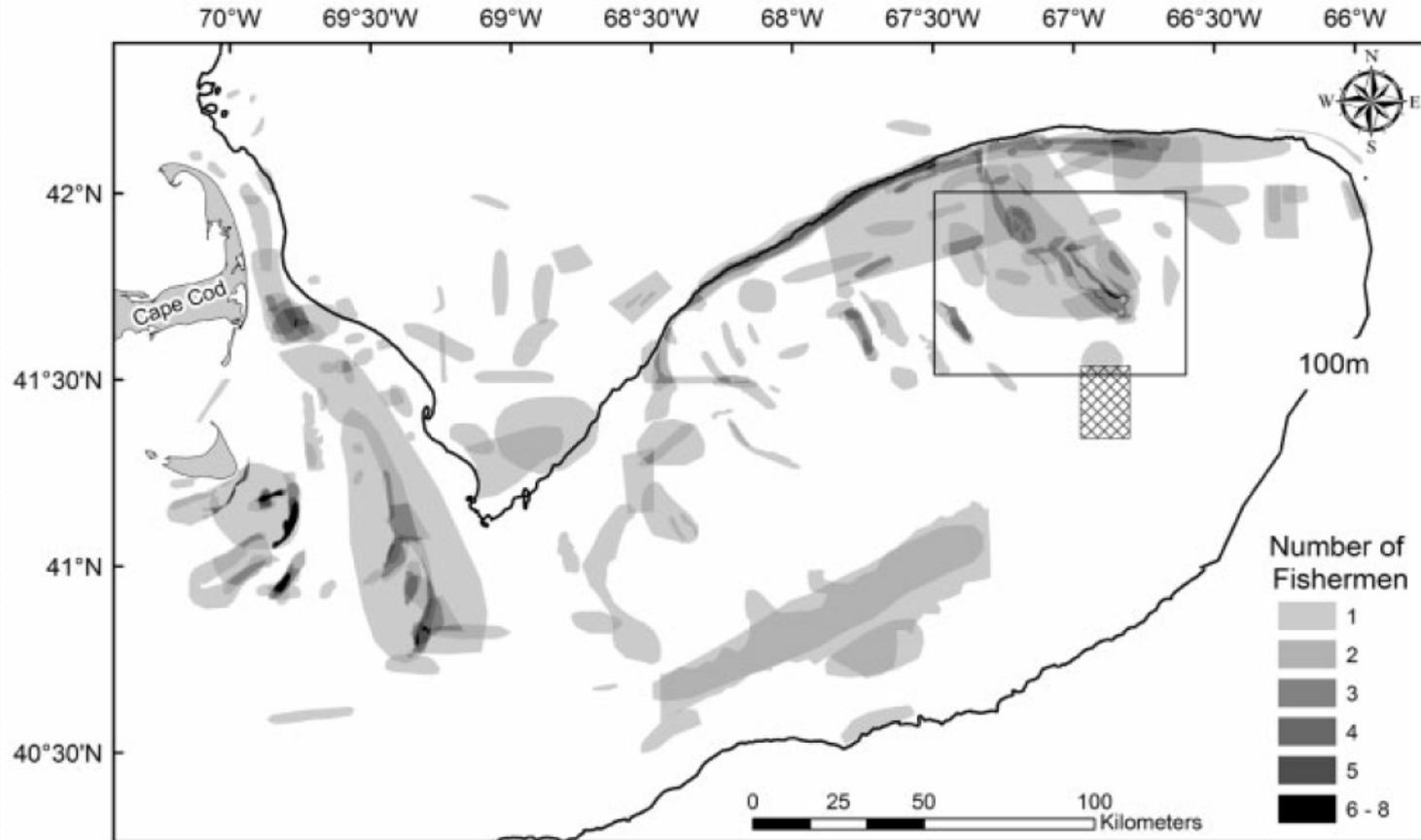
### Using Fishermen's Ecological Knowledge to map Atlantic cod spawning grounds on Georges Bank

Gregory R. DeCelles<sup>1,2\*</sup>, David Martins<sup>1,2</sup>, Douglas R. Zemeckis<sup>1,‡</sup>, and Steven X. Cadrin<sup>1</sup>

Consensus based on multiple fishermen's input...



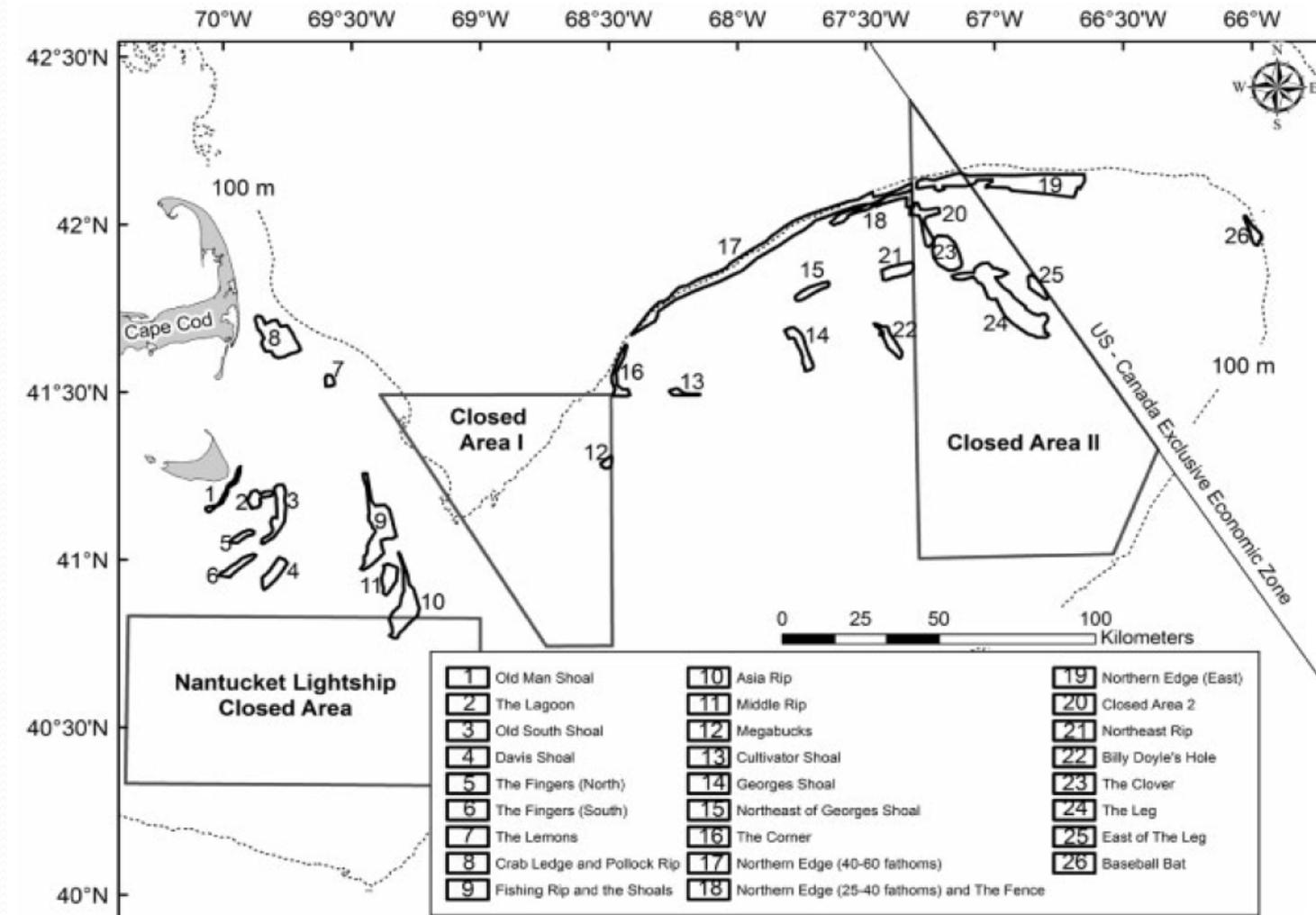
# Individual polygons



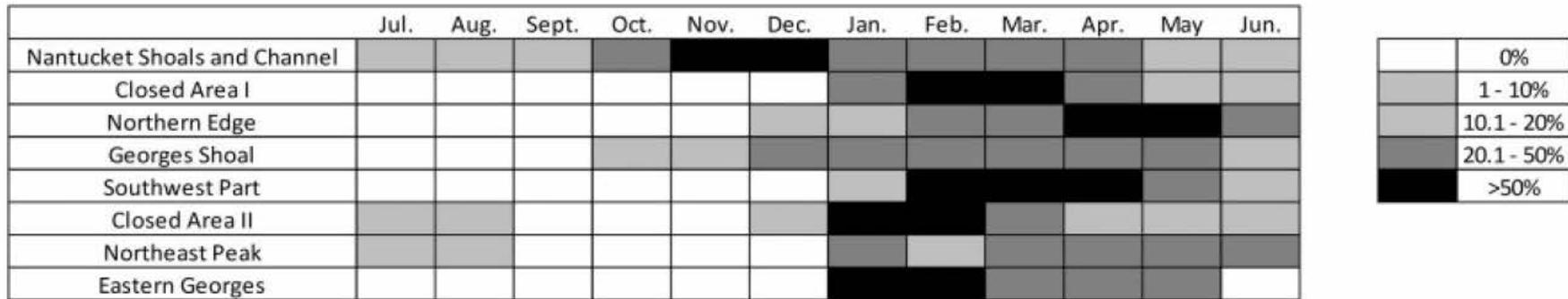
DeCelles et al. 2017



# Areas of overlap (consensus)



## Also information on timing



**Figure 8.** Proportion of fishermen who reported spawning activity each month in the different geographic regions of Georges Bank.

DeCelles et al. 2017



# Sources of data/figures

- Maine DMR dockside monitoring data (1971 – 2018) (M. Cieri, DMR)
- Mass DMF portside sampling data (1998 – 2018) (M. Dean, MDMF)
- Trawl survey data (spring and fall; 1987 – 2018) (J. Deroba, NEFSC)
- Larval distribution (1971 – 2017) (D. Richardson, NEFSC)
- Egg EFH (NEFMC 2013)
- Historical spawning grounds (Olsen et al. 1977)
- Food habits database (B. Smith, NEFSC)



# DMR Dockside Monitoring Data

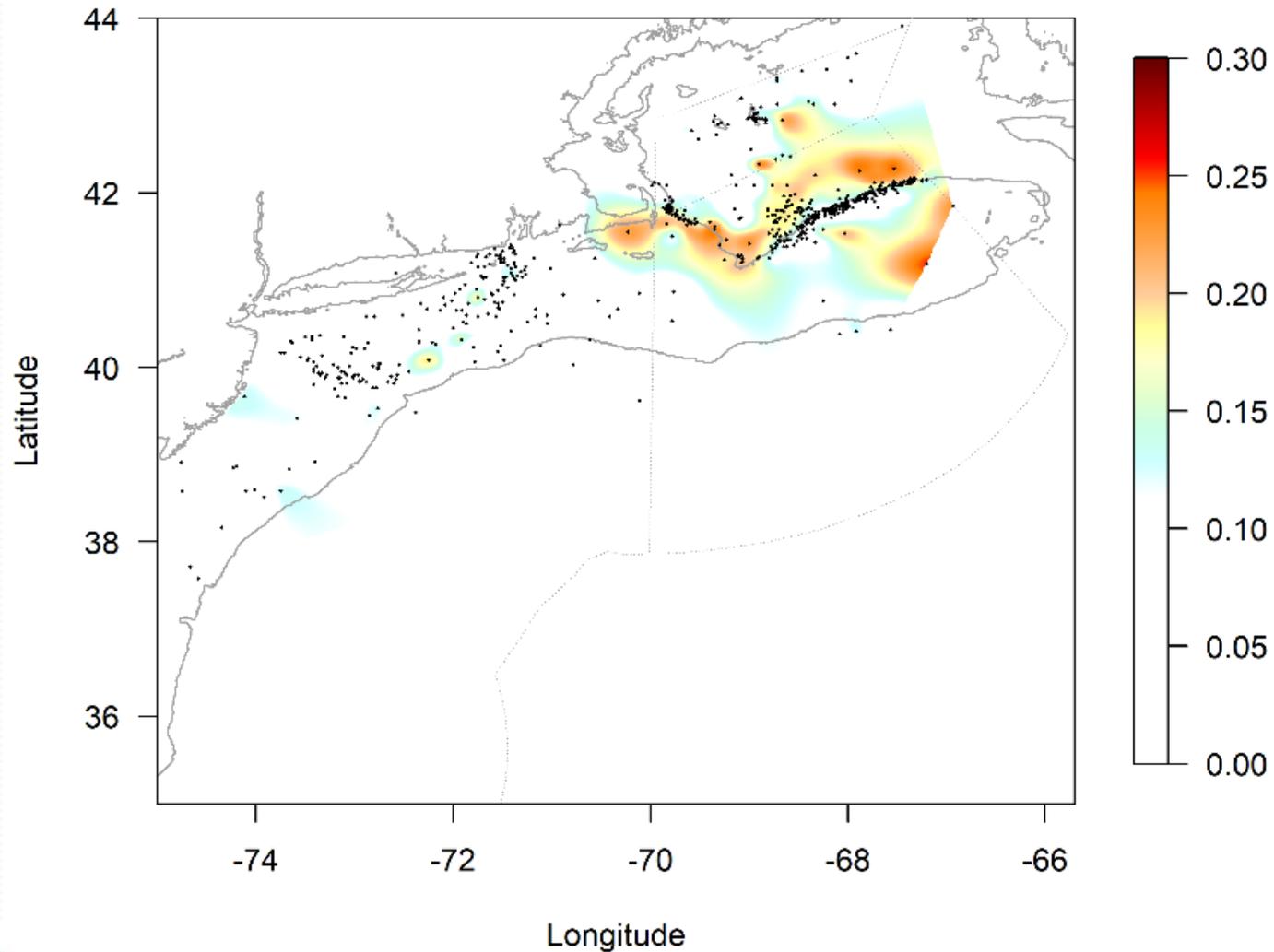
- 1971 – 2018 (17,529 records of individual herring)
  - GSI
  - Maturity stage
  - Location
  - Date



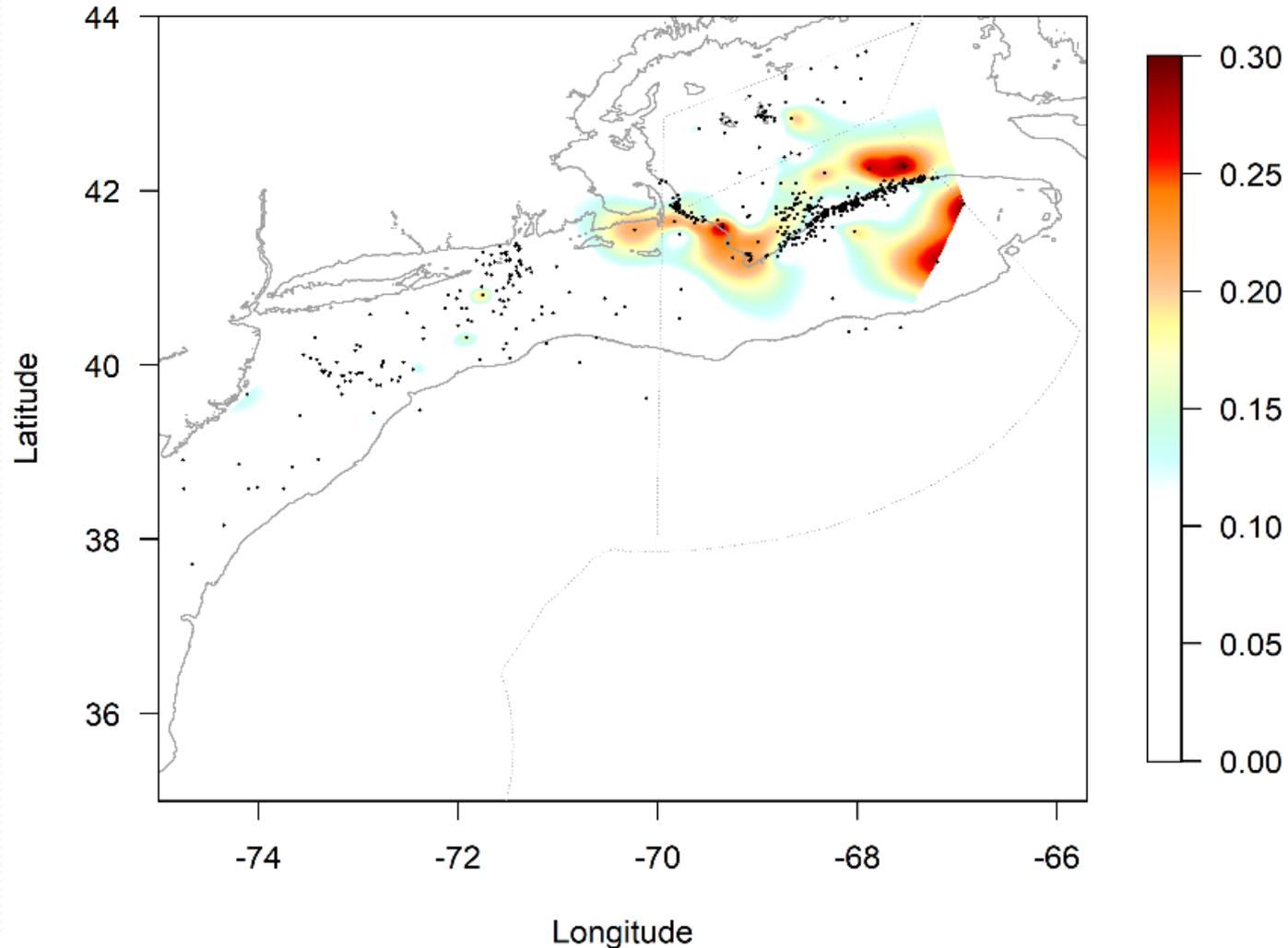
# DMR Data Spatial Patterns



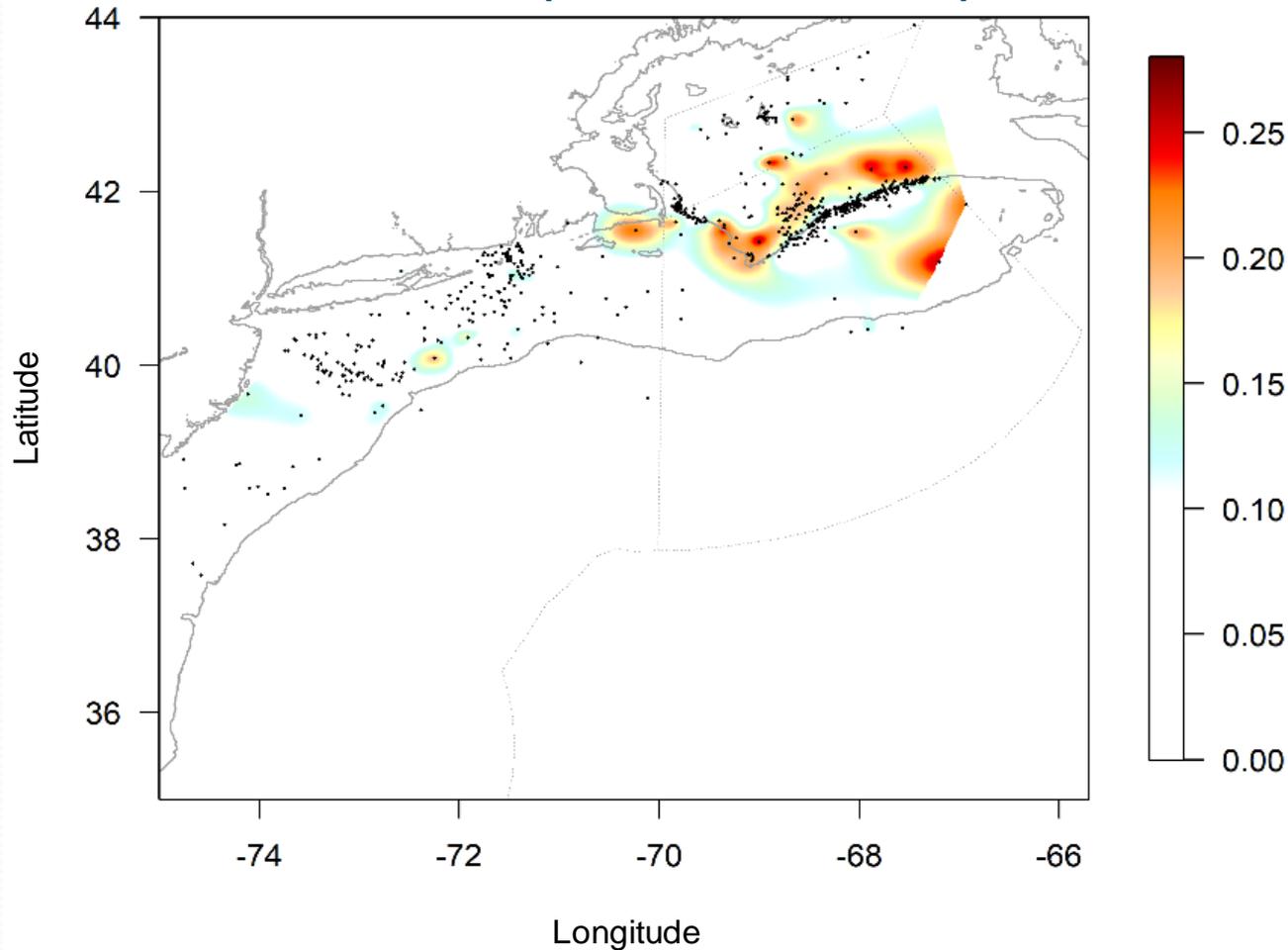
# Surface spline interpolation of mean male and female GSI (1971 – 2018)



