Density surface models for the North Atlantic right whale in U.S. waters

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Beginning in 2010, we initiated a multi-institution collaboration to build density surface models for U.S. waters of the western North Atlantic and Gulf of Mexico, for all extant cetacean species, from all available visual line transect surveys conducted with distance-sampling compatible protocols over the past two decades. This initial effort culminated in 2016 in the publication of models and associated absolute density maps (estimating individual animals per km^2) for 26 species, including North Atlantic right whales, and 3 multi-species guilds (Roberts et al. 2016). The models were used first by the U.S. Navy, the
primary funder of the effort, for the development of an Environmental Impact Statement that estimated marine mammal takes for Navy training and testing activities. Over the 2016-2018 period, we prepared several updates that expanded the number of collaborators and incorporated newly-available survey data and NOAA went on to use these results for various management activities, including the permitting of offshore energy development and geophysical surveying and the development of regulations for oil and gas leasing. Most recently, NOAA proposed to use the right whale model as a component in a Risk Reduction Decision Support Tool to be used to develop new regulations for U.S. trap and pot fisheries, with the intent of reducing risk that right whales become entangled in vertical fishing lines. NOAA presented initial results from this exercise at the April 2019 meeting of the Atlantic Large Whale Take Reduction Team. An important limitation of those results is that our right whale model available at that time, known as the v8 model, only incorporated data through mid-2016. Since then we have worked to prepare another update, the v9 model, which incorporates data through the end of 2018 and is intended for use in NOAA's final analysis. This presentation will update the community on our progress.

Density surface models for the North Atlantic right whale in U.S. Waters

Photo: NOAA Fisheries/Leah Crowe (Permit #17355)

NARWC Annual Meeting

15 November 2019

Jason Roberts, Rob Schick, and Pat Halpin

Marine Geospatial Ecology Lab

Duke University

Duke | NICHOLAS SCHOOL OF THE ENVIRONMENT

In collaboration with survey programs and scientists from:

Should your logo be here? My apologies! Please email me!

Primary funding for modeling from:

Additional funding from:

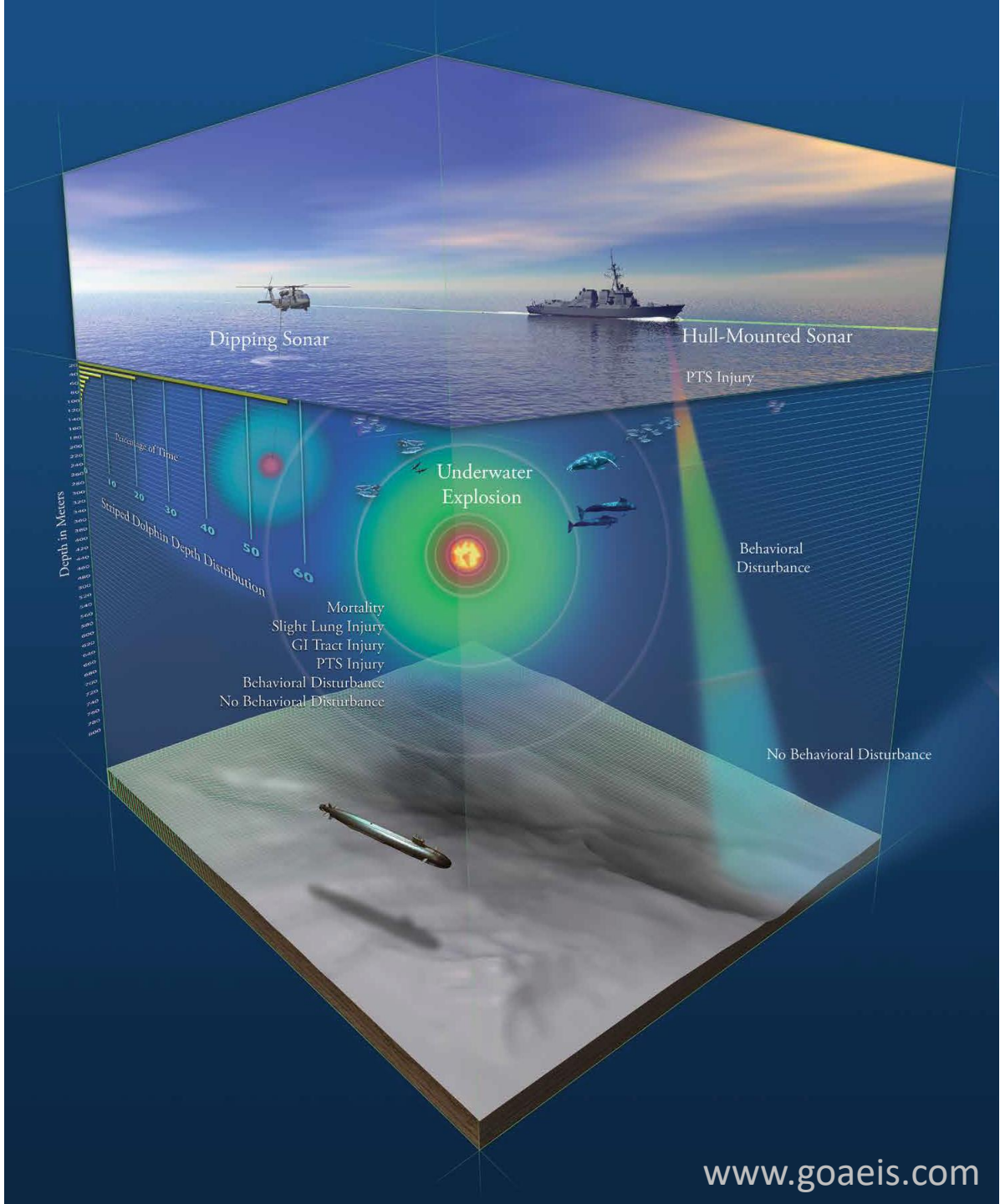
How this project got started

The U.S. Navy encounters marine mammals…

Photo: nbcnews.com

Navy MMPA compliance

- Every 7 years*, the Navy must obtain a Letter of Authorization permitting the “take” of marine mammal during training and testing activities
- The permit must estimate the *number of individual animals* of each mammal stock that would be taken



*Prior to 2018, Letters of Authorization lasted 5 years

Navy Acoustic Effects Model (NAEMO)