# Surface spline interpolation of mean female GSI (1971 – 2018)



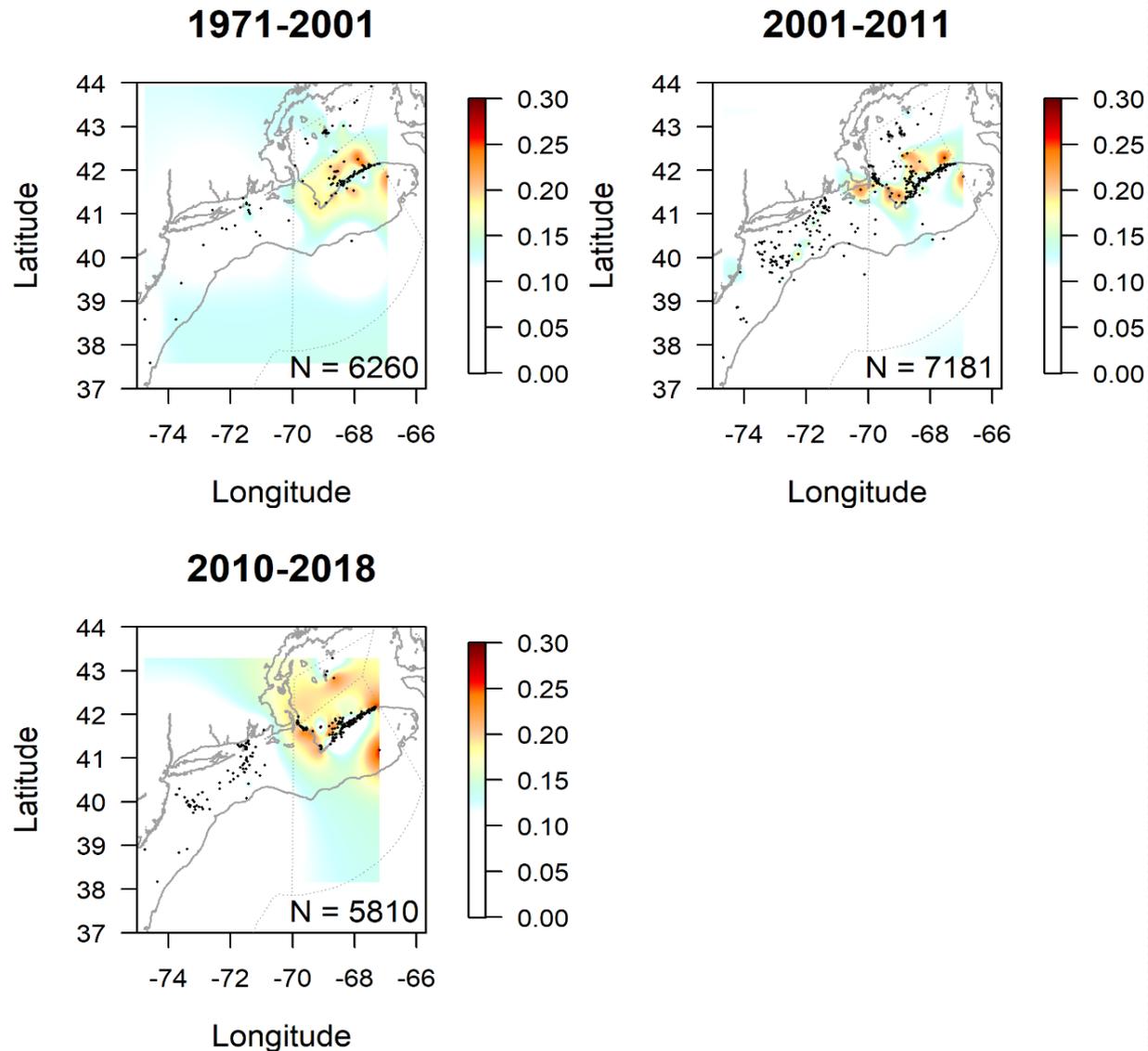
# Surface spline interpolation of male and female GSI\* (1971 – 2018)



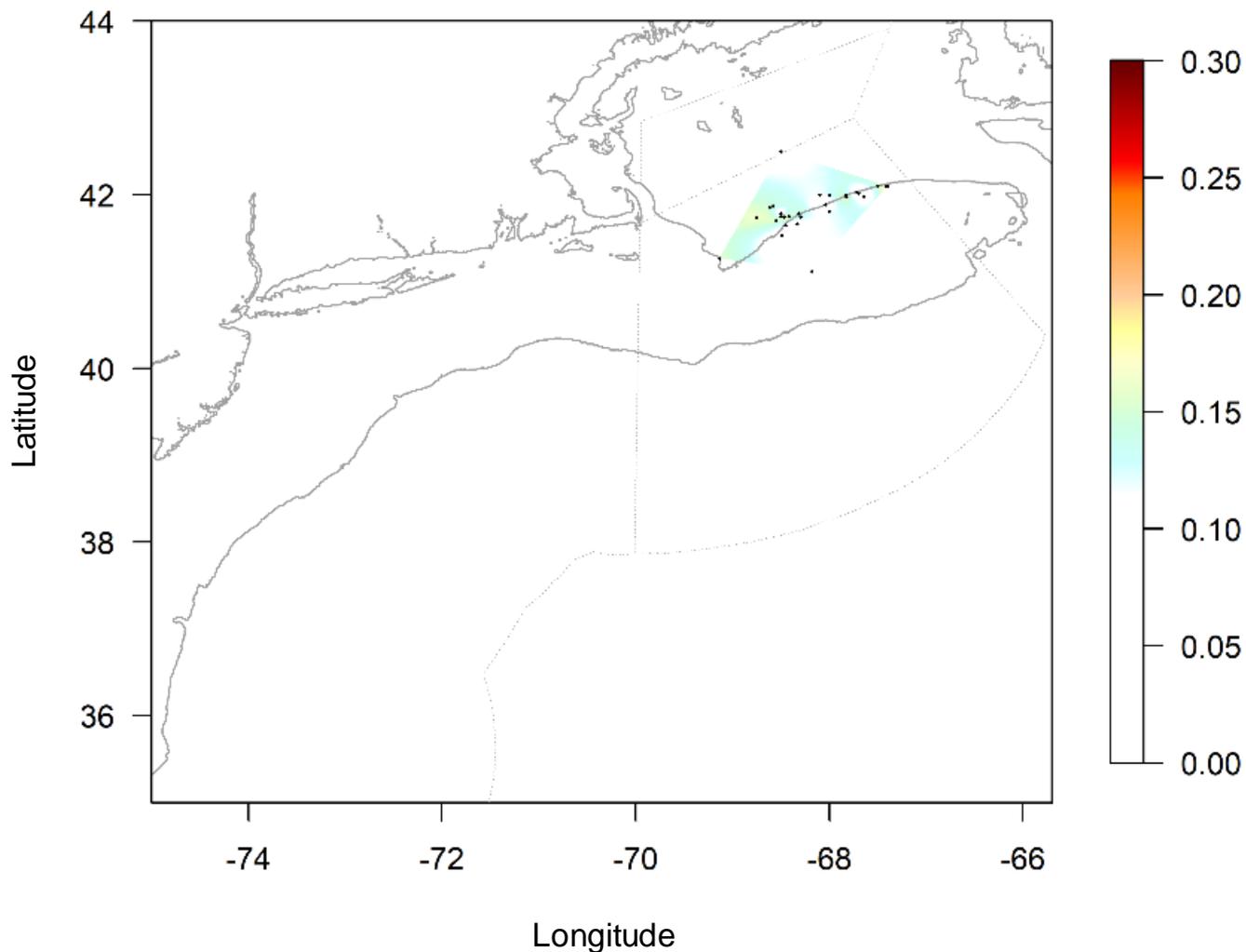
\*Average GSI by sample



# Surface spline interpolation of mean male and female GSI by decade



# Surface spline interpolation of mean female\* GSI from Mass DMF (1998 – 2018)



\*only female observations were available



# Maturity Stages

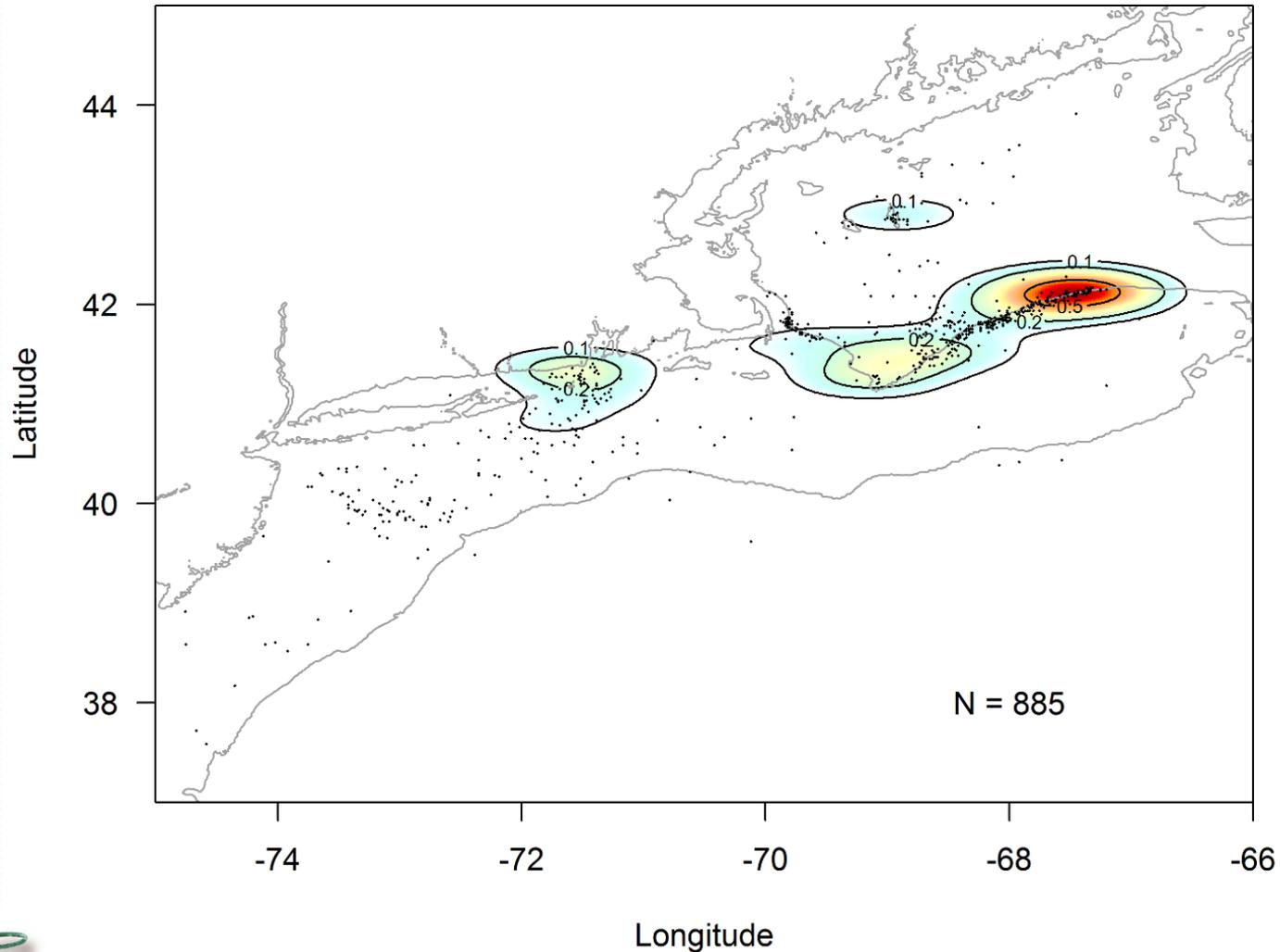
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DMR	Description	NMFS	Description
1	immature	I	immature
2	starting		
3	developing	D	developing
4	maturing		
<b>5</b>	<b>mature</b>	<b>R</b>	<b>ripe</b>
<b>6</b>	<b>ripe/running</b>	<b>U</b>	<b>ripe/running</b>
7	spent	S	spent
8	resting	T	resting
		X	unknown

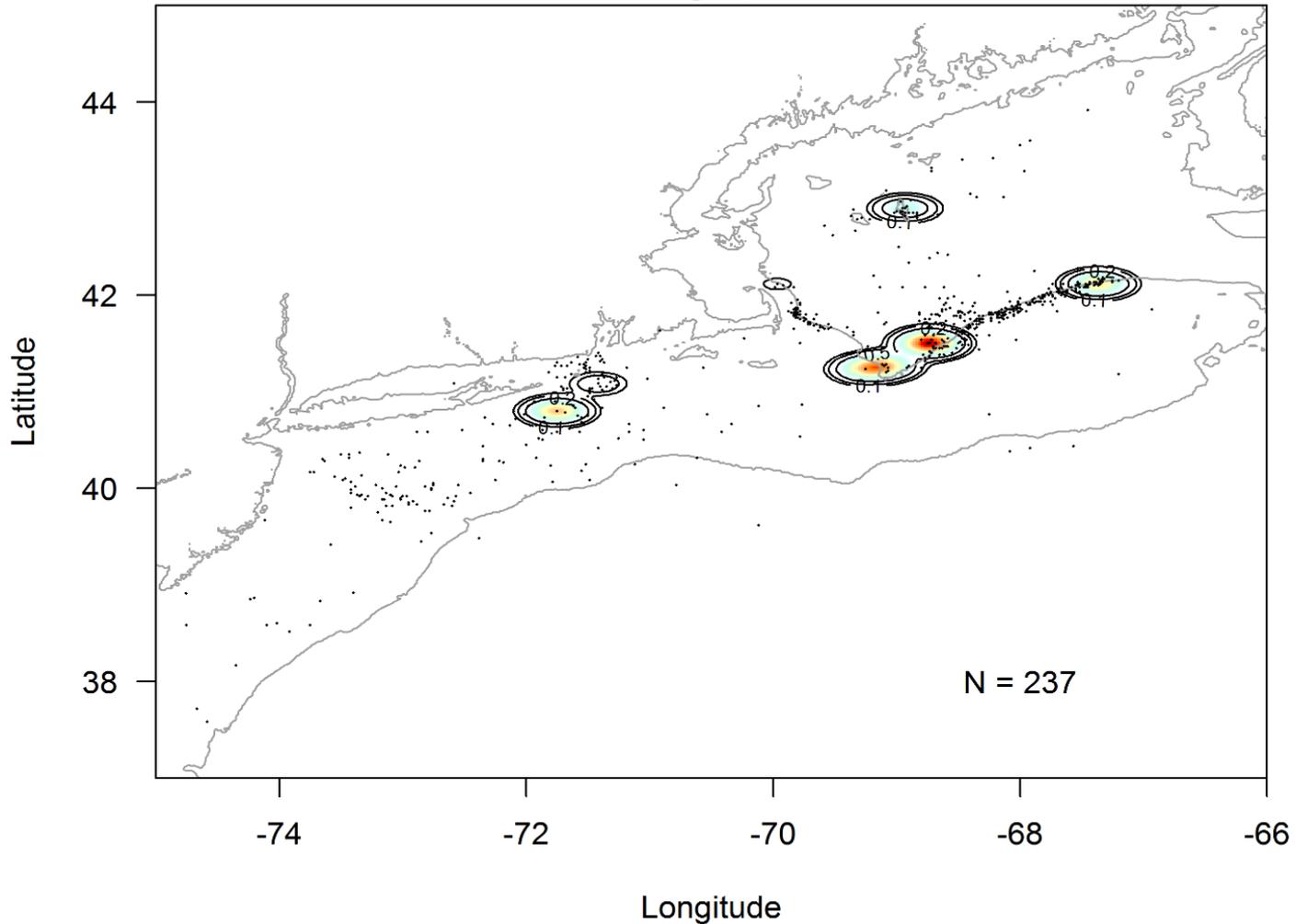
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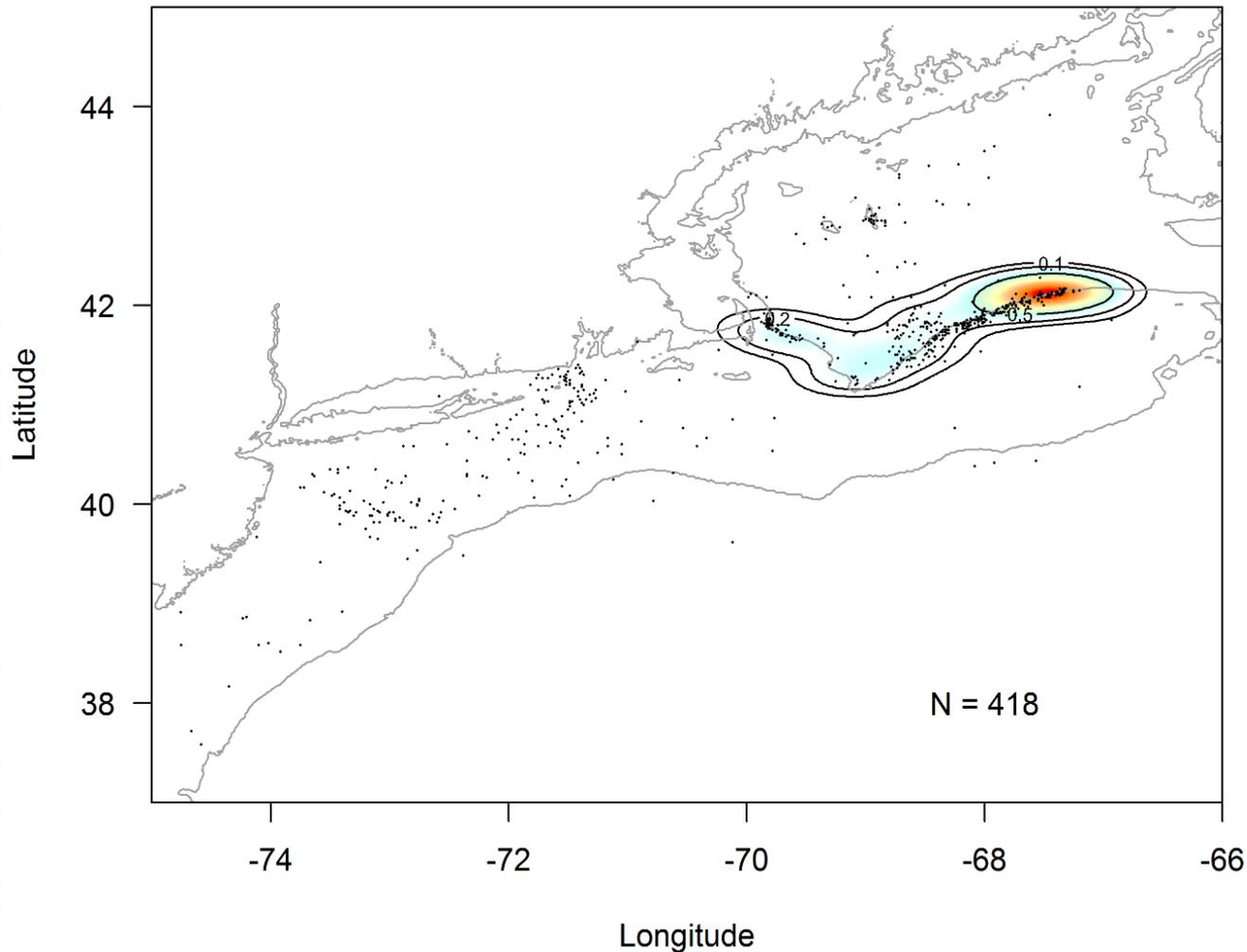
# 2-D kernel density estimate of male and female R + U herring (1971 – 2018)



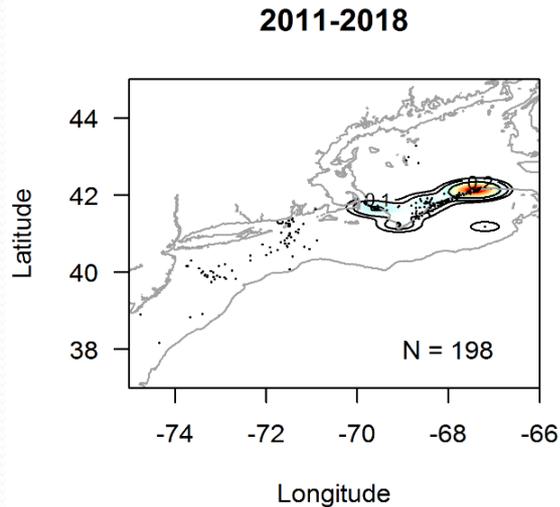
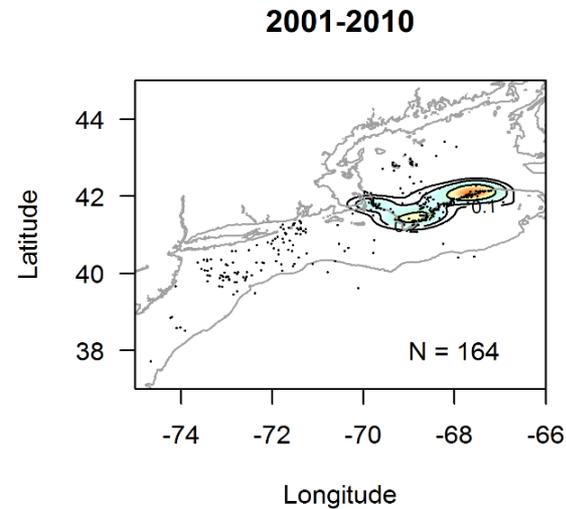
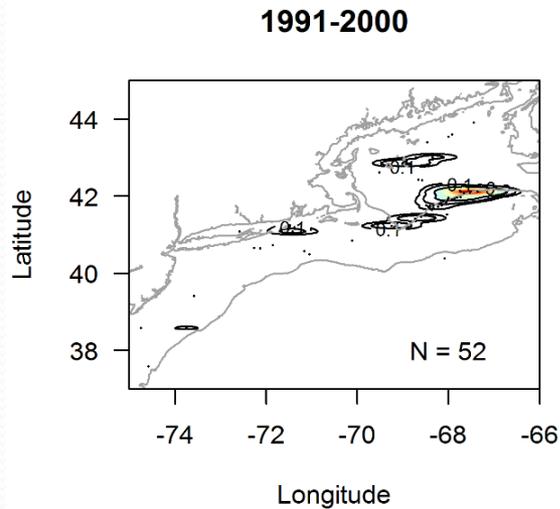
## 2-D kernel density estimate of male and female U herring (1971 – 2018)



# 2-D kernel density estimate of male and female herring with GSI values $> 0.3$ (1971 – 2018)



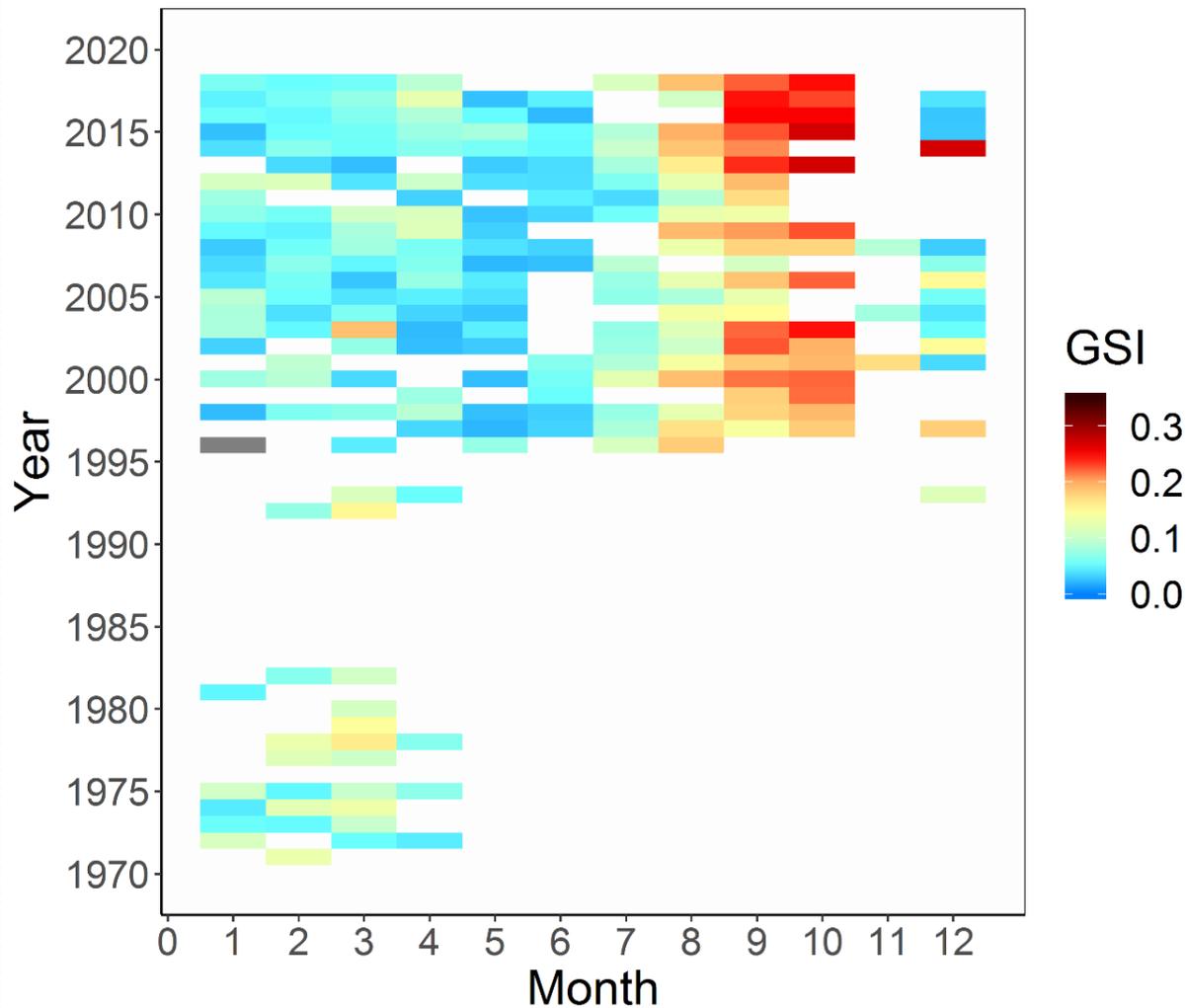
# 2-D kernel density estimate of male and female herring with GSI values $> 0.3$ (by decade)



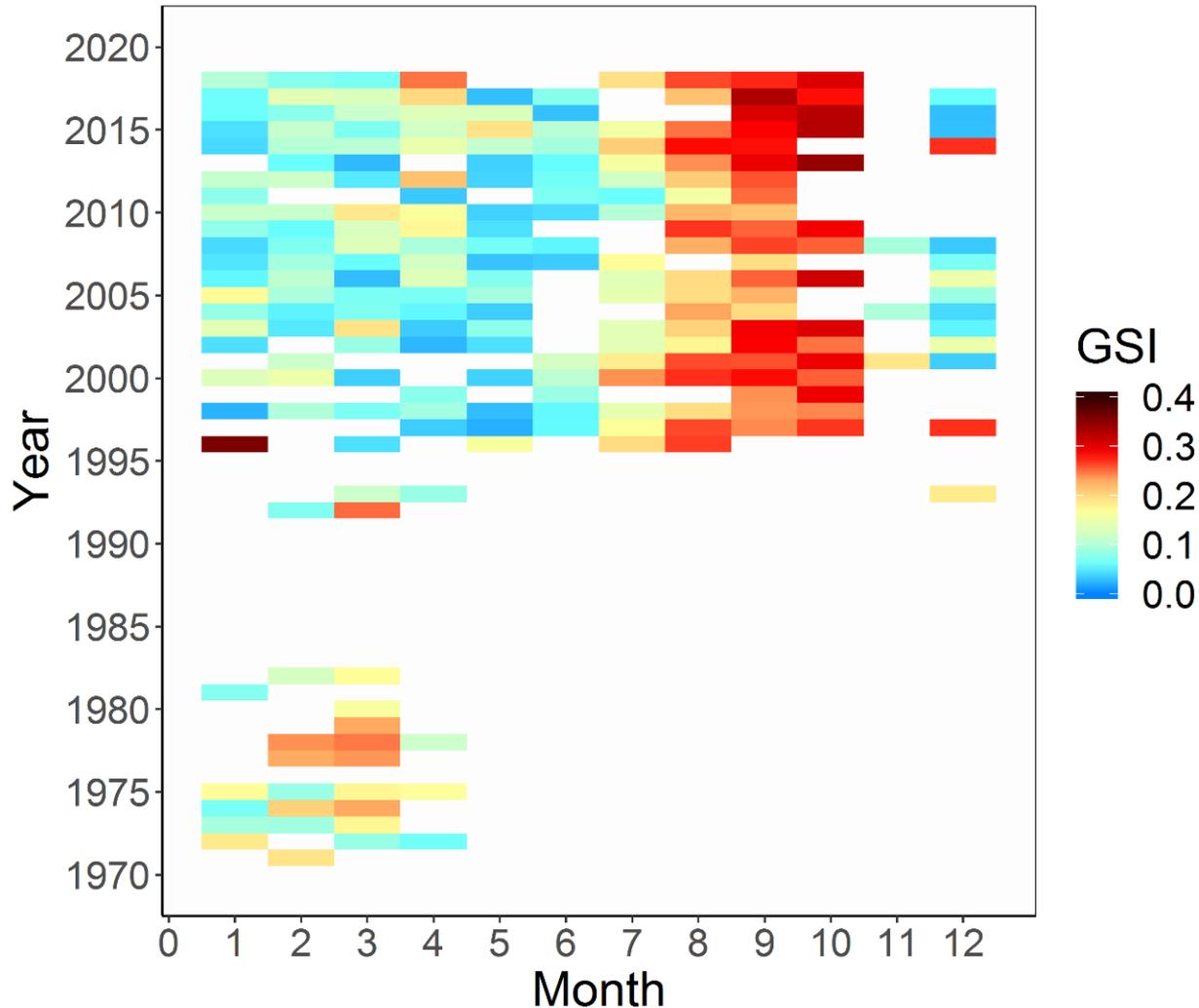
# DMR Data Temporal Patterns (Spawning Season)



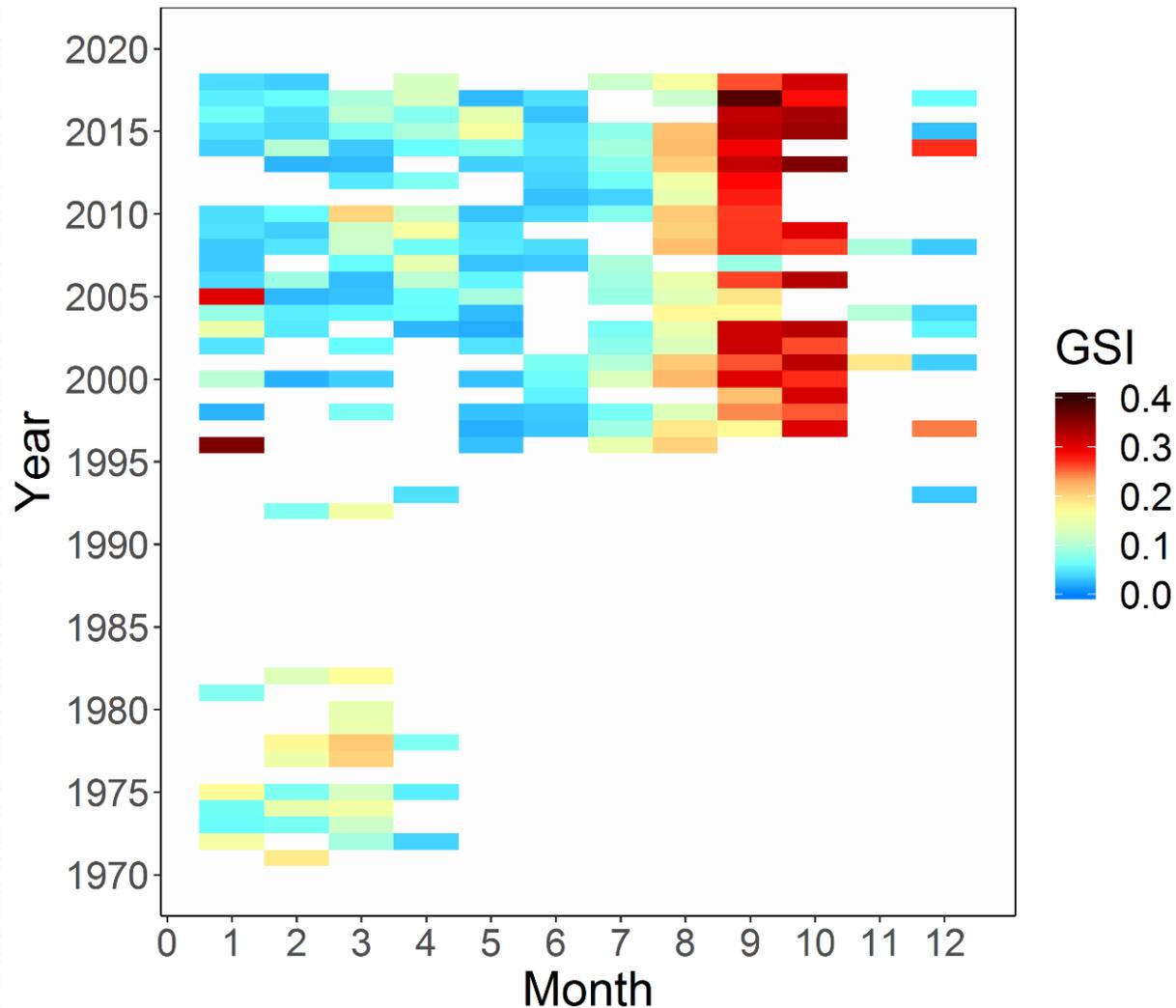
# Heatmap of mean GSI values by month and year (both sexes)



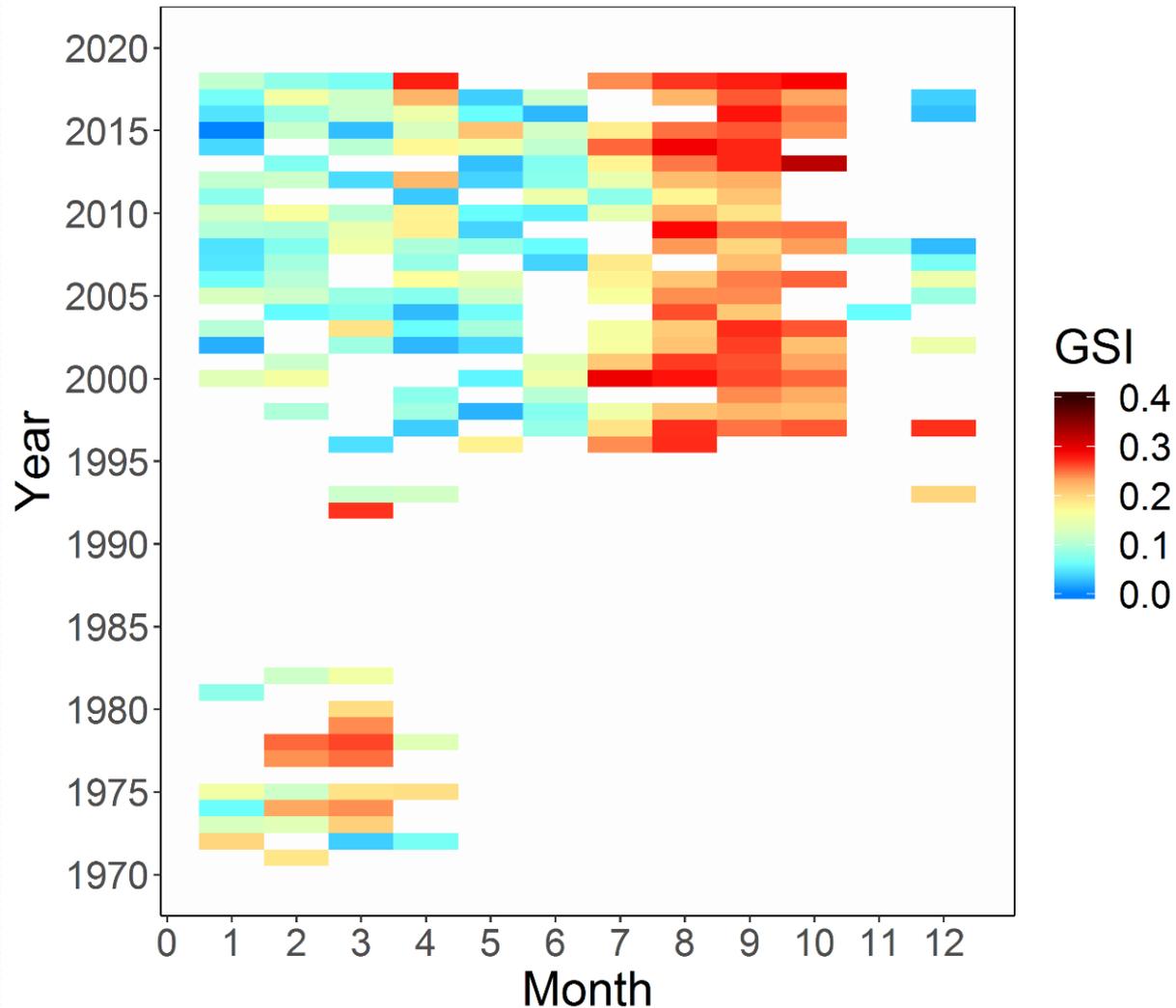
# Heatmap of 90<sup>th</sup> quantile of GSI values by month and year (both sexes)