NAVSEA WARFARE CENTERS NEWPORT

Inputs

Navy Activity Information

Sound Propagation Modeling

Population Density Maps

Exposure History of Each Simulated Individual Animal

Criteria Thresholds Applied

Estimated Number of Exposures

Results Database

Post Analysis Evaluation

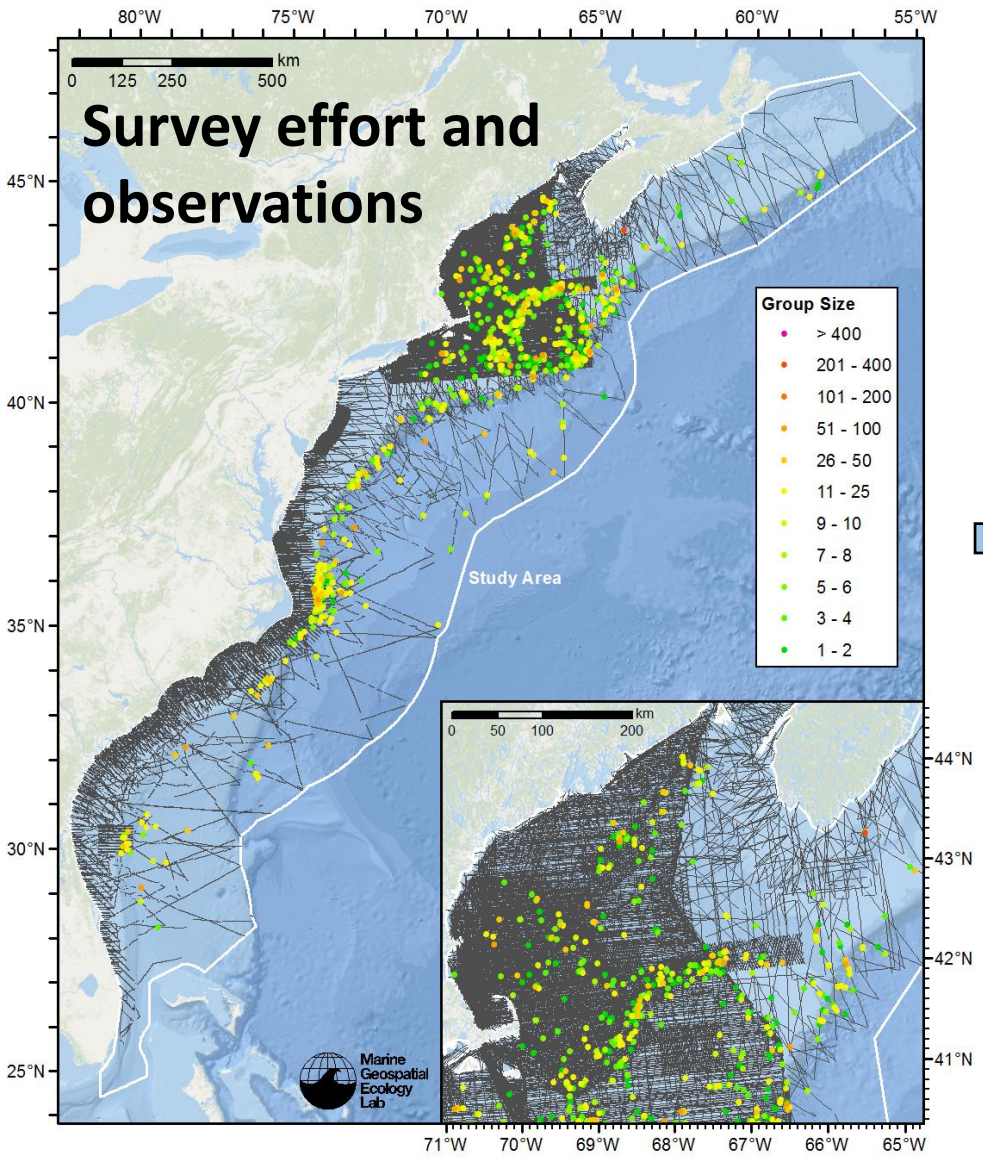
Requested Takes

MMPA Request / ESA Consult

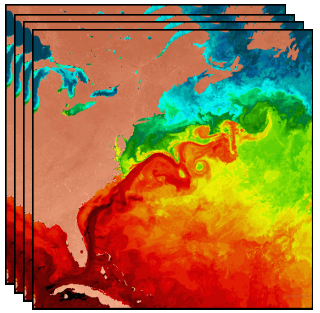
⇦ Density = individuals / km^2

This is where we come in…

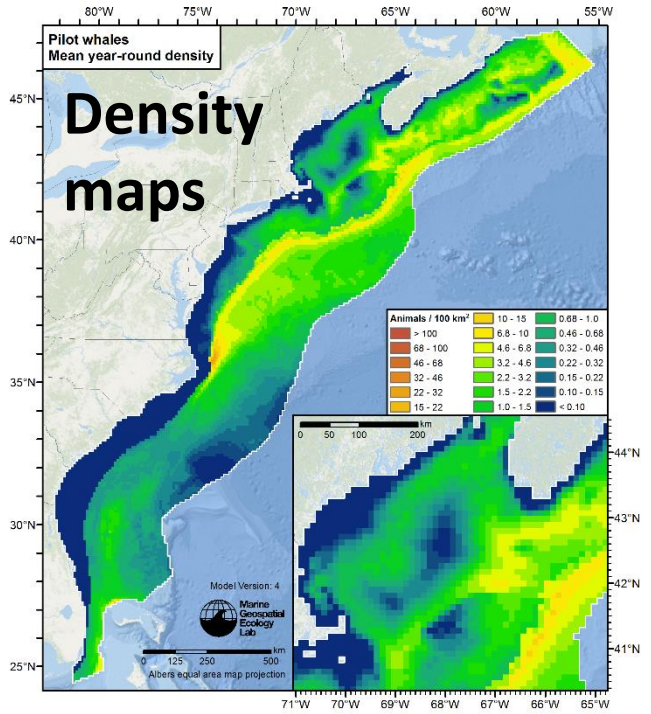