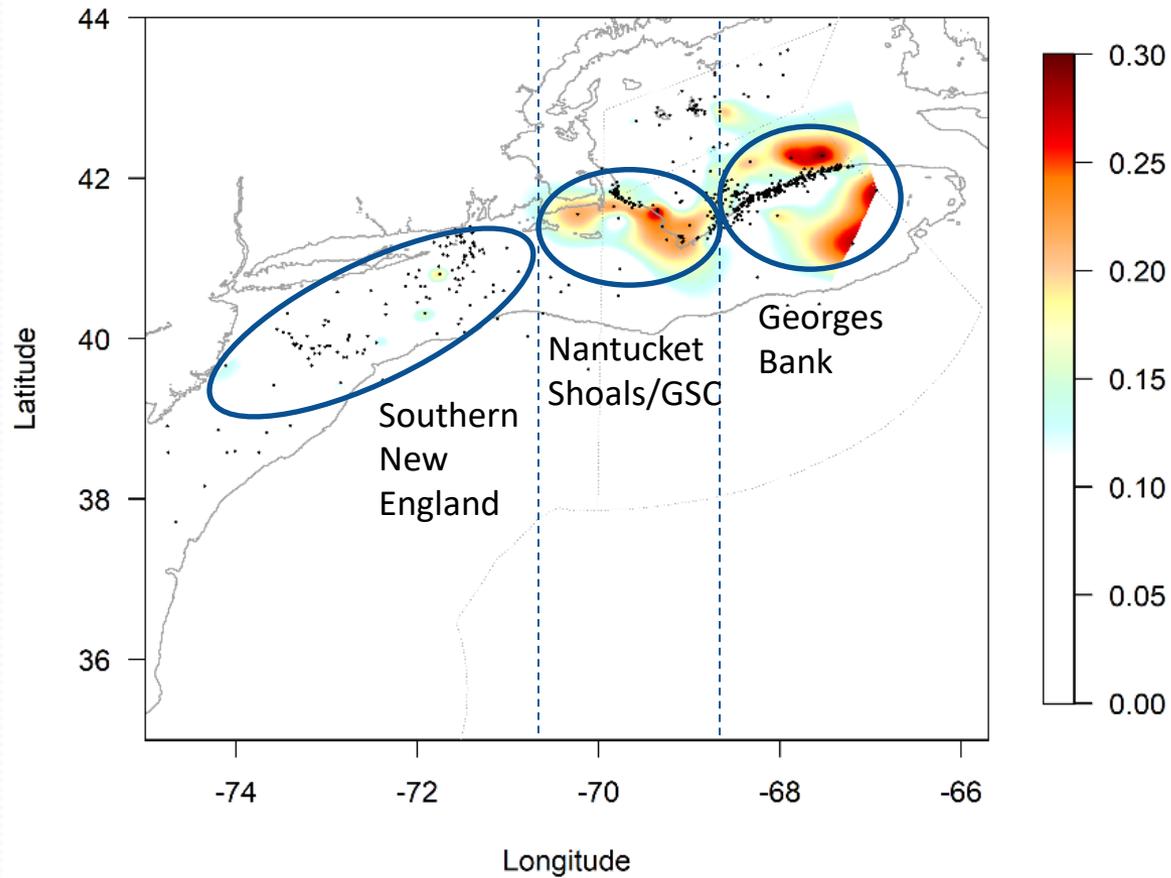
# Heatmap of 90<sup>th</sup> quantile of GSI values by month and year for females



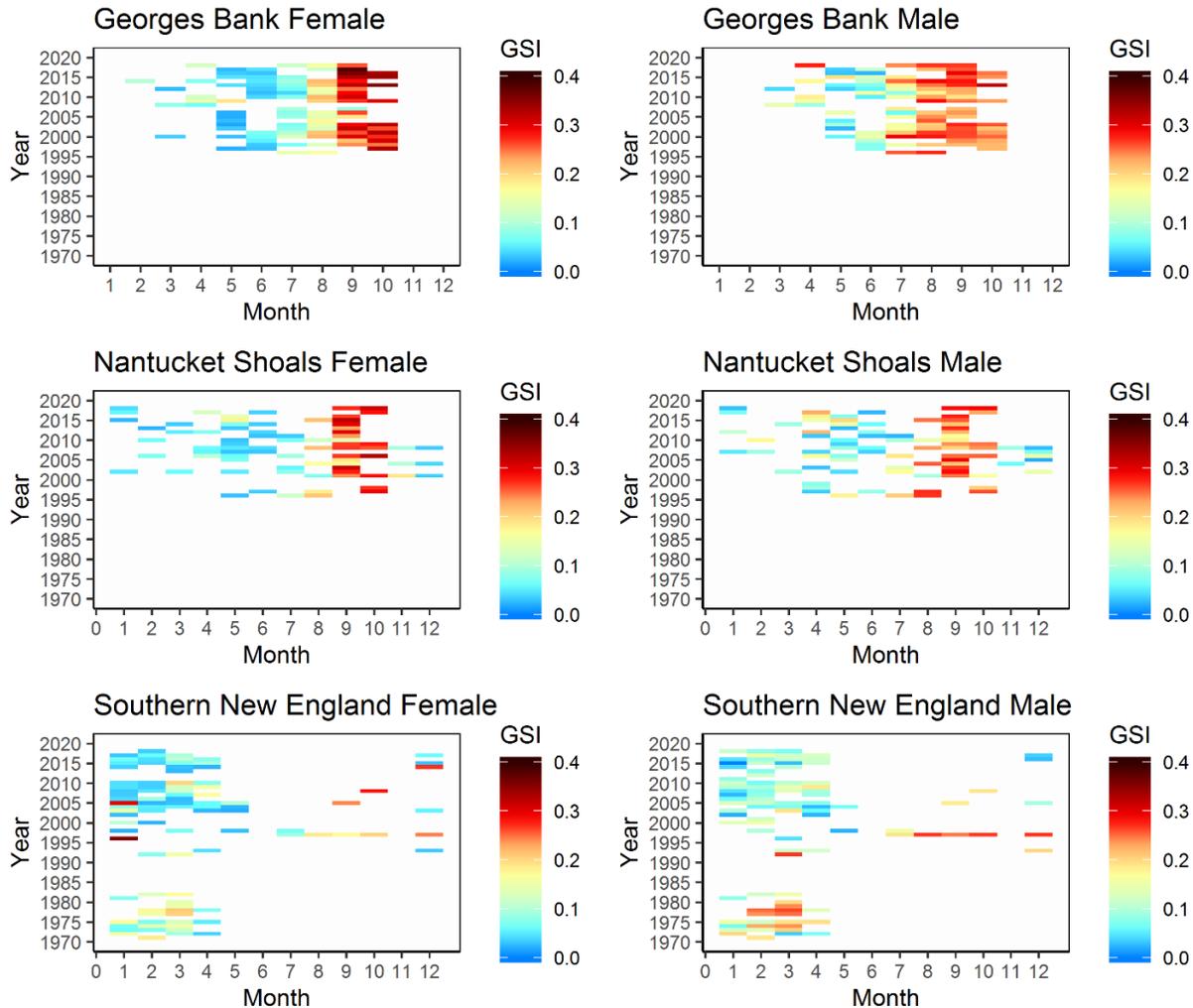
# Heatmap of 90<sup>th</sup> quantile of GSI values by month and year for males



# Defining regions



# Heatmap of 90<sup>th</sup> quantile of GSI values by month and year by area for males and females

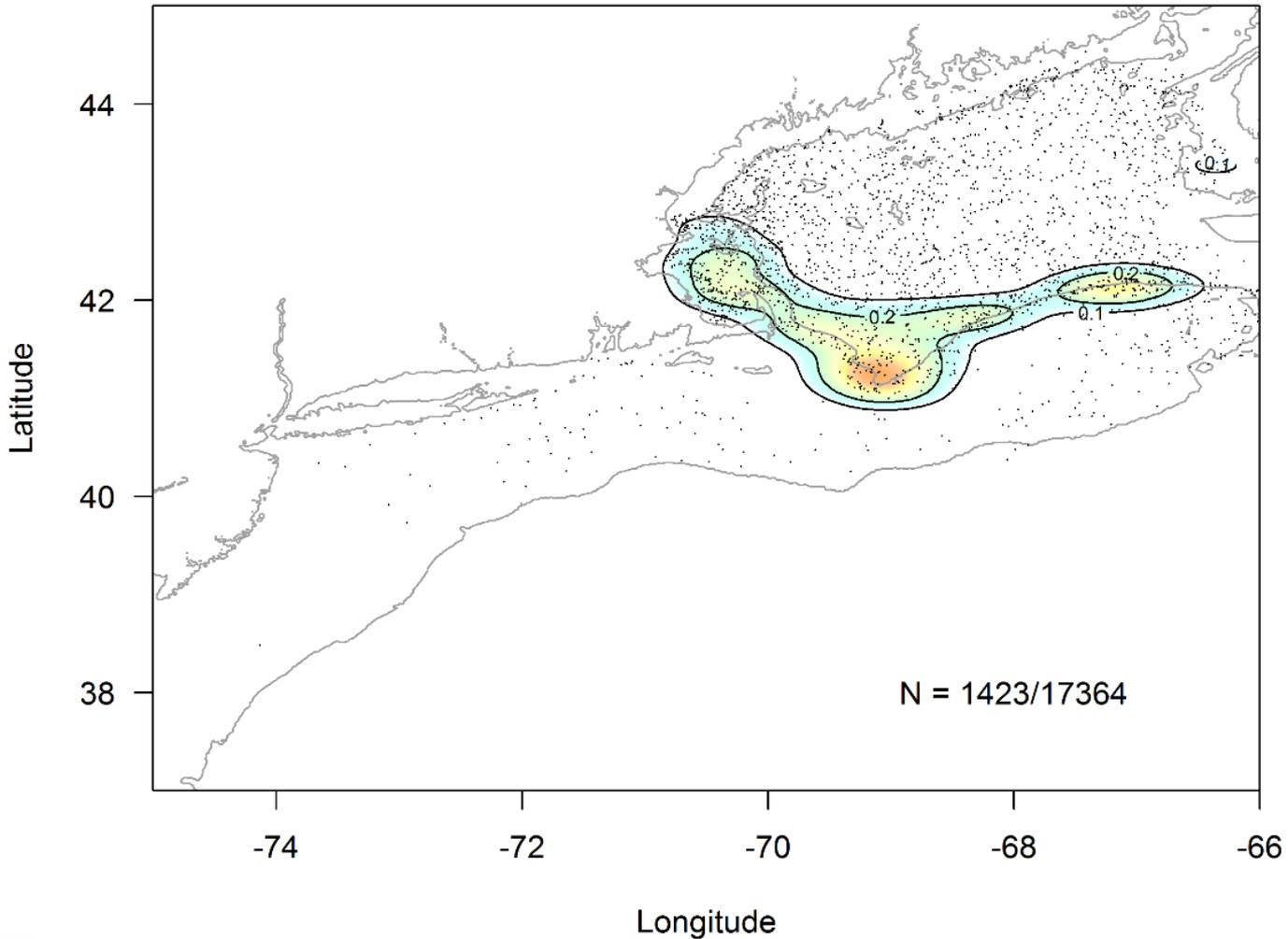


# Trawl Survey Data

- 1987 – 2018 (46,242 records of individual herring; 17,364 fall, 28,878 spring)
  - Maturity stage
  - Location
  - Date



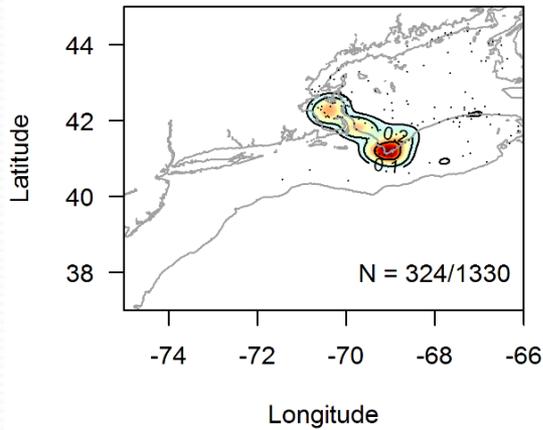
## 2-D kernel density estimate of male and female R+U stage herring (1987 – 2018)



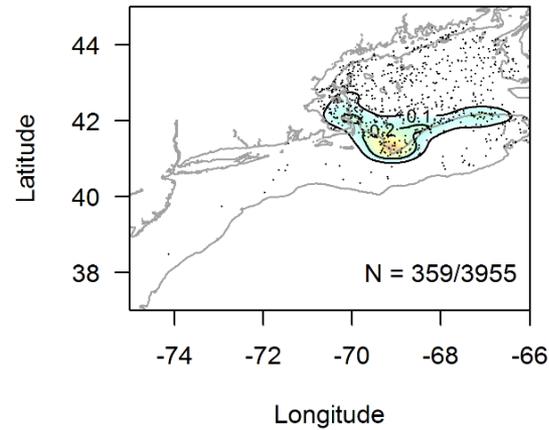
# FALL TRAWL SURVEY

## 2-D kernel density estimate of male and female R+U stage herring by decade

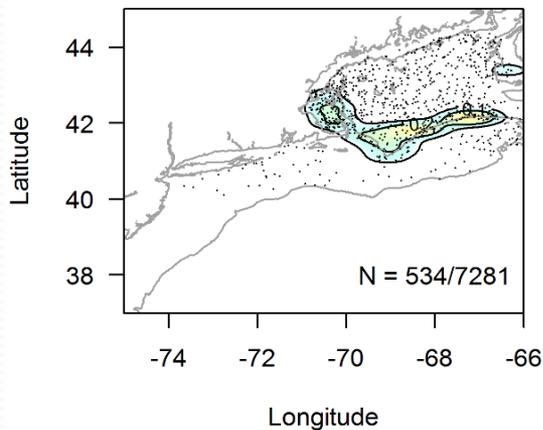
**1987-1990**



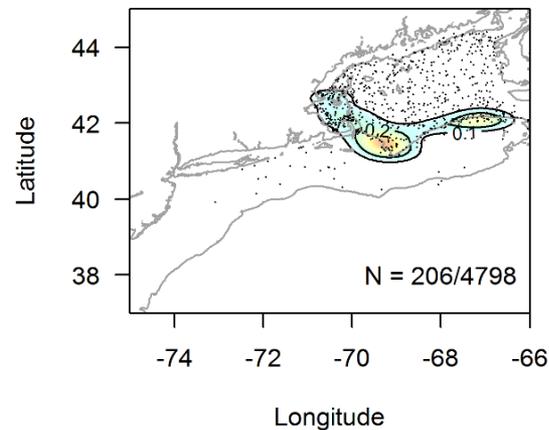
**1991-2000**



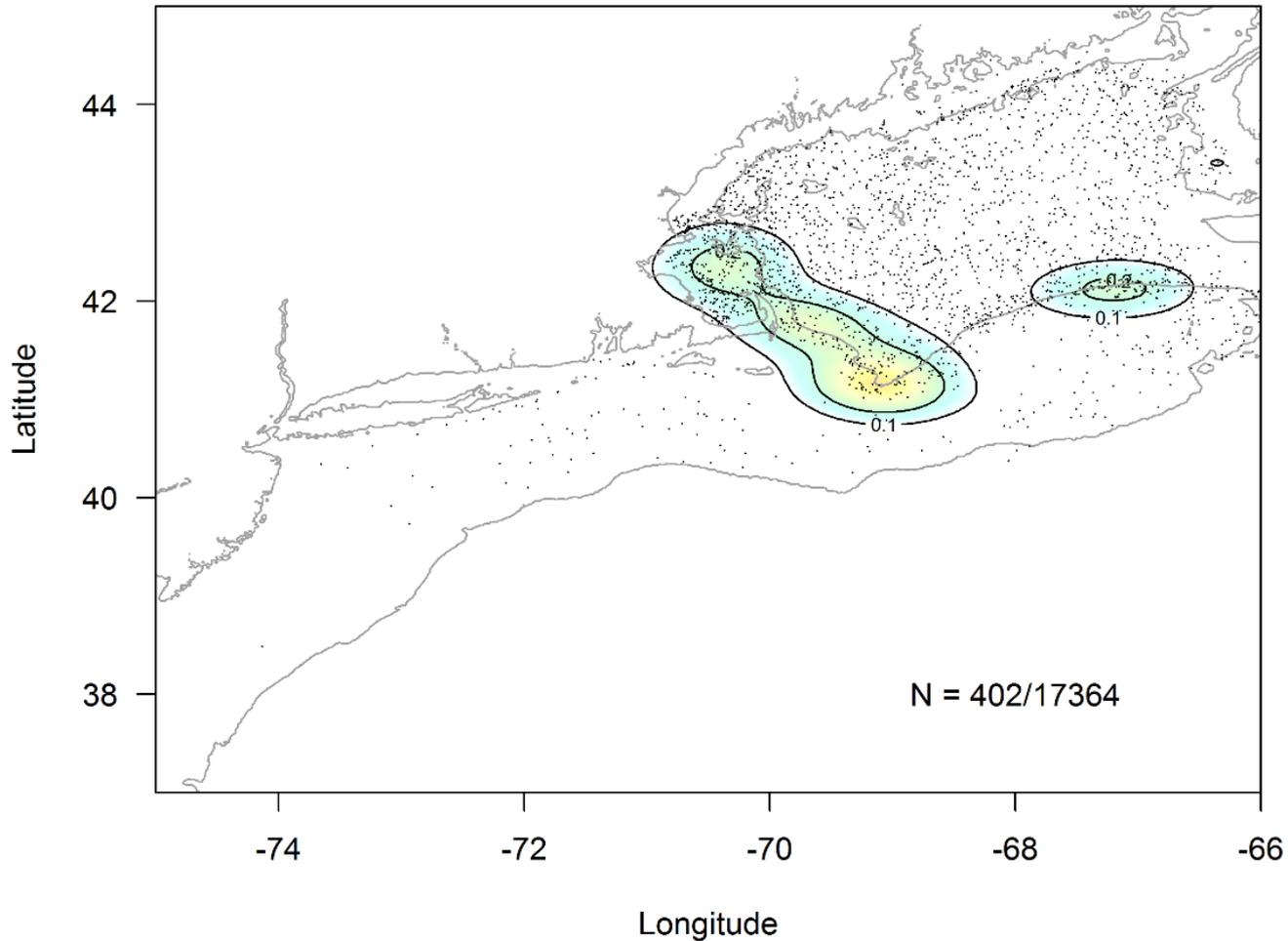
**2001-2010**



**2011-2018**

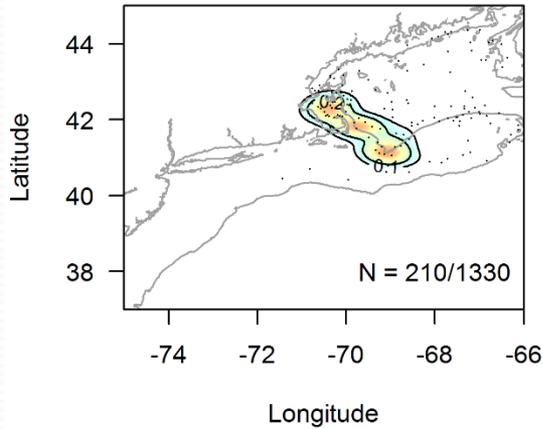


2-D kernel density estimate of male and female U stage herring (1987 – 2018)