Density modeling

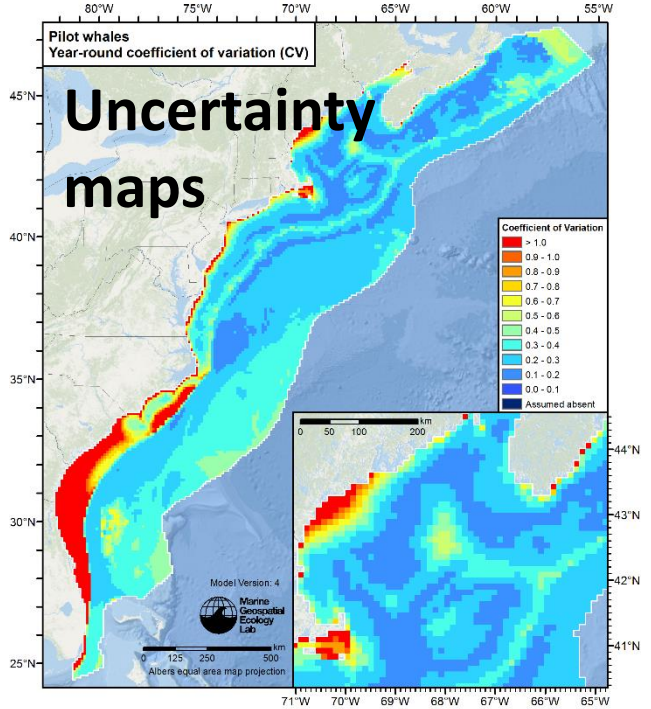


Oceanographic maps



Statistical models

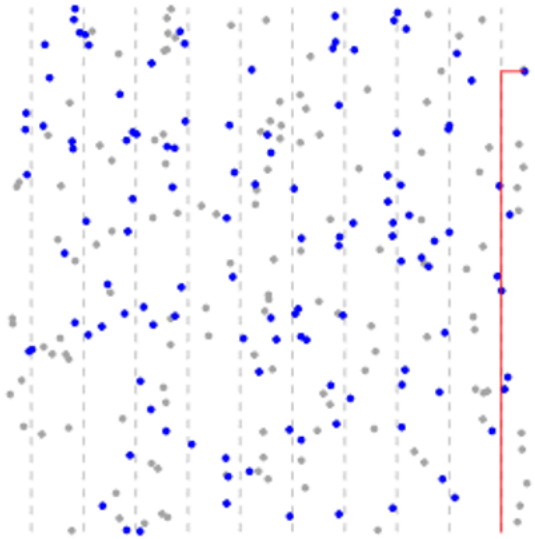





A critical problem:
The farther away they are,
the lower the chance you'll detect them
?
Photo: Scott and Mary Flanders

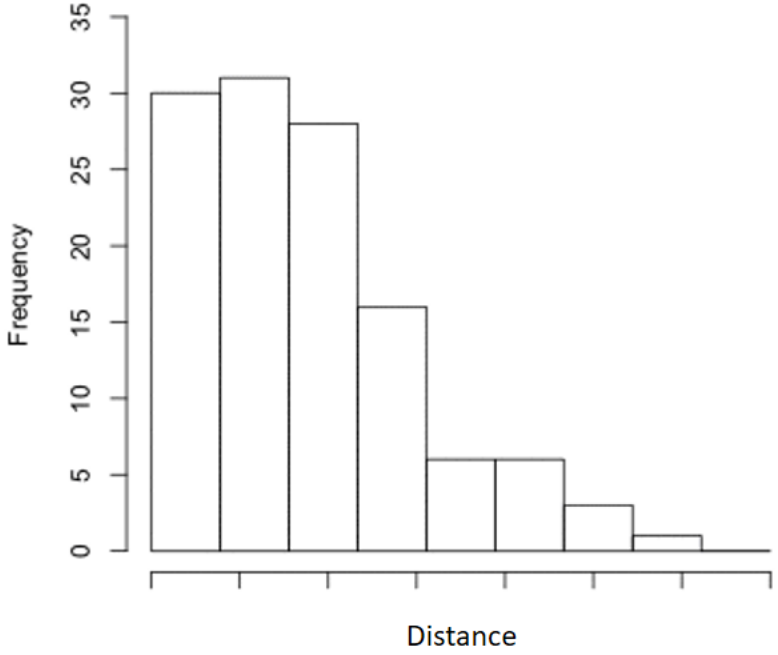
Modeling detectability

Cetacean sightings

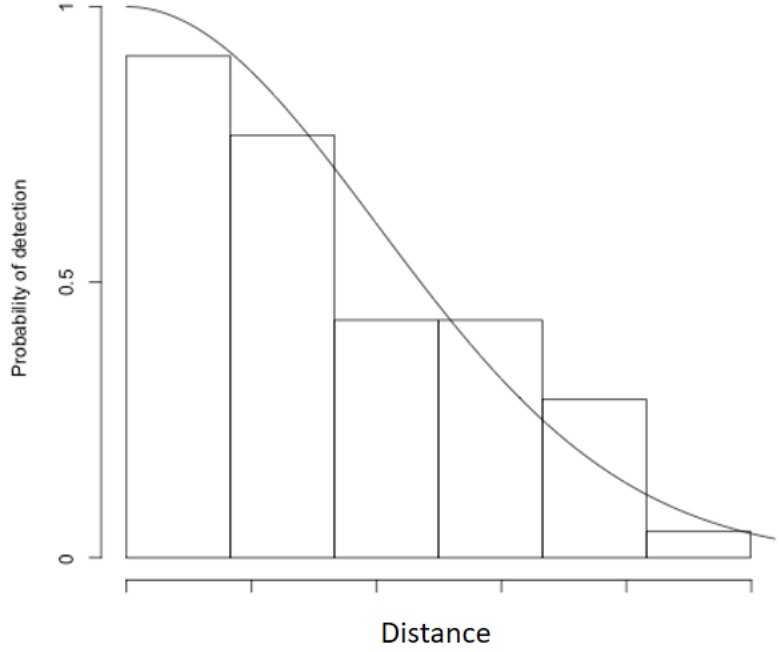


- Vessel trackline
- Cetacean sighted by observers
- Cetacean missed by observers

Histogram of observed distances



Detection function

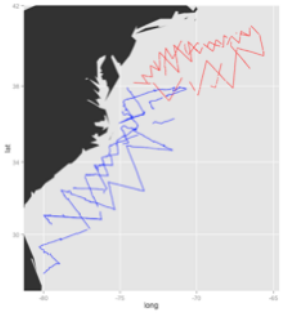


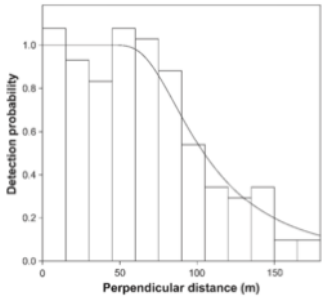
Figures: David L. Miller

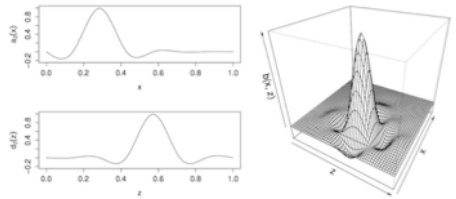
This technique is called “distance sampling”

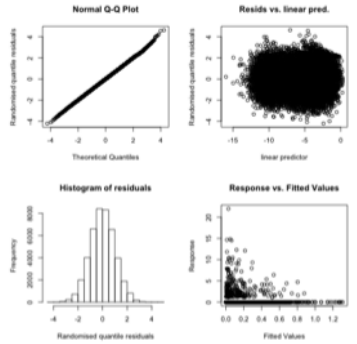
Density surface modeling (DSM)

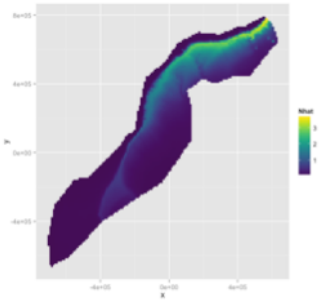
(Hedley and Buckland 2004; Thomas et al. 2010; Miller et al. 2013)











Line transects → Detectability → Spatial model (GAM) → Model checking/ criticism → Predictions

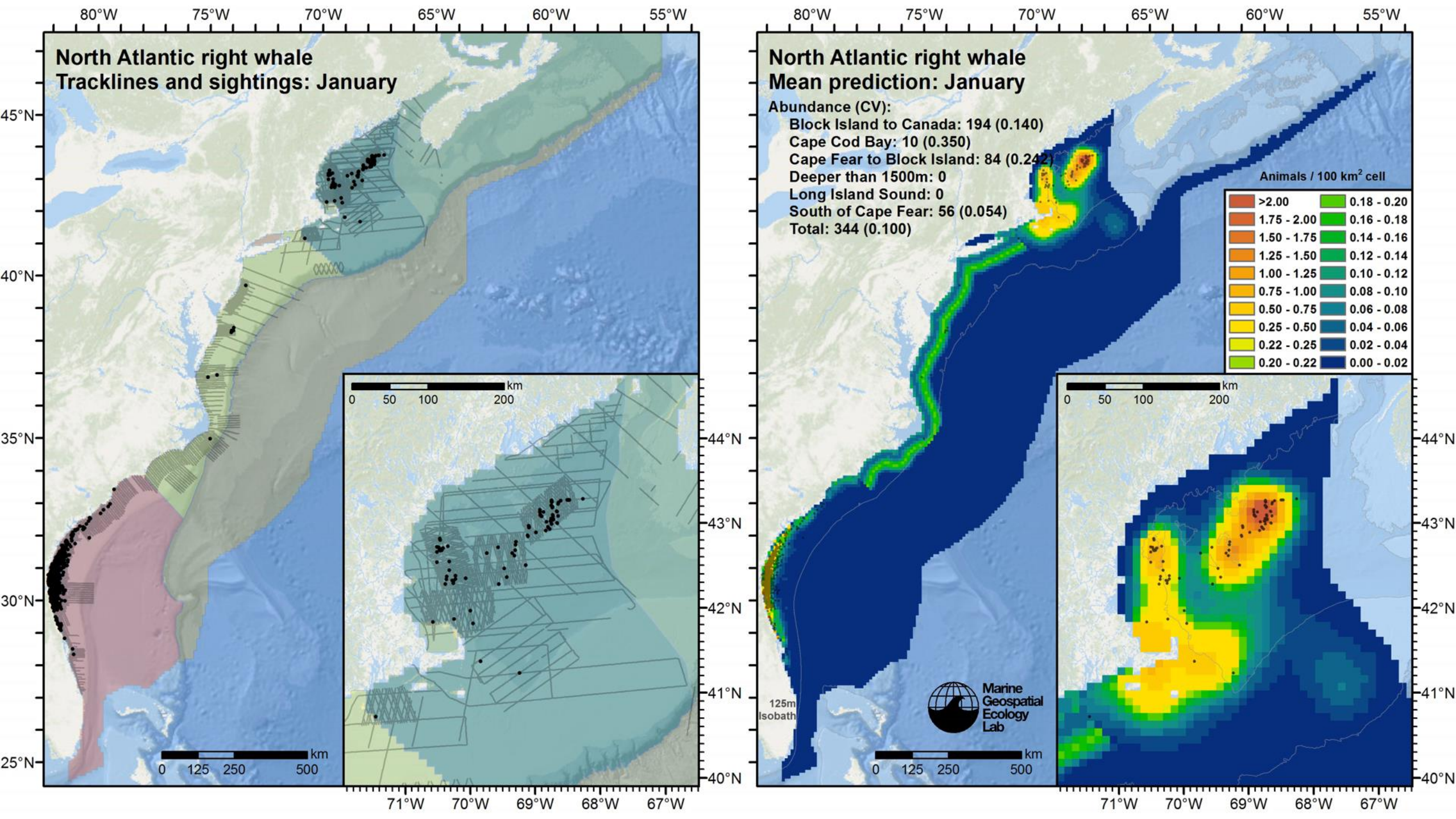
Oceanographic data → Spatial model (GAM)