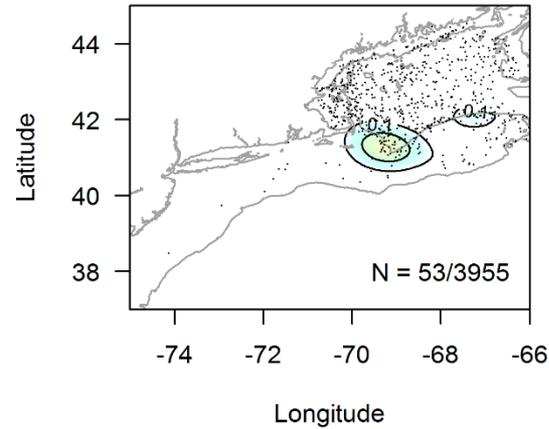


## 2-D kernel density estimate of male and female U stage herring by decade

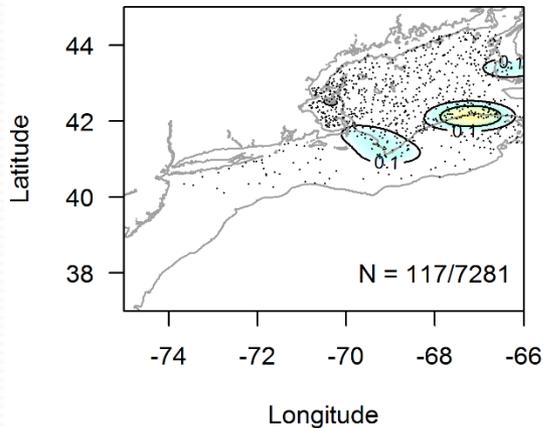
**1987-1990**



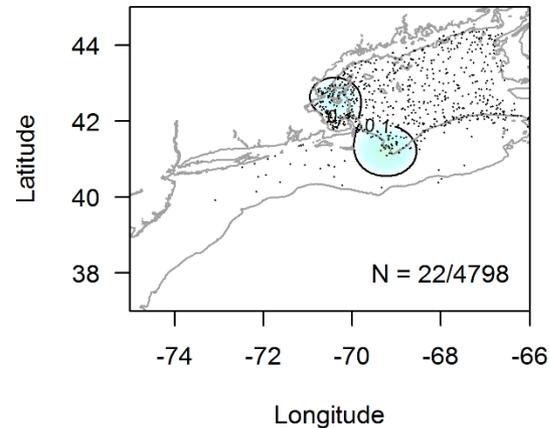
**1991-2000**



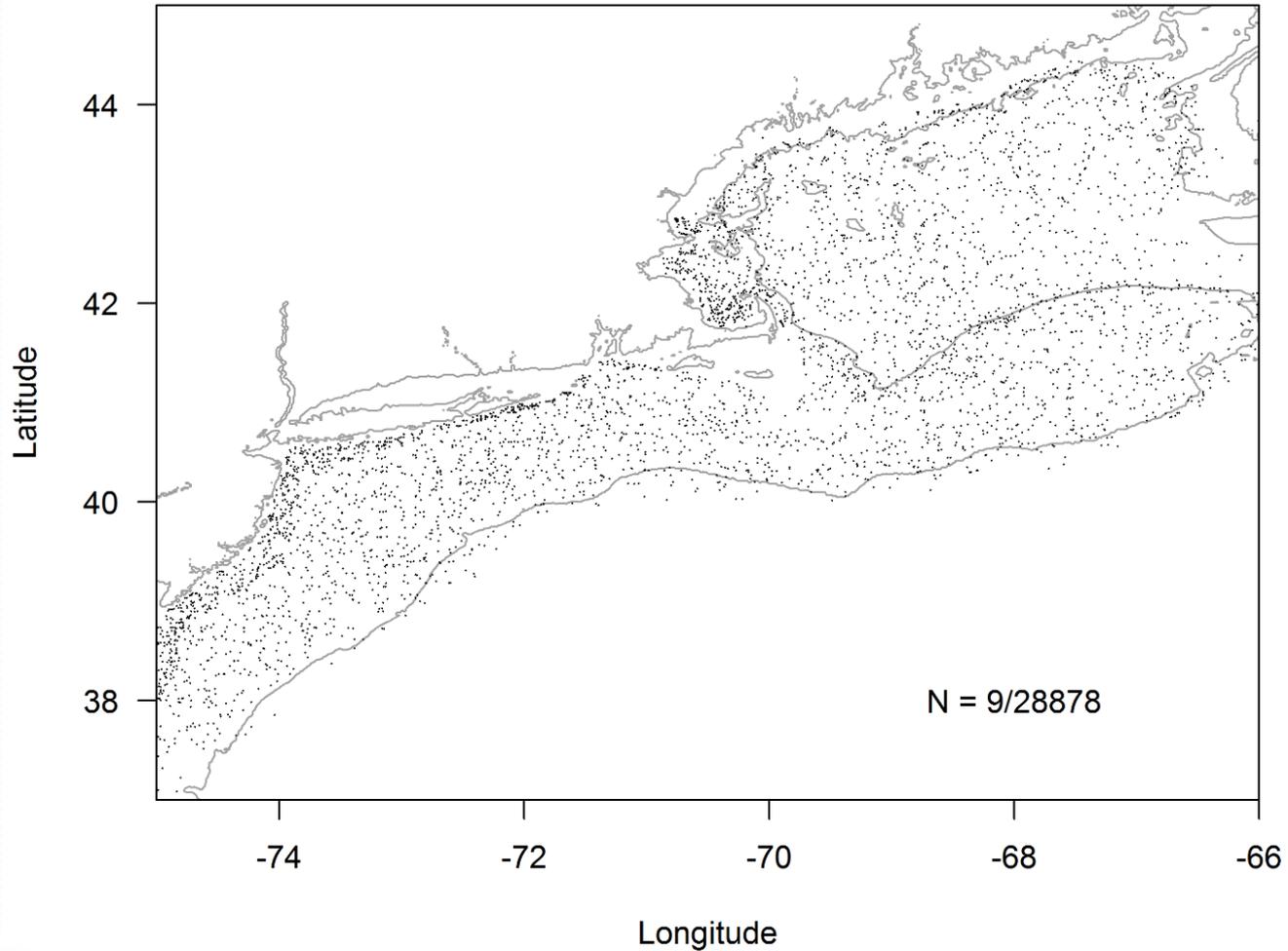
**2001-2010**



**2011-2018**



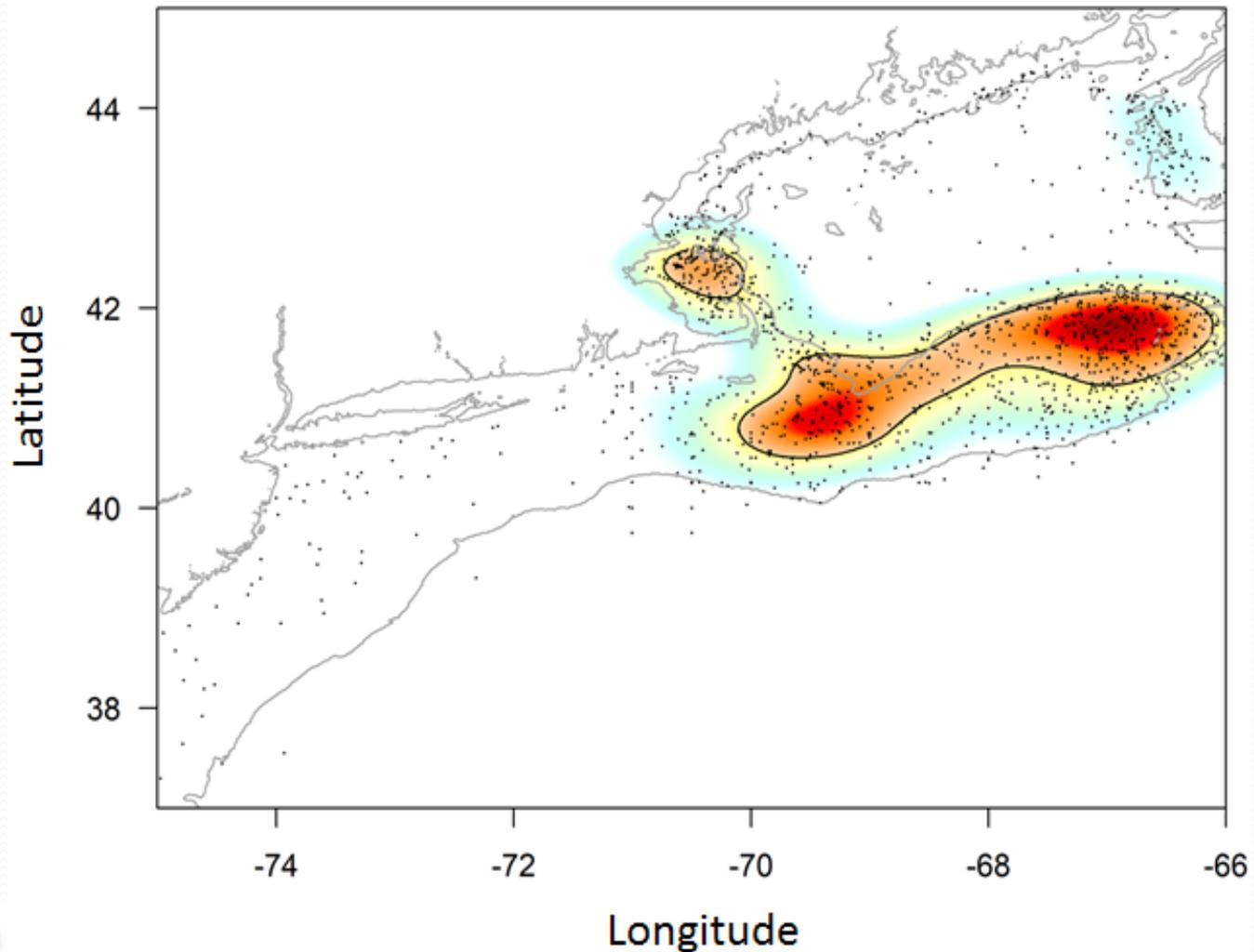
2-D kernel density estimate of male and female U stage herring (1987 – 2018)



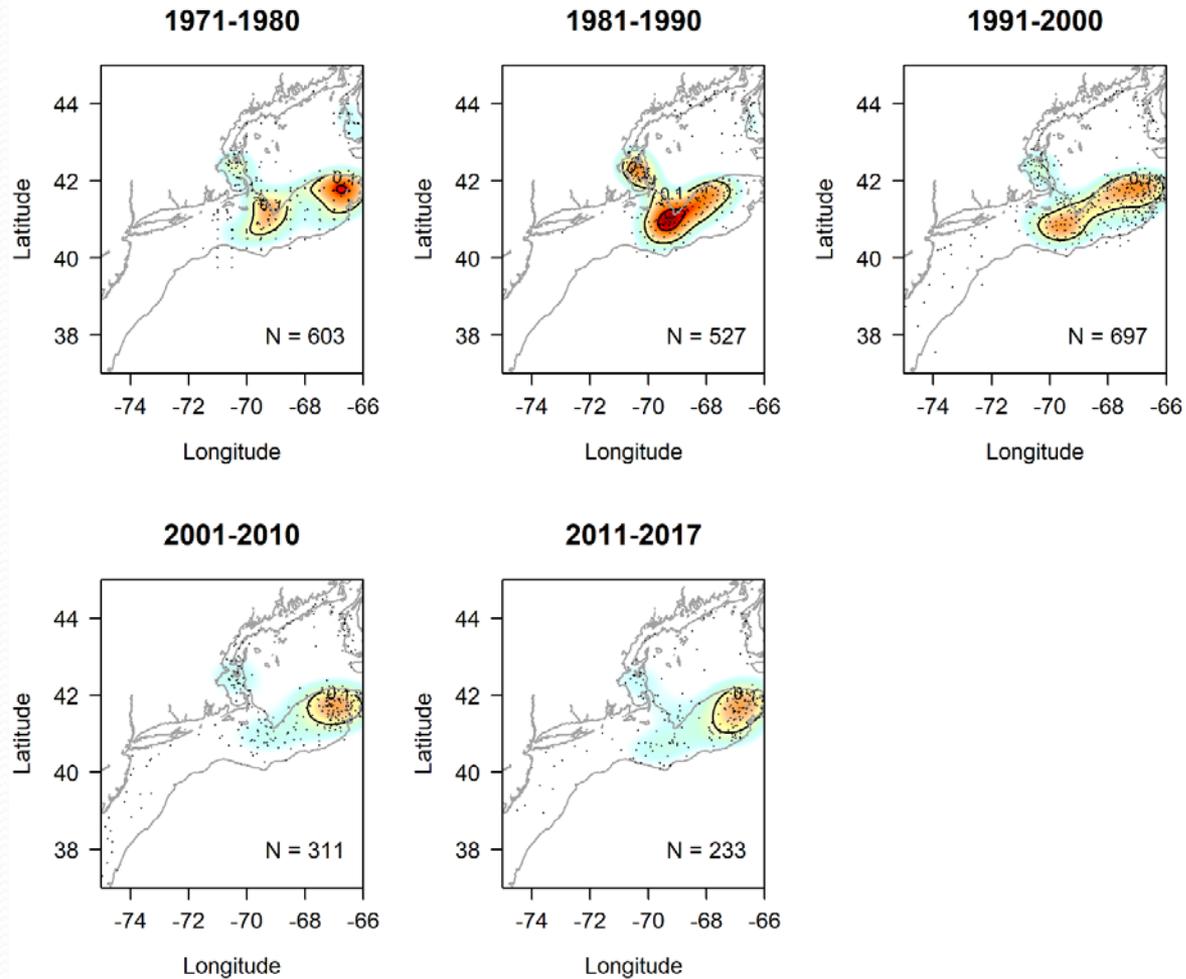
# Larval Distribution



# 2-D kernel density estimate of larval herring (<9mm) abundance by sample (1971 – 2017)



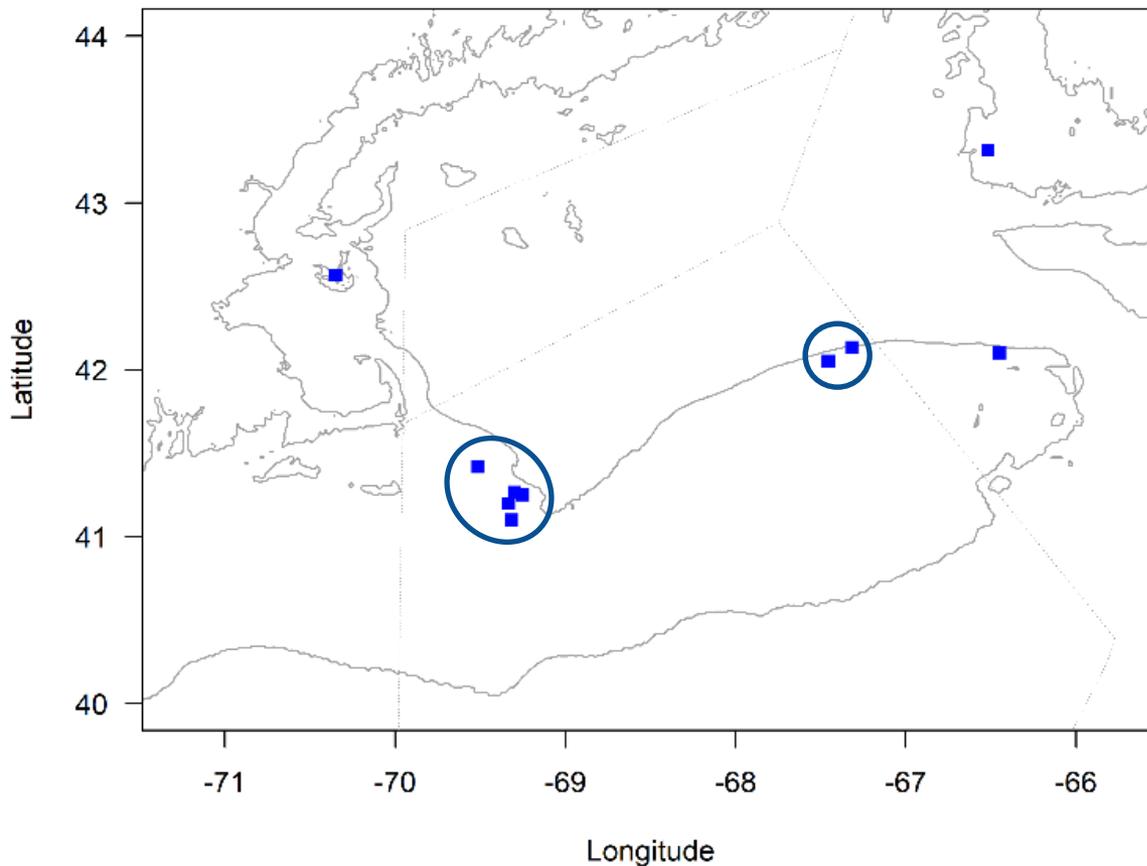
## 2-D kernel density estimate of larval herring (<9mm) abundance by sample (by decade)



# Food Habits Database



# Location of herring eggs observed in diet

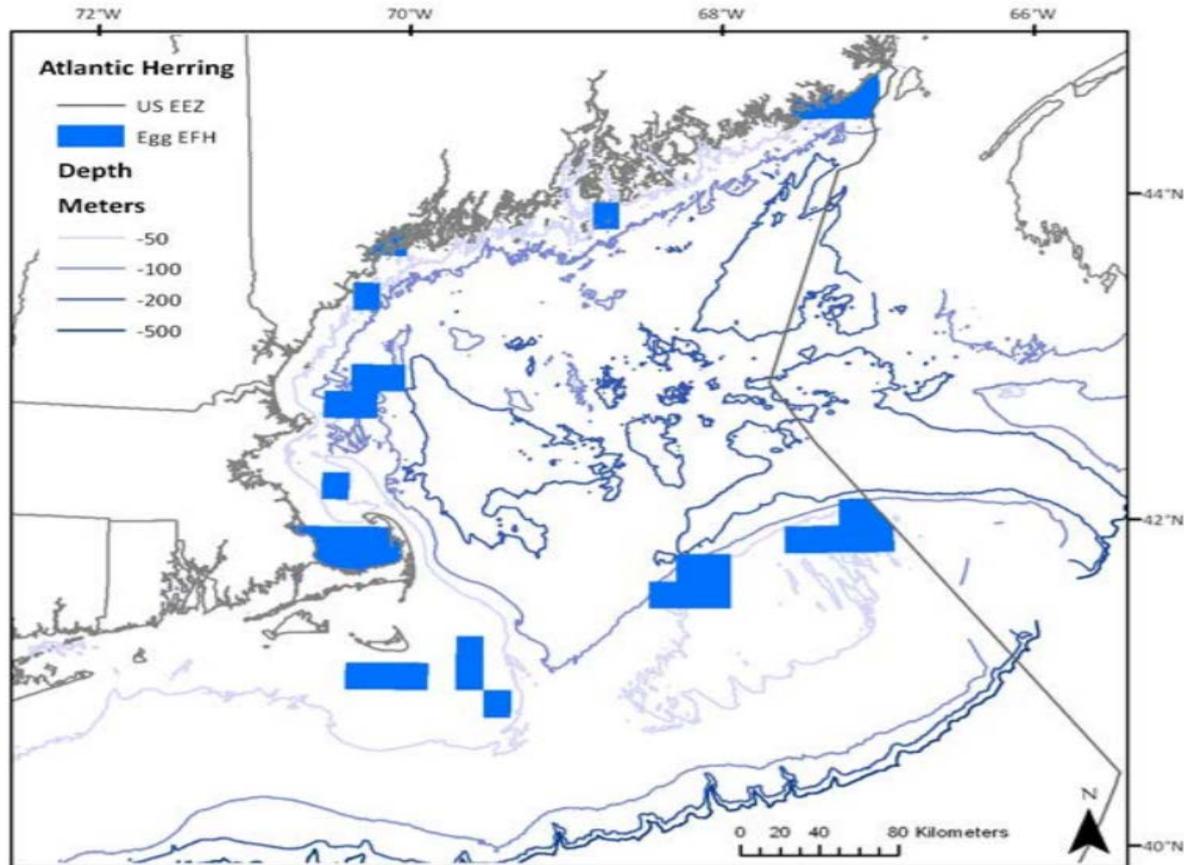


Only 113 stomachs had positive ID For herring eggs (10 hauls)