Oceanographic data → Predictions

Stage 1

Stage 2

Adapted from figure by David L. Miller


North Atlantic right whale
Tracklines and sightings: January
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
km
0 125 250 500
km
0 50 100 200
71°W
70°W
69°W
68°W
67°W
44°N
43°N
42°N
41°N
40°N
North Atlantic right whale
Mean prediction: January
Abundance (CV):
Block Island to Canada: 194 (0.140)
Cape Cod Bay: 10 (0.350)
Cape Fear to Block Island: 84 (0.242)
Deeper than 1500m: 0
Long Island Sound: 0
South of Cape Fear: 56 (0.054)
Total: 344 (0.100)
Animals / 100 km² cell
>2.00
1.75 - 2.00
1.50 - 1.75
1.25 - 1.50
1.00 - 1.25
0.75 - 1.00
0.50 - 0.75
0.25 - 0.50
0.22 - 0.25
0.20 - 0.22
0.18 - 0.20
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
0.00 - 0.02
125m Isobath
Marine Geospatial Ecology Lab

Project timeline and model versions

2015-2016

v5.6 1998-2014

- Roberts et al. 2016
- Used by Navy for AFTT Phase III EIS and Nov 2018 Letter of Authorization

2017

v7 1998-2016

- Added AMAPPS and SEUS NARW surveys
- Used by NMFS for Atlantic G&G IHA permitting

What NMFS currently uses for IHAs, etc.

April 2019

v8 1998-2016

- Prepared for ALWTRT meeting
- Same surveys as v7
- Filled Cape Cod Bay with Ganley et al. (2019) results

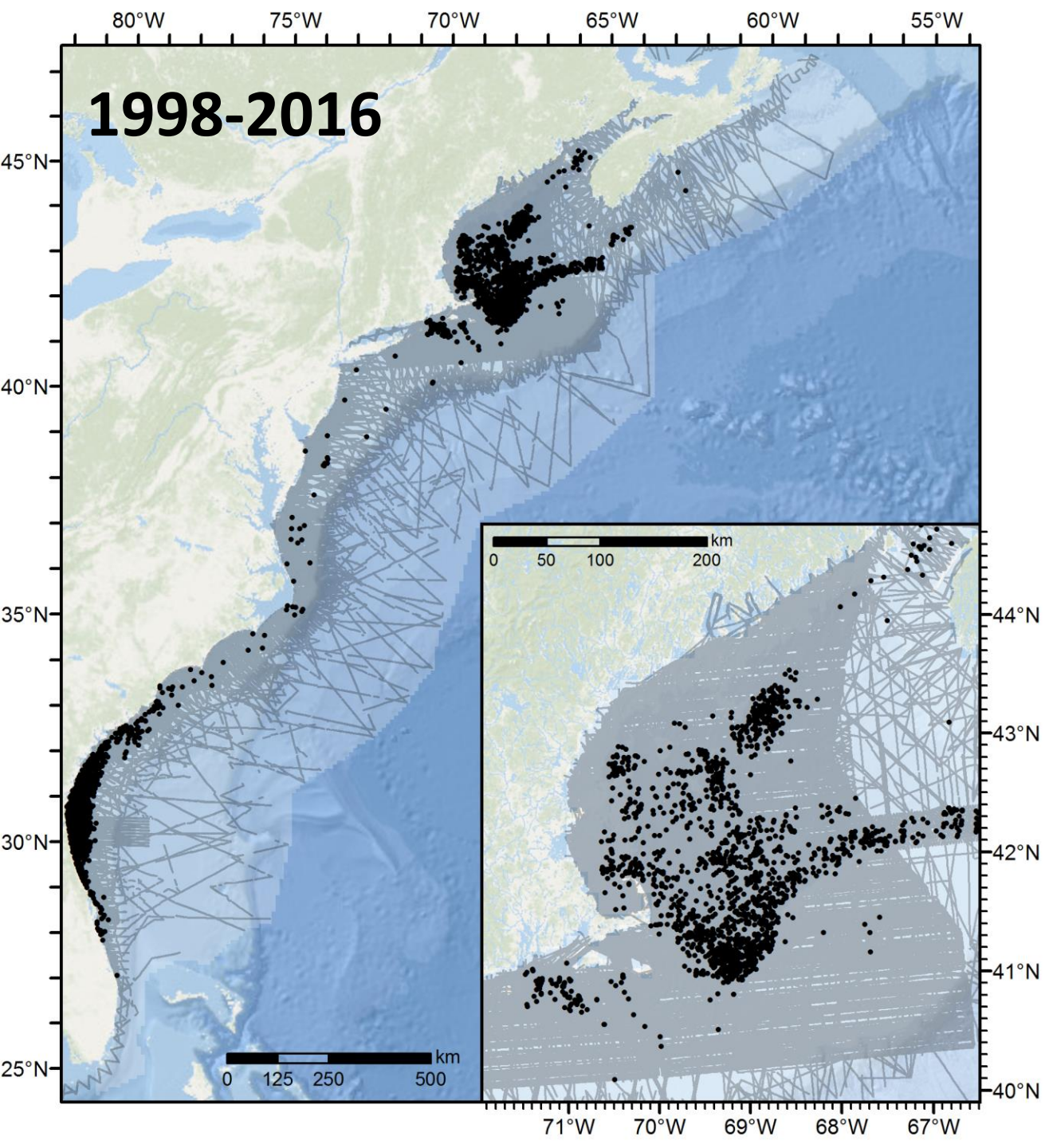
Maps you saw; what NMFS currently uses for the Risk Reduction Decision Support Tool

Early 2020

v9 1998-2018

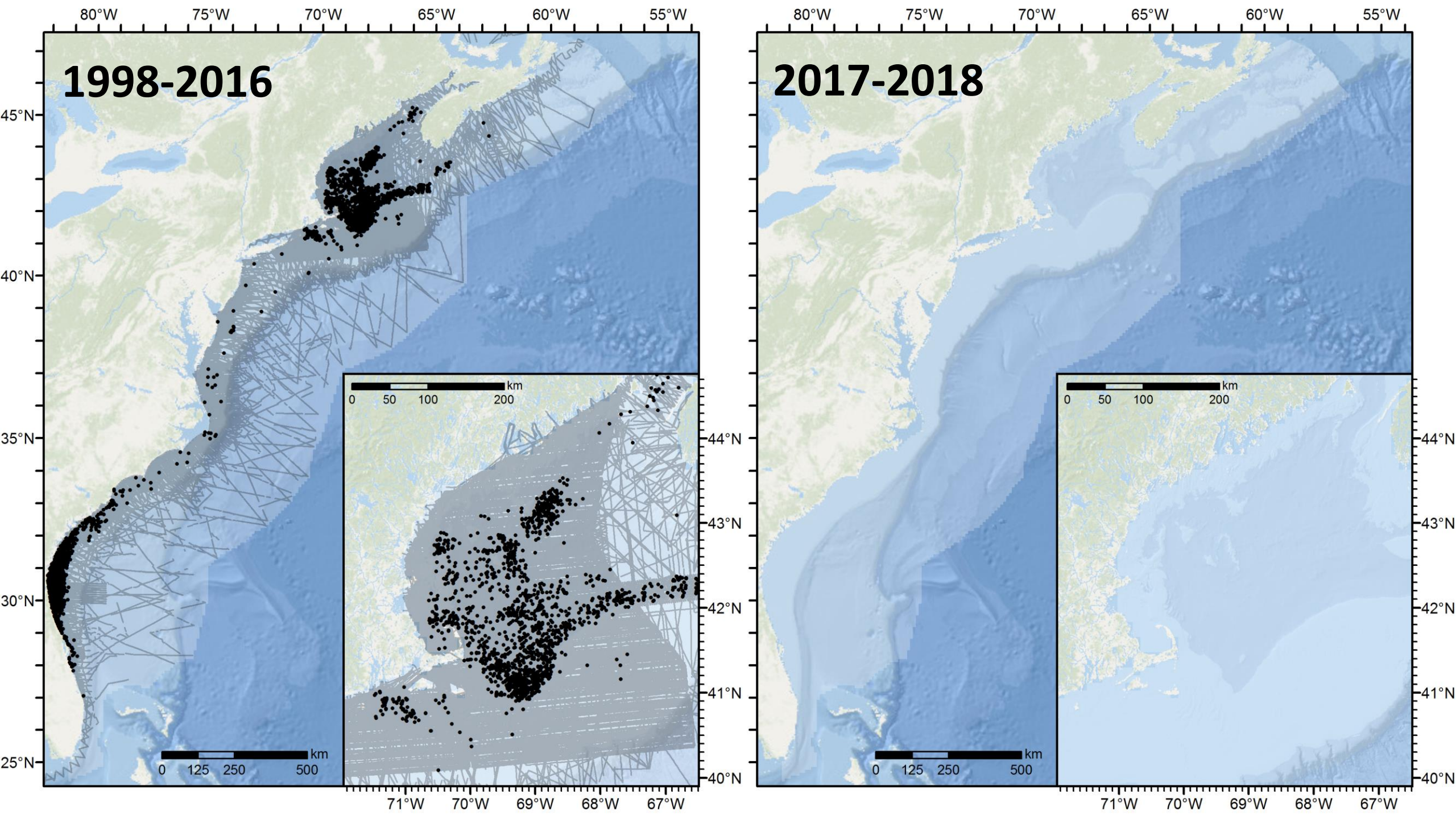
- Adds surveys from 2017-2018
- Will fit and compare models of recent period to older period, e.g. 1998-2010 vs 2010-2018
- Build a mother-calf model, if data permit