# Egg EFH



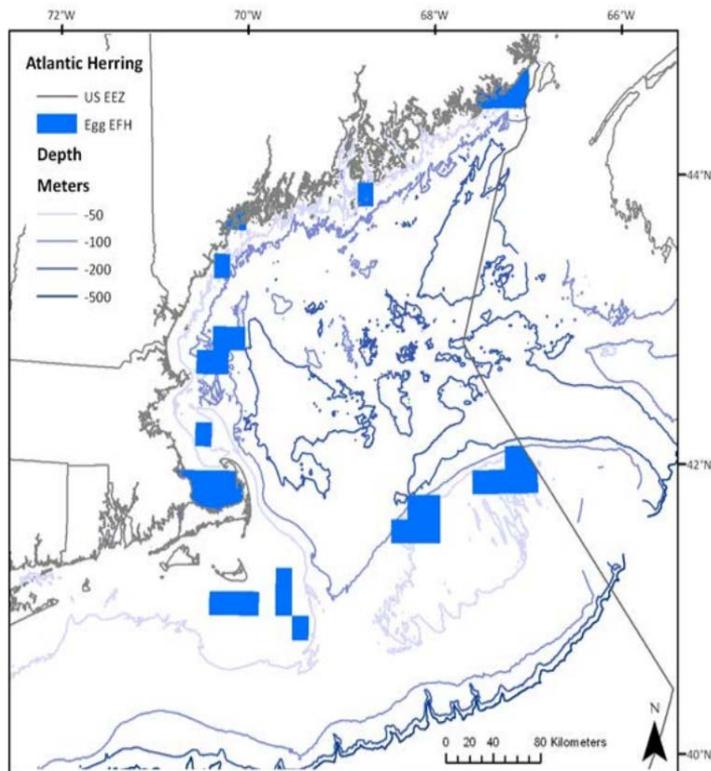
# EFH for herring eggs



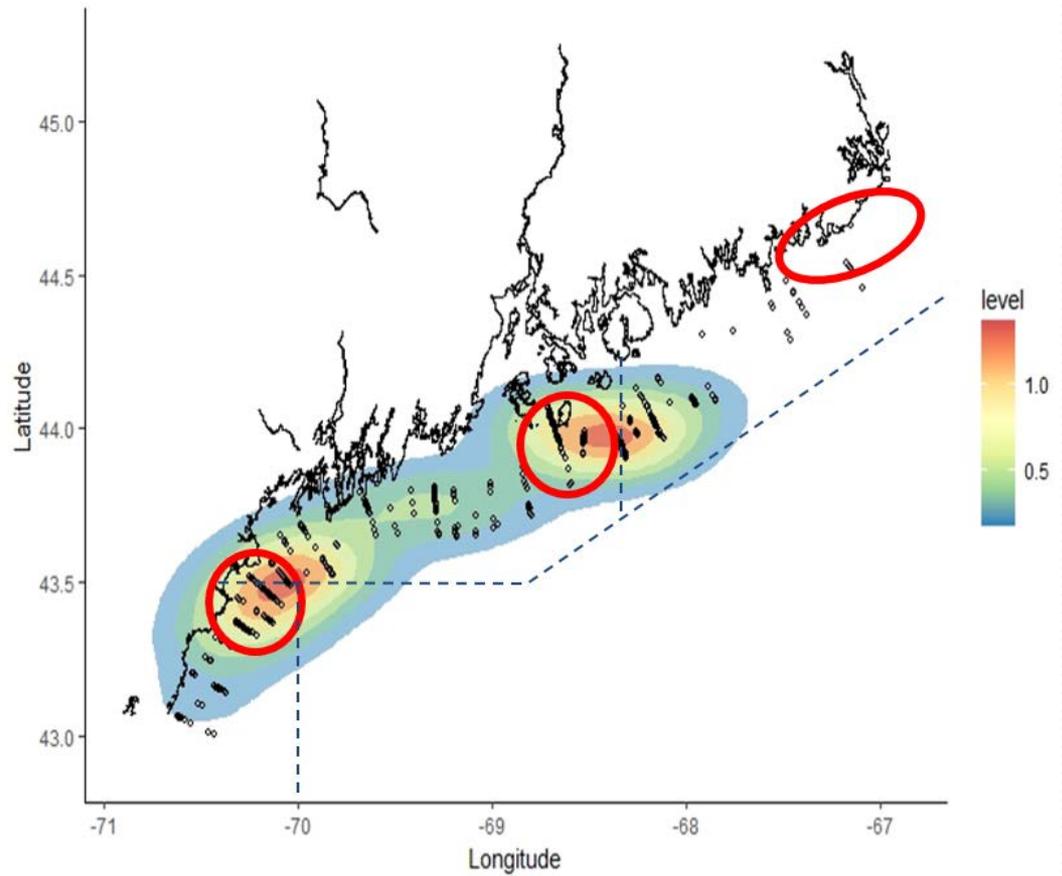
Amendment 5 to the FMP for Atlantic herring (NEFMC 2013)



# Significance of egg beds



NEFMC (2013)

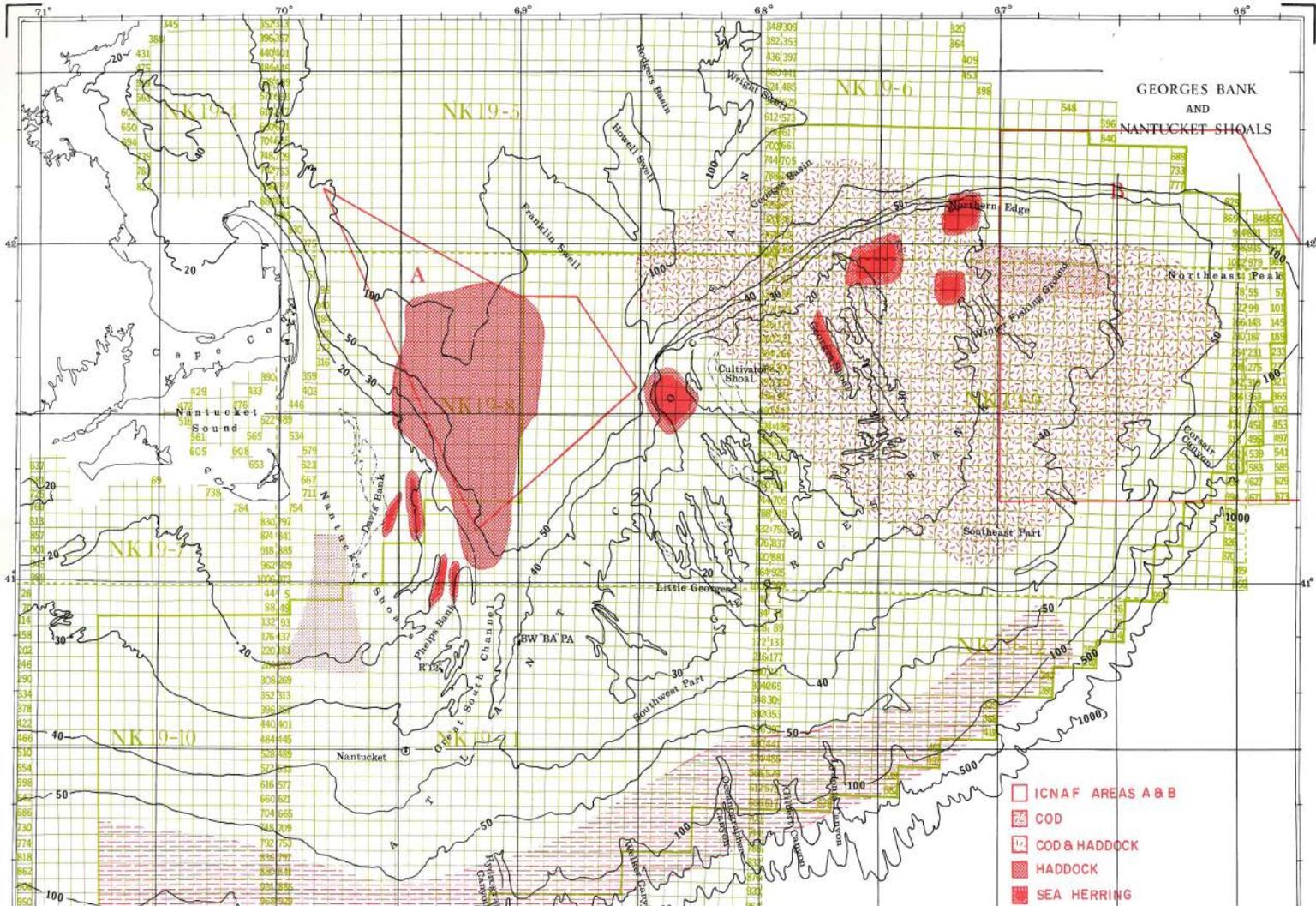


Sherwood et al (2017)

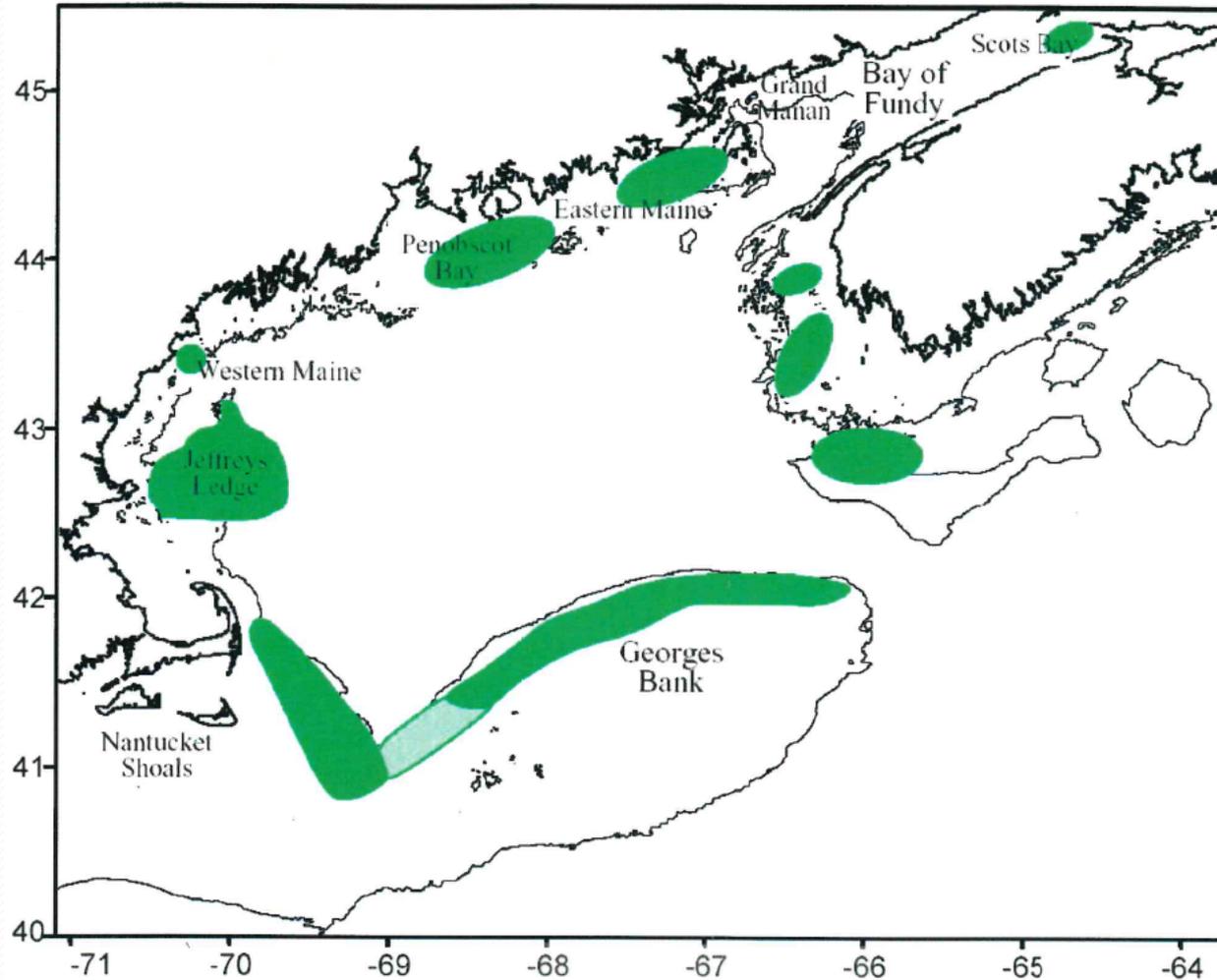
# Historical Spawning Grounds



# Olsen et al (1977) Fishing and Petroleum Interactions on Georges Bank



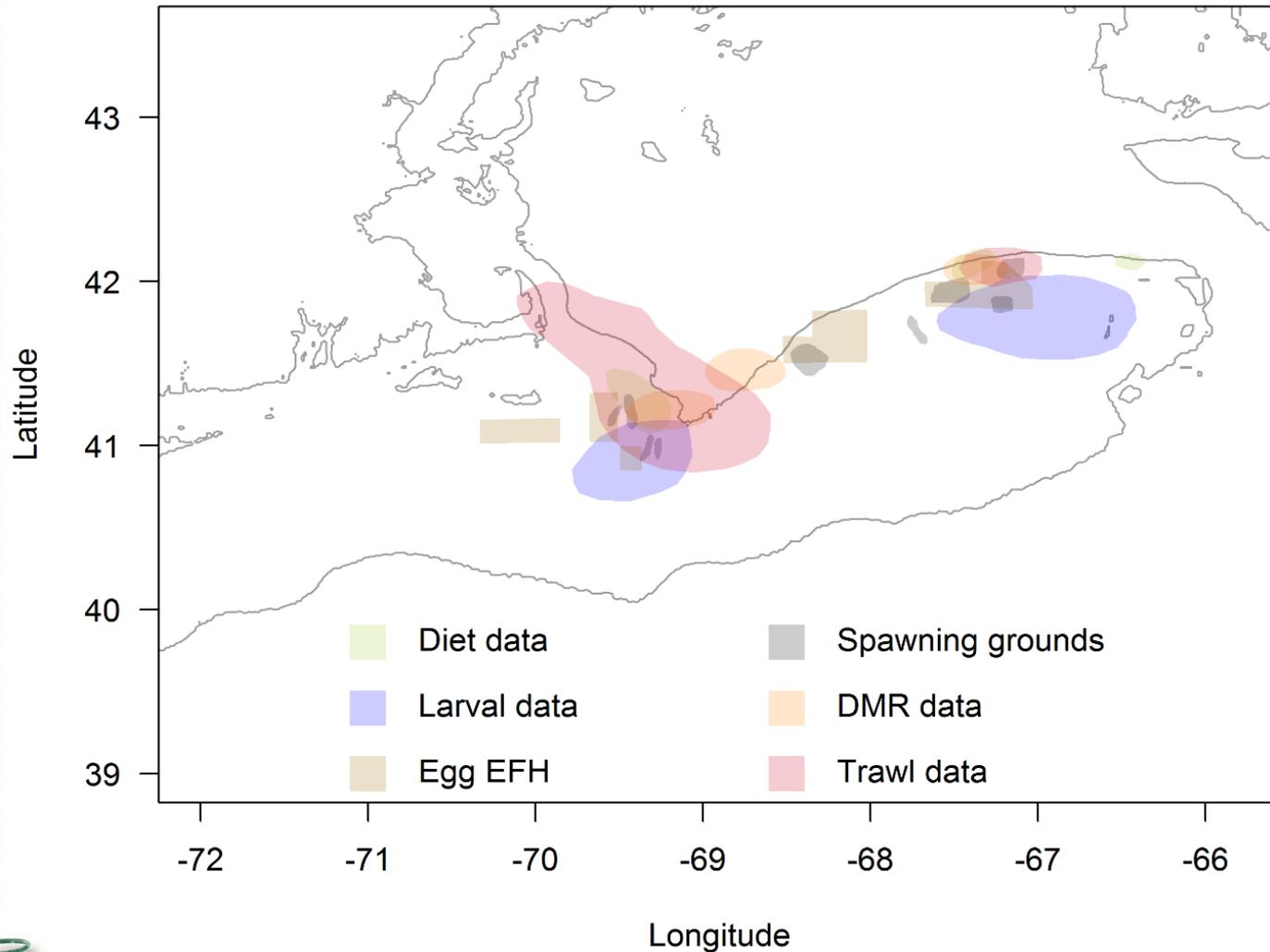
# Overholtz et al (NEFSC 2004)



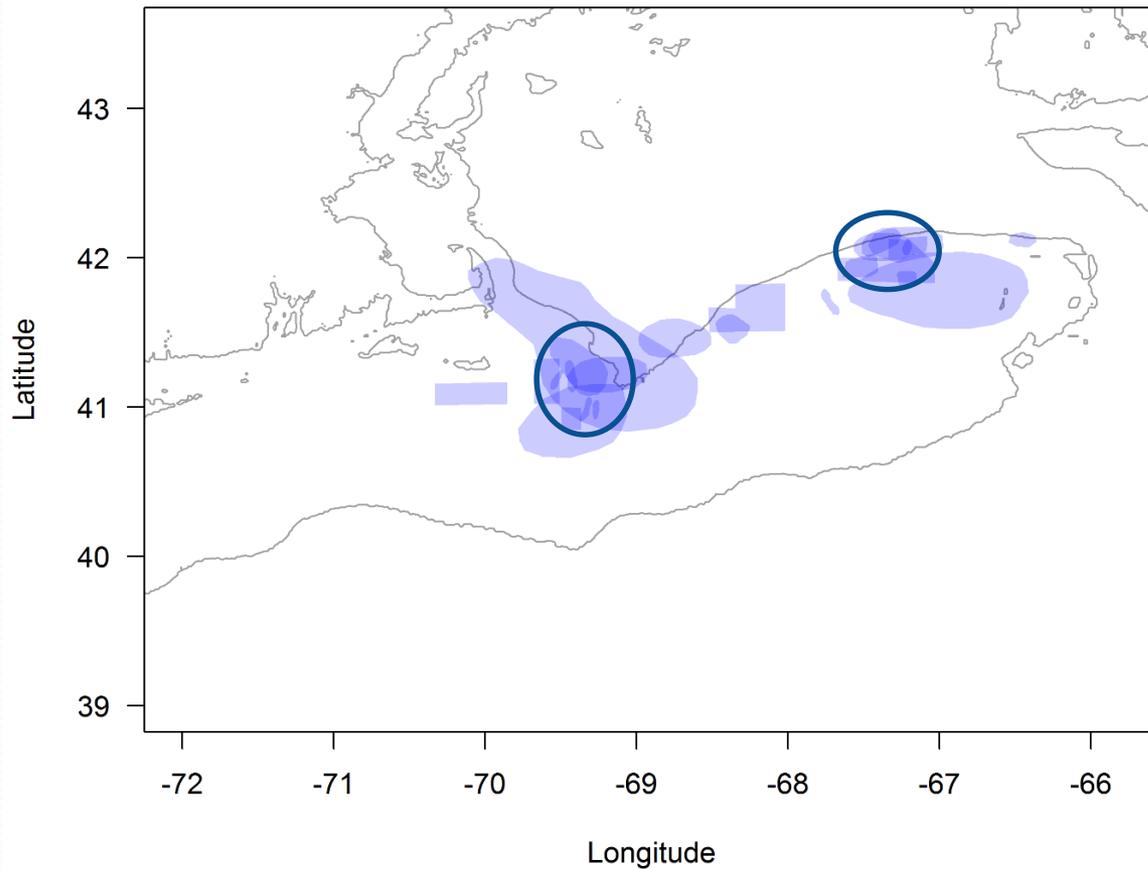
# Building a Consensus



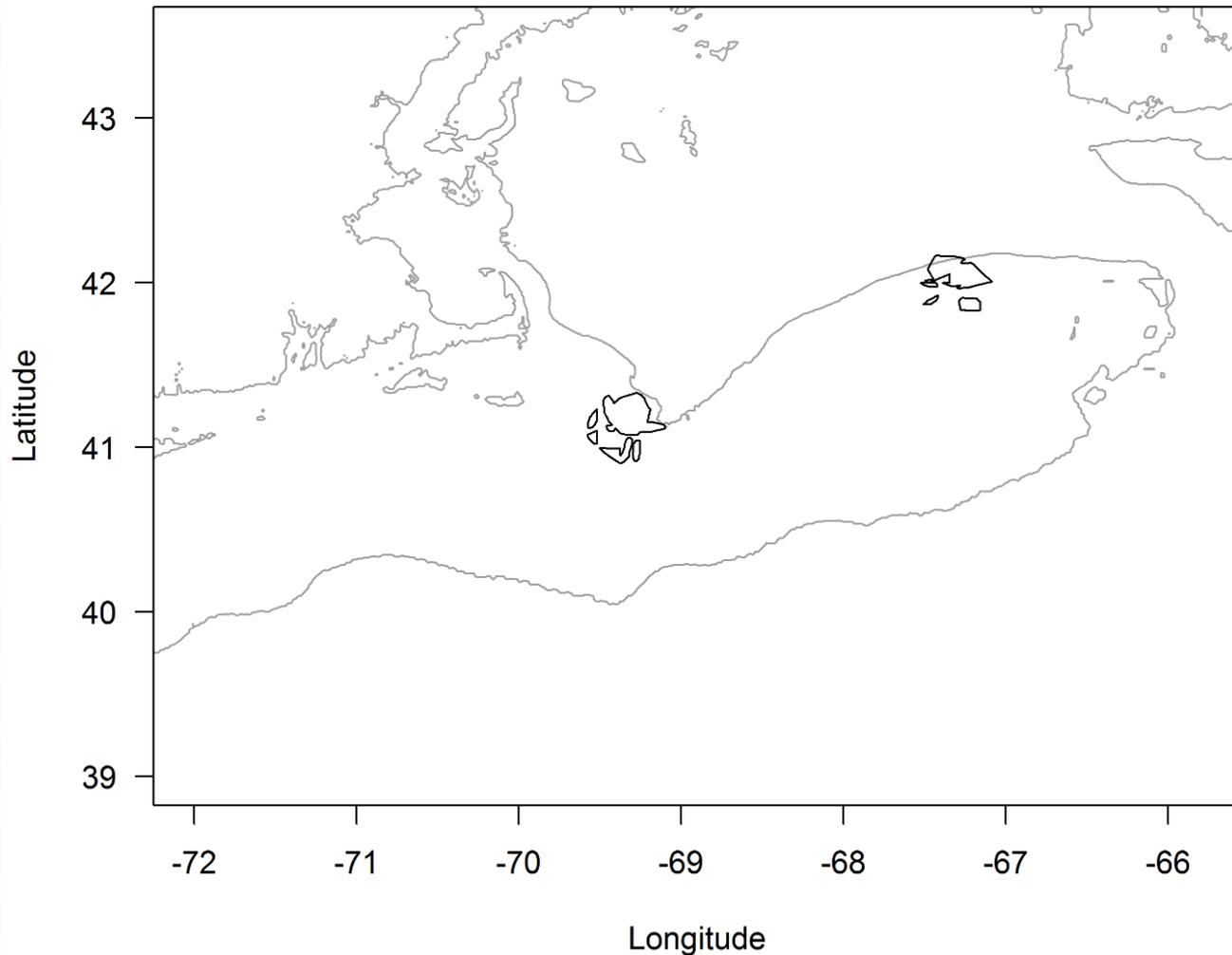
# Overlap between spawning indicators from multiple sources



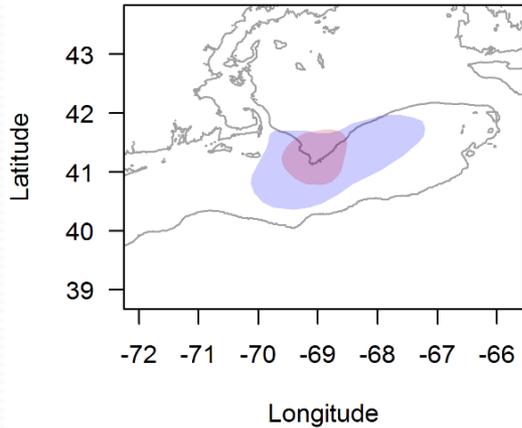
# Overlap between spawning indicators from multiple sources



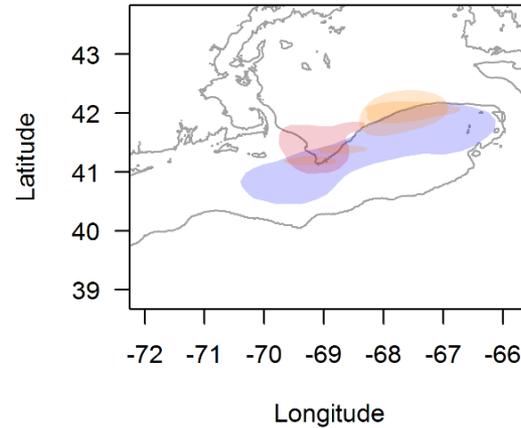
# Overlap between spawning indicators from multiple sources (consensus areas: 3 or more sources)



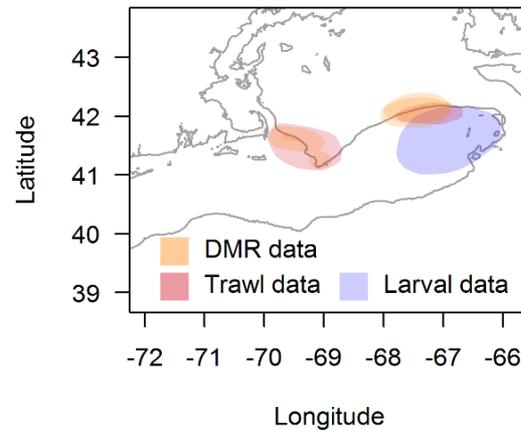
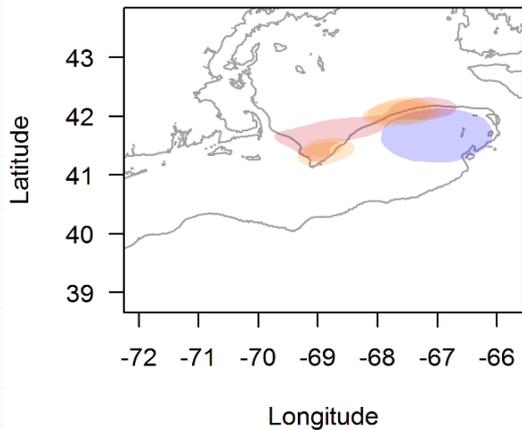
# Overlap between spawning indicators from multiple sources by decade



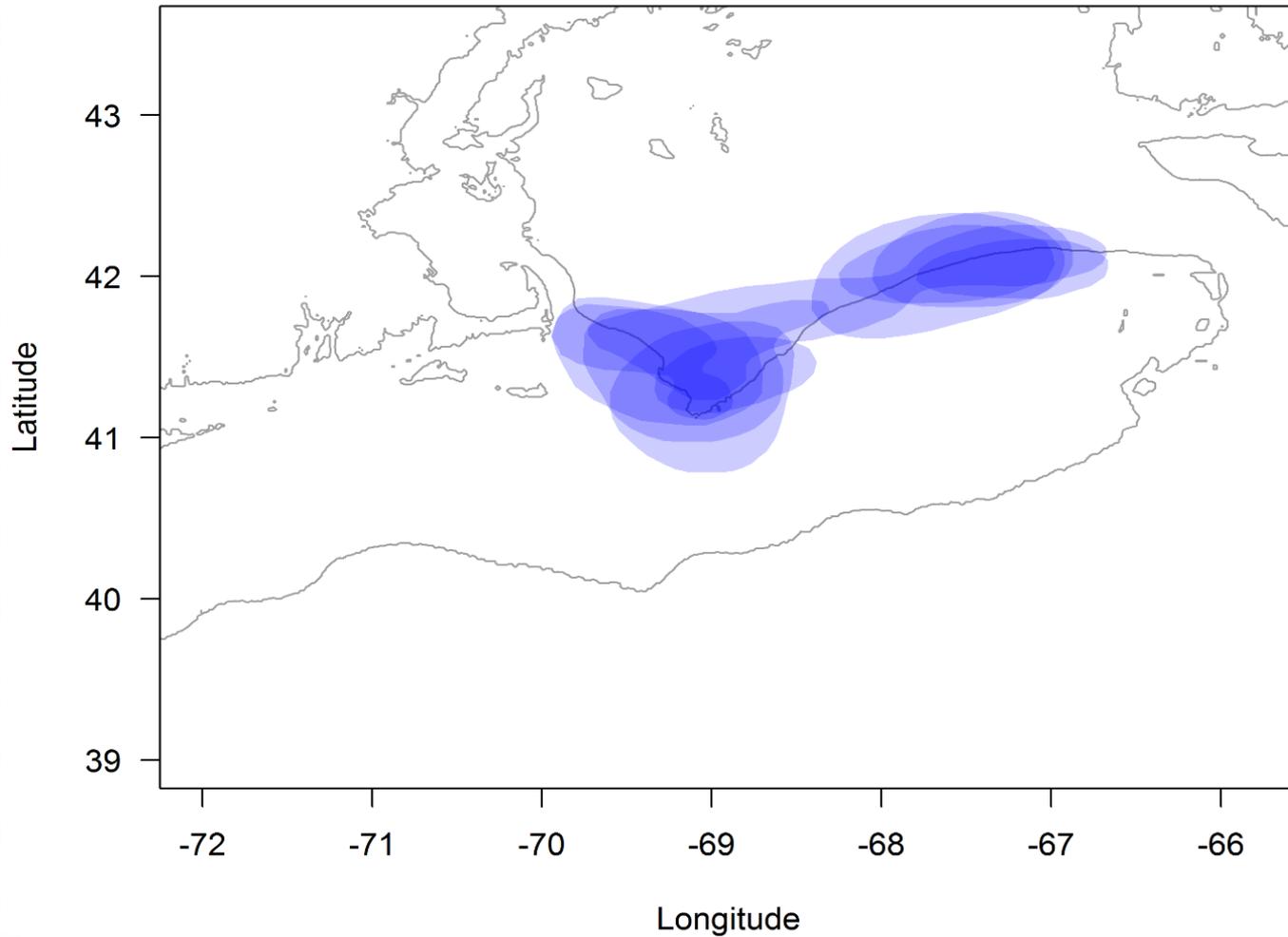
**2001 - 2010**



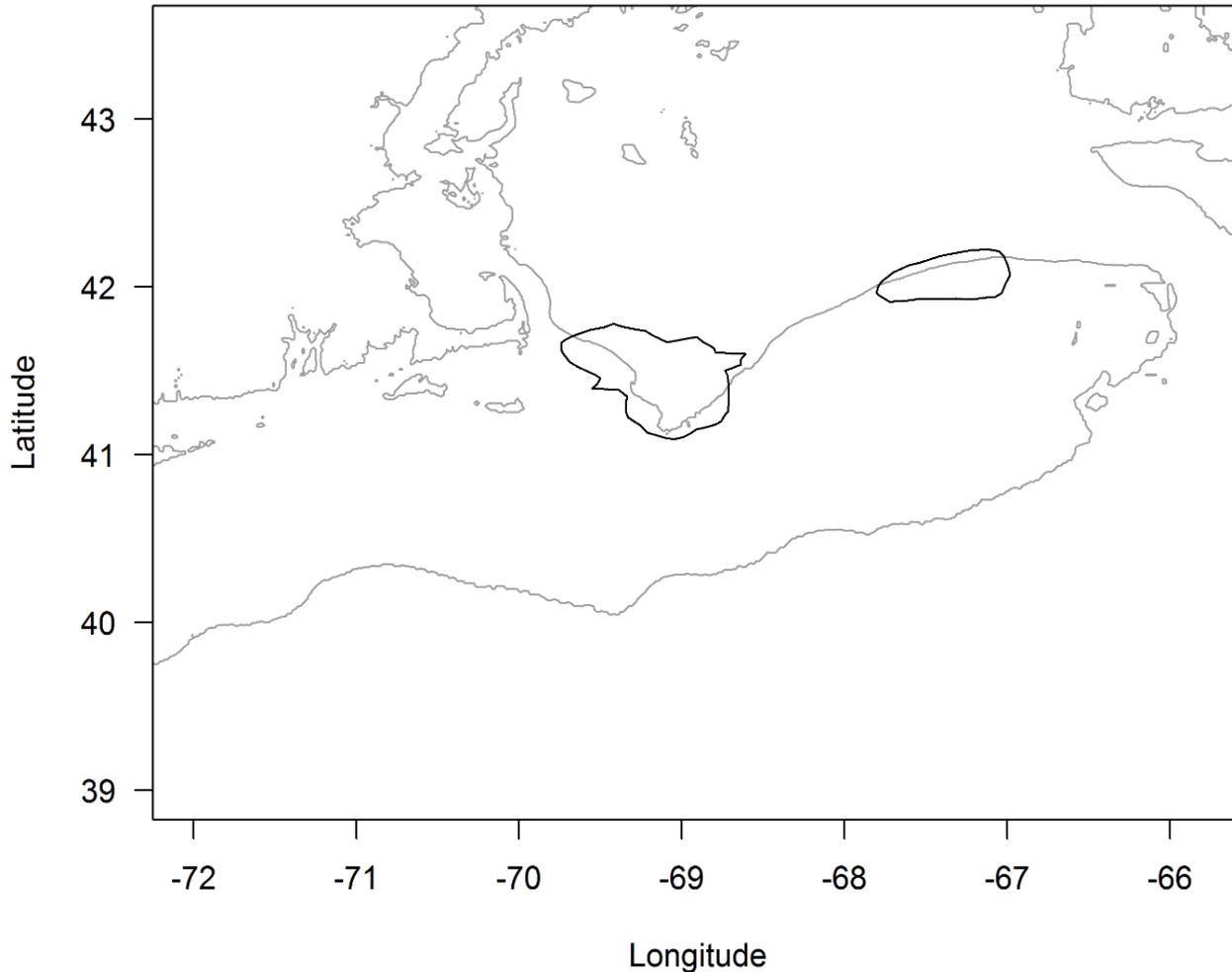
**2011 - 2018**



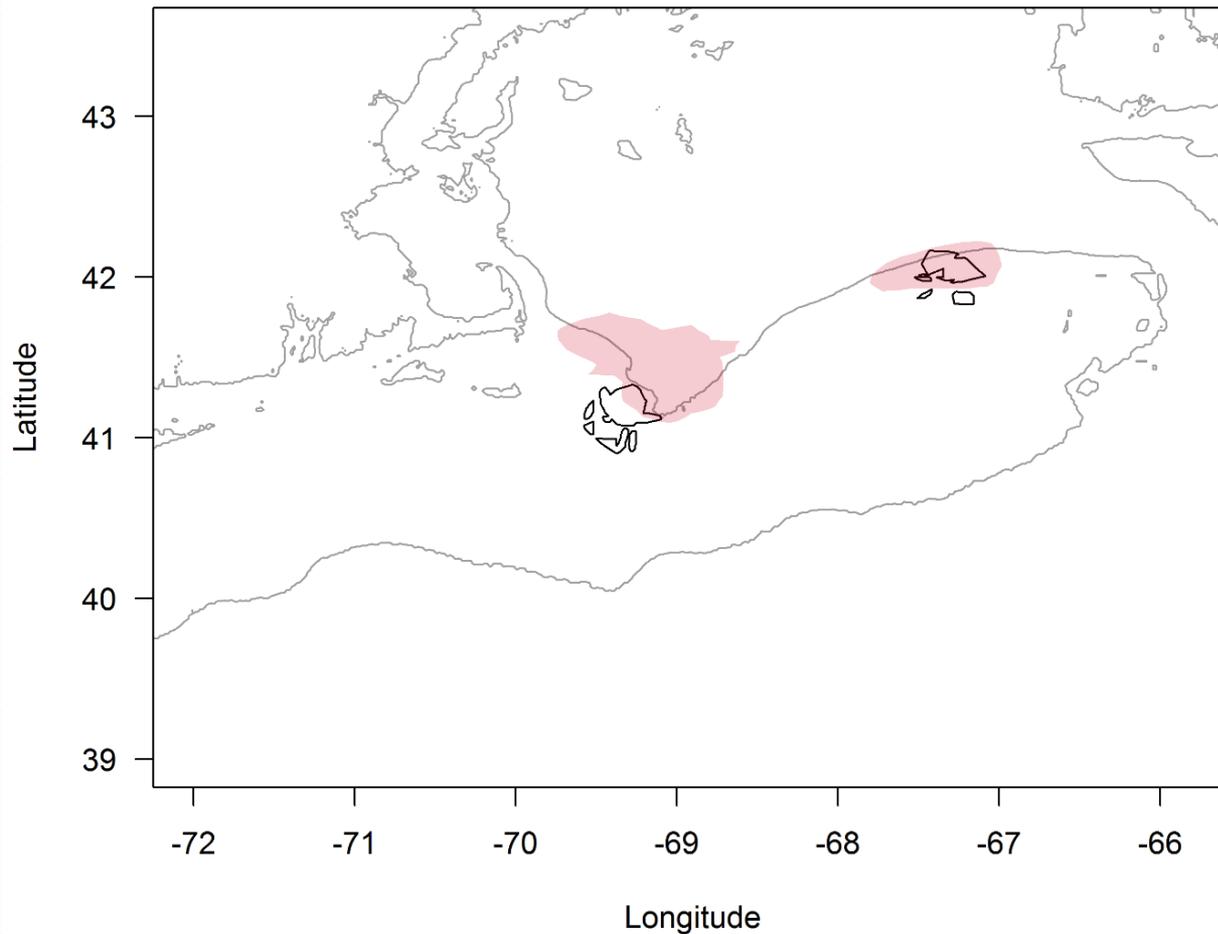
## Overlap between DMR and trawl survey by decade for R+U stage herring



# Overlap between DMR and trawl survey by decade for R+U stage herring (consensus areas: 4 or more sources)



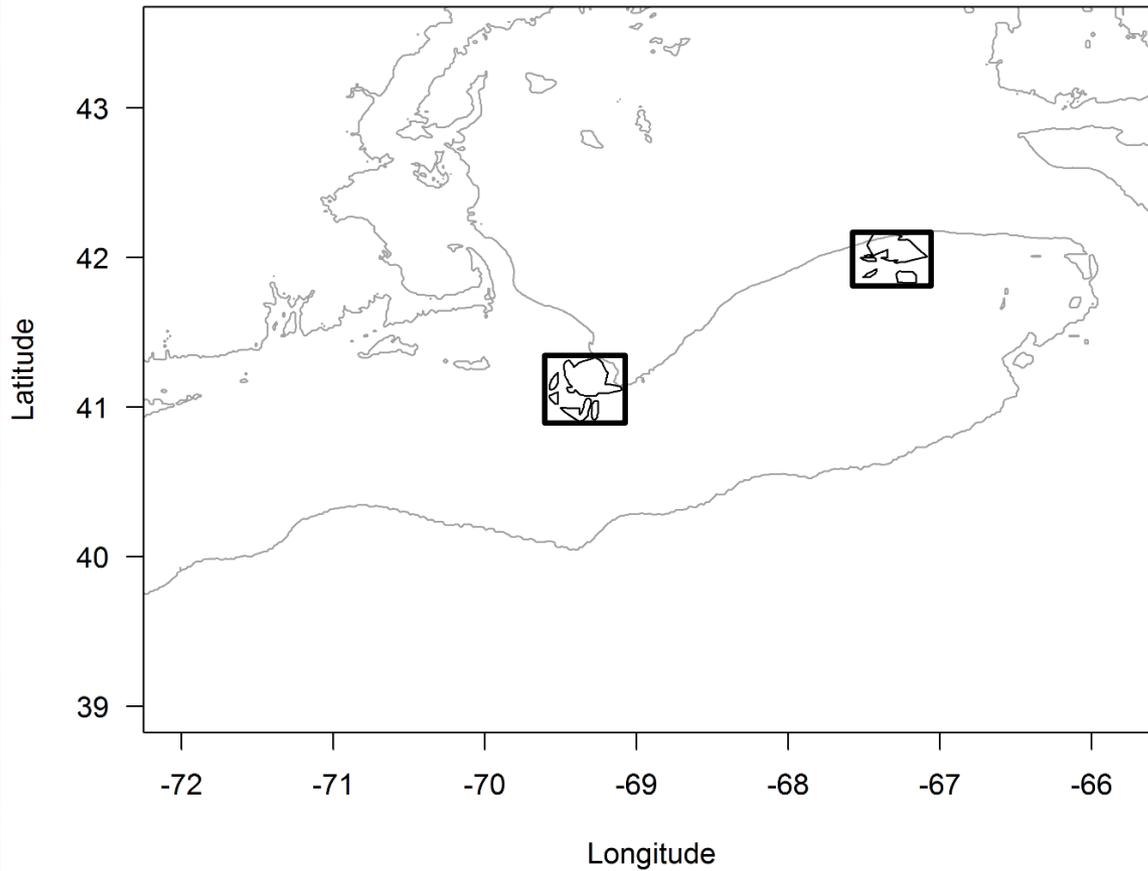
# Comparison between consensus areas: all sources vs. adult spawning herring (DMR + trawl survey)



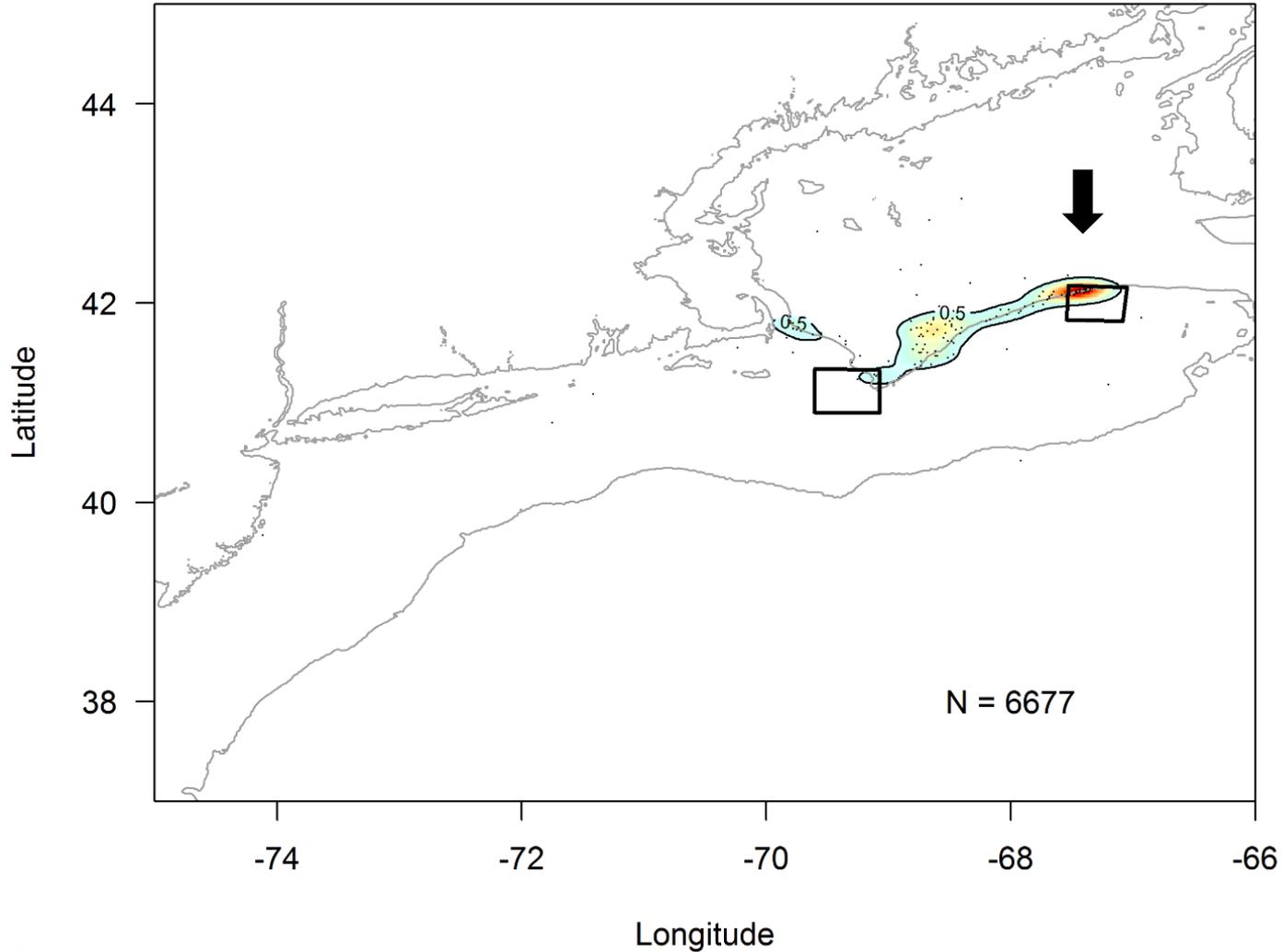
# Fishing Effort



## How does fishing footprint compare with spawning consensus areas?

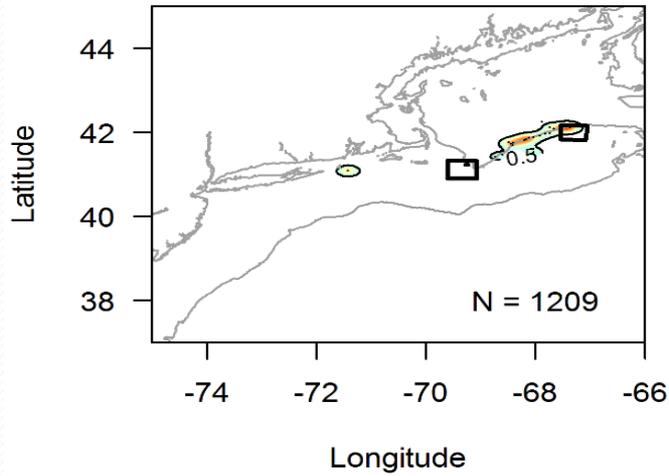


# Overlap with fishing locations from DMR dockside monitoring

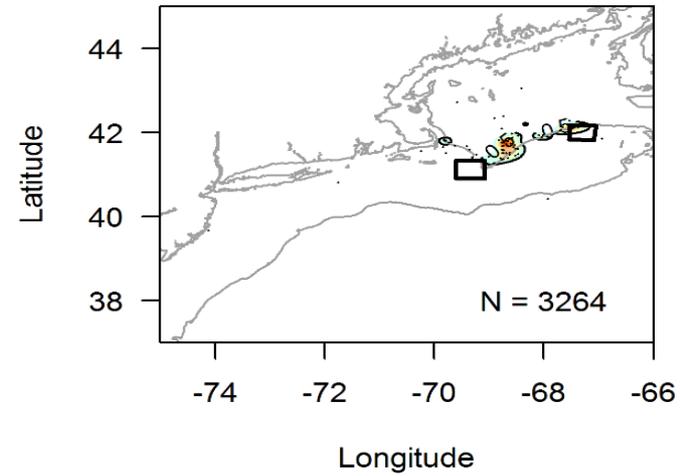


# Overlap with DMR locations by decade

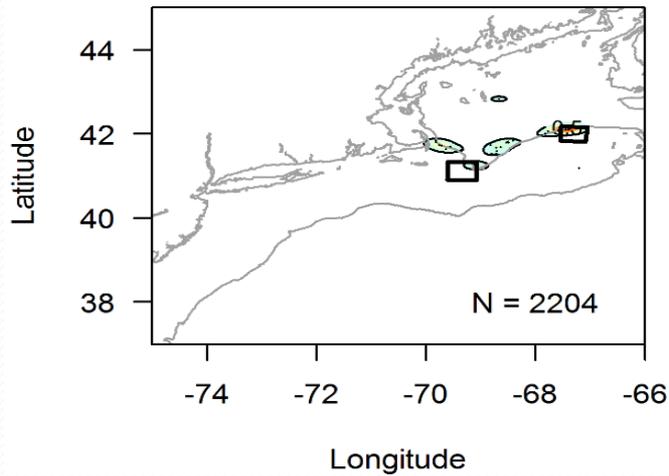
**1991-2000**



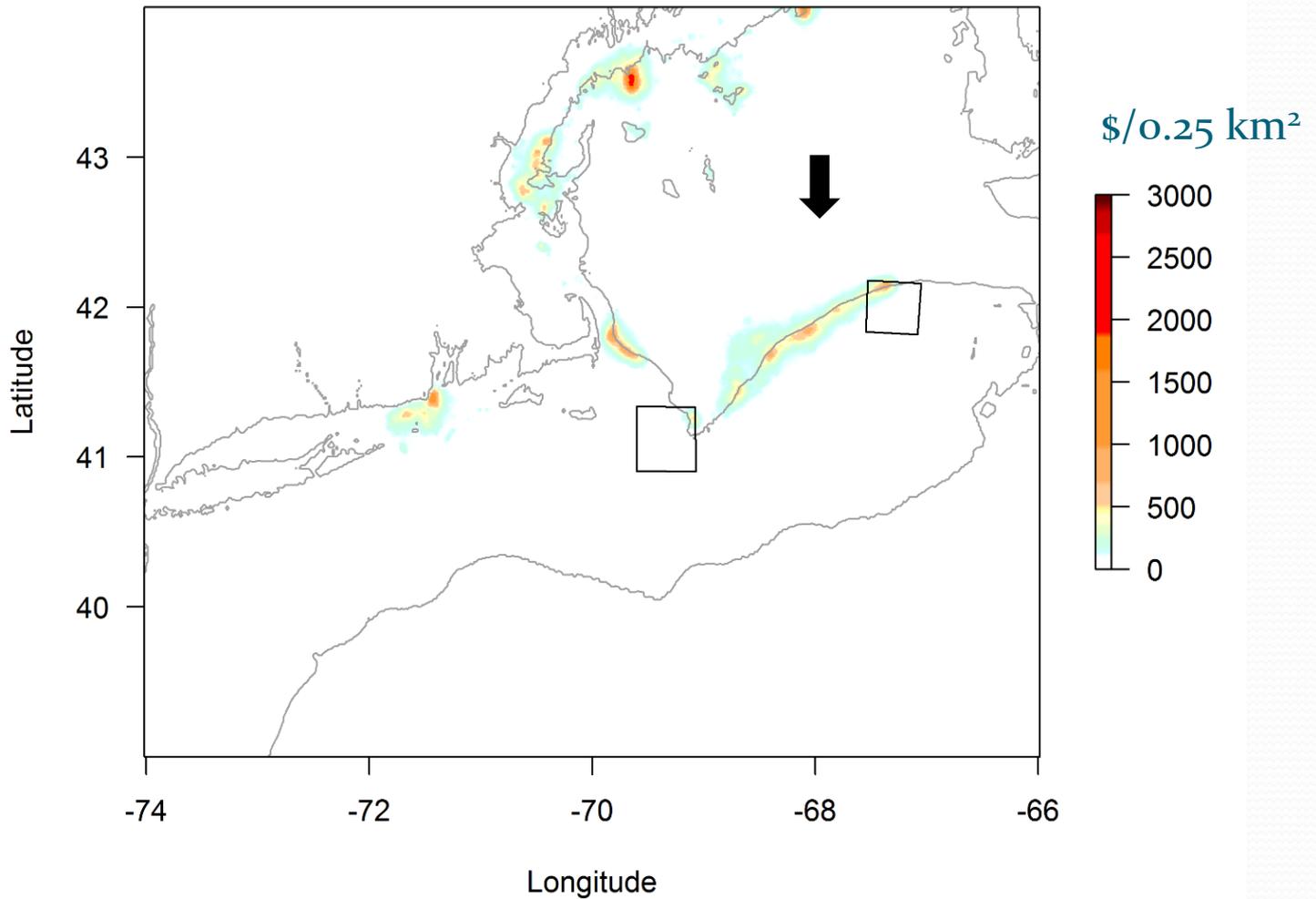
**2001-2010**



**2011-2018**



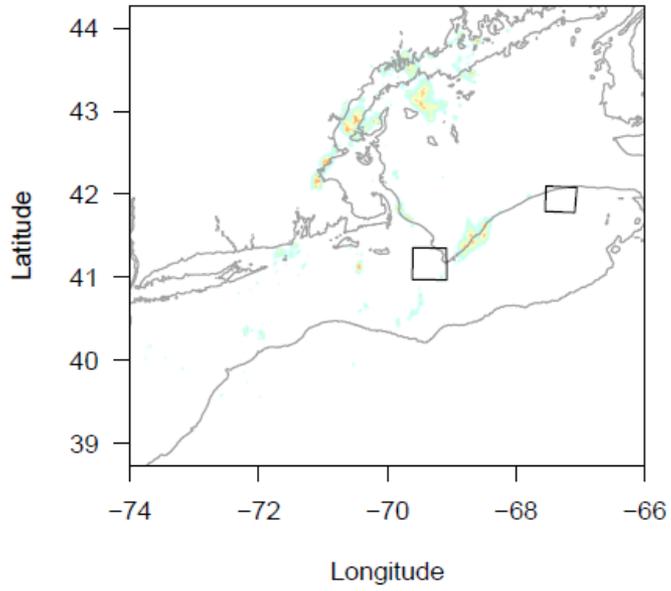
## Overlap with herring revenue data



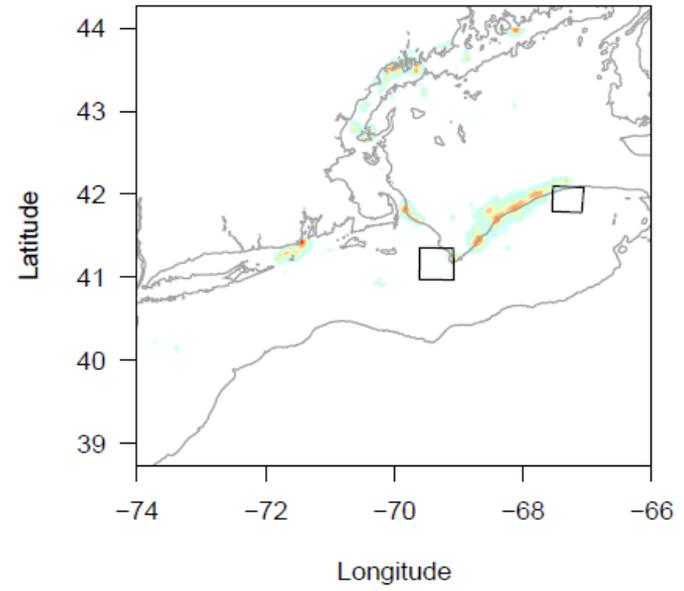
Benjamin et al (2018)



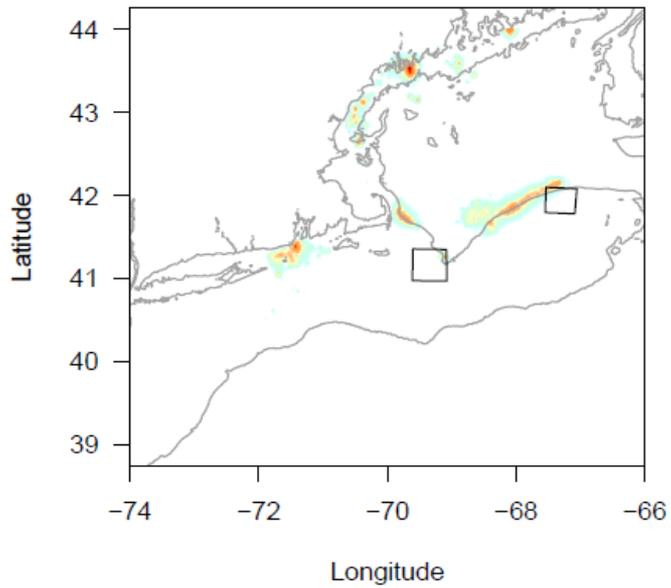
**2007-2009**



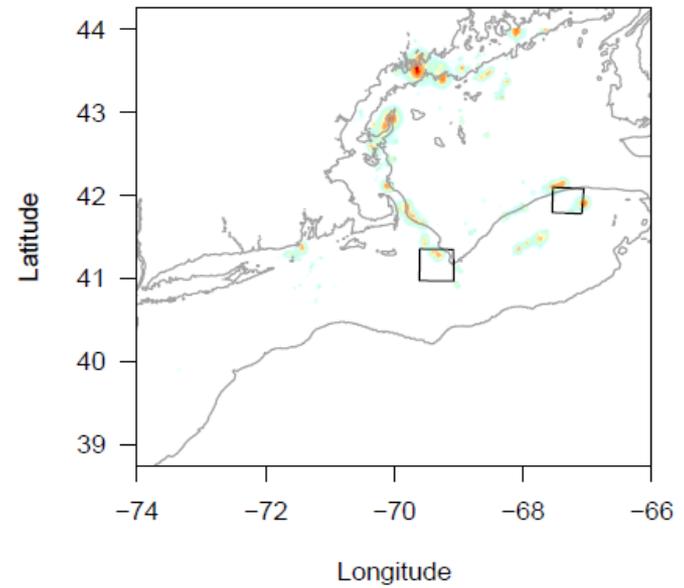
**2010-2012**



**2013-2015**



**2016-2017**



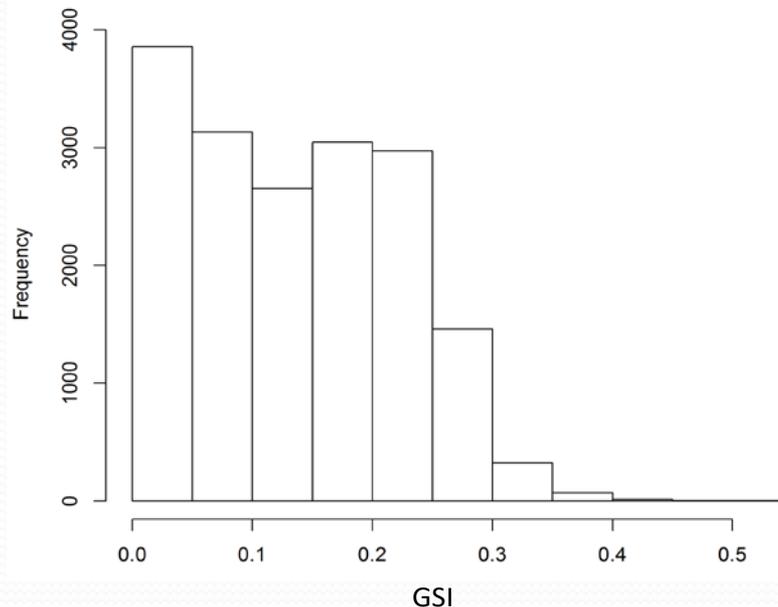
# Industry Interviews



## Interviewed representatives from mid-water pair trawlers

### Some key takeaways:

- General view was that spawning is too variable to pinpoint exact location and time
- Spawning condition herring are relatively rare in catch. This agrees with data...
- 418 of 17,529 (2.4%) had GSI values greater than 0.3



## Interviewed representatives from mid-water pair trawlers

### Some key takeaways:

- General view was that spawning is too variable to pinpoint exact location and time.
- Spawning condition herring are relatively rare in catch. This agrees with data...
- Areas fished are not conducive to spawning; believe that herring spawn in shoal water (i.e., along northern edge) from August to November.
- Many would like to see more sampling including tagging, otolith work and surveys utilizing multiple gears with industry involved.
- They believe that small fish are present.
- Some fears that herring have shifted towards Canadian waters.
- One group raised issue of haddock; haddock are mixed in with catch and likely preying upon eggs.
- Abundance of river herring was also a concern; competition for resources

## Key Takeaways:

- Multiple data sources were reviewed and analyzed and all pointed towards spawning in two locations along northern edge of Georges Bank; one in the west (Nantucket Shoals/Great South Channel) and one in the east (Northern Flank)
- Spawning takes place primarily between September and October (all years and all areas)
- Spring spawning is not important
- Industry interacts minimally with spawning grounds (mostly in the east)



# Research Recommendations (PDT)

- Developed by the Herring PDT (which includes all members of the ASMFC TC)
  1. Enhancing portside sampling – most cost effective
  2. At-sea collection of spawning data – need to evaluate feasibility first
  3. Fishery independent survey – more expensive, 5 years or so, but data from entire area and season.
- Herring stock at low abundance, may not be representative of stock at larger size.