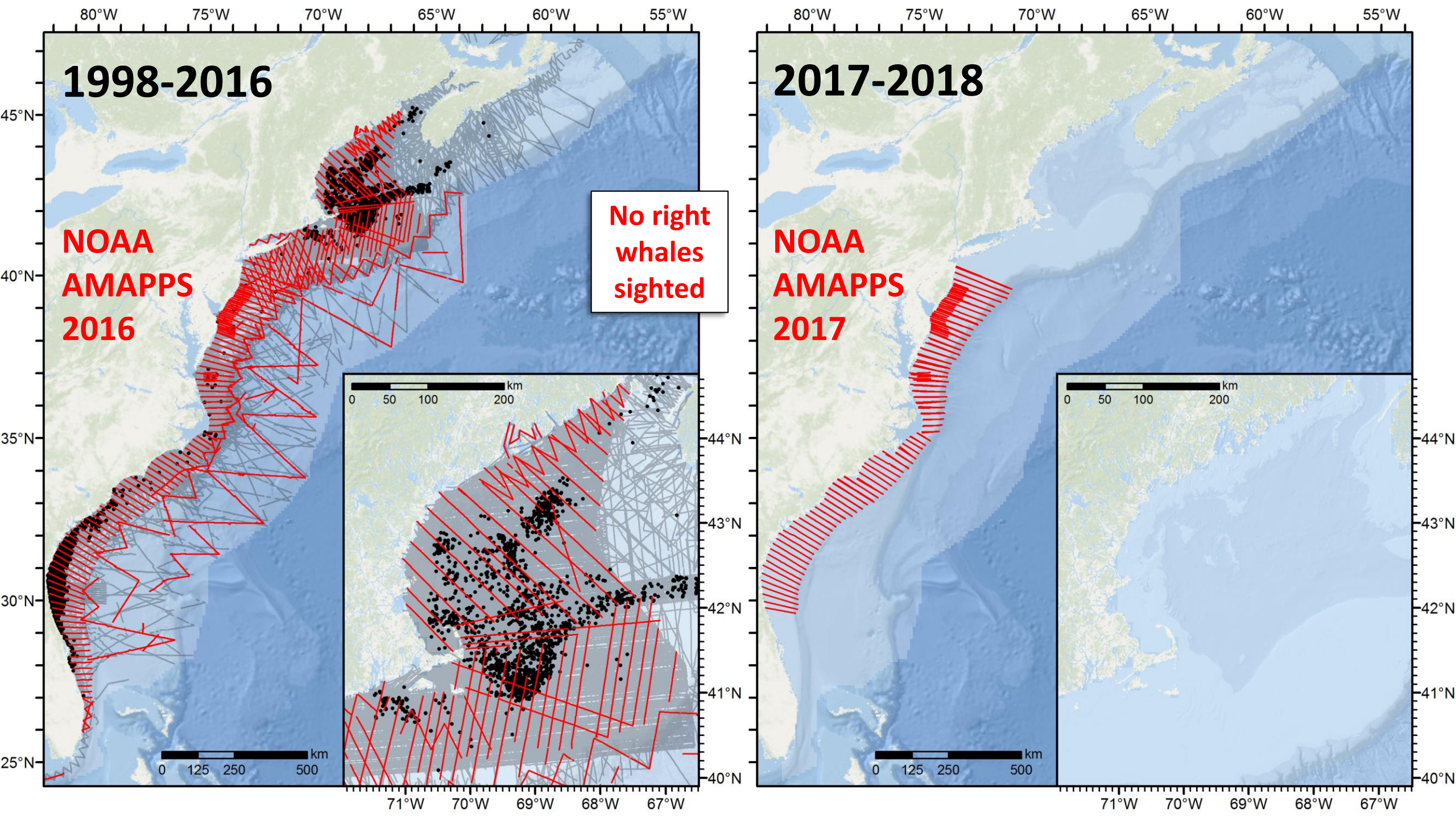
In progress

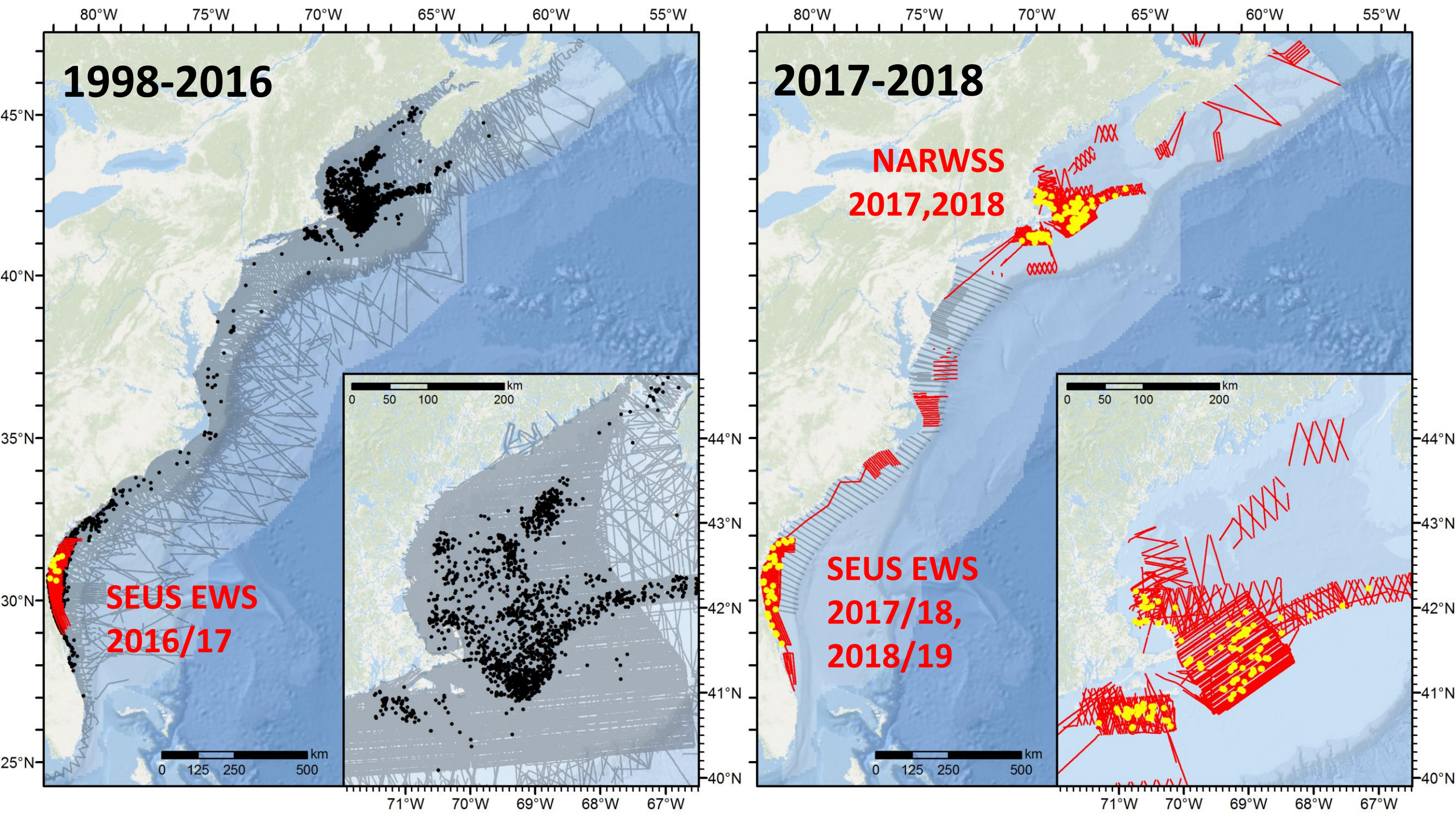


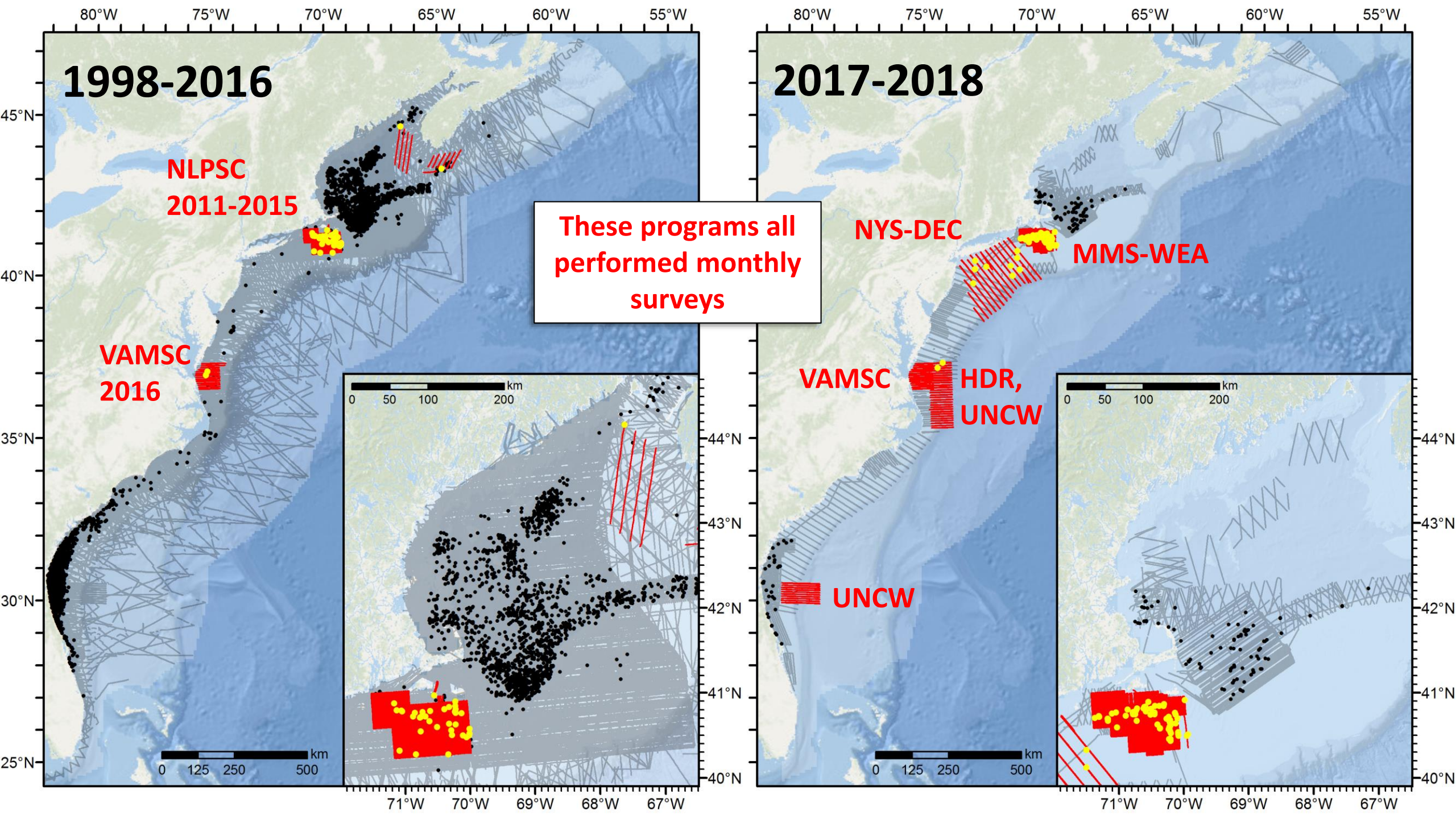
So v9 is not done yet…

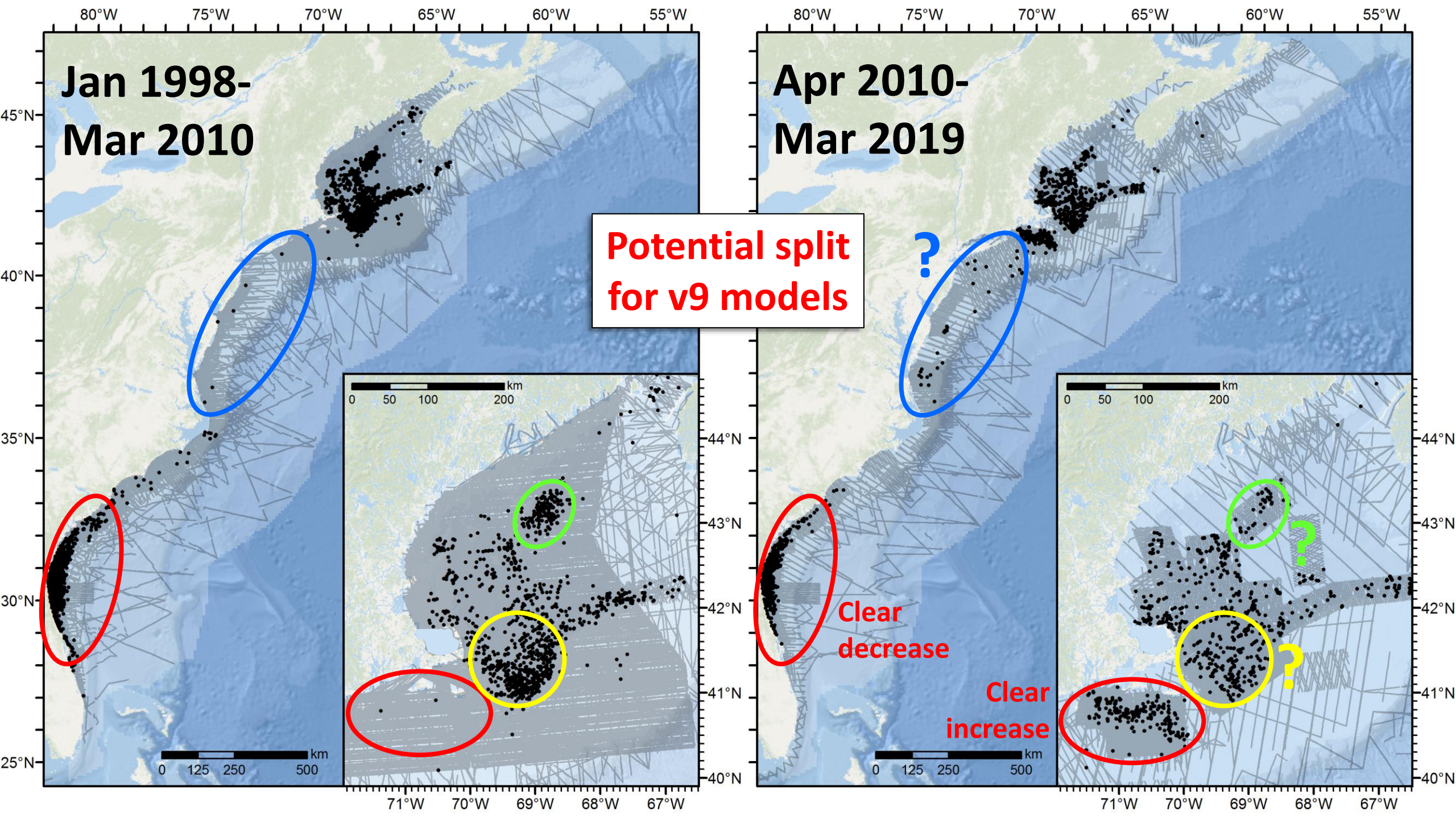
- What will it look like?
- We can't know for sure, but let's examine:
  1. The new data added
  2. 1998-2010 vs. 2010-2018
- Let's start with surveys used in the v8 model (map on the left)

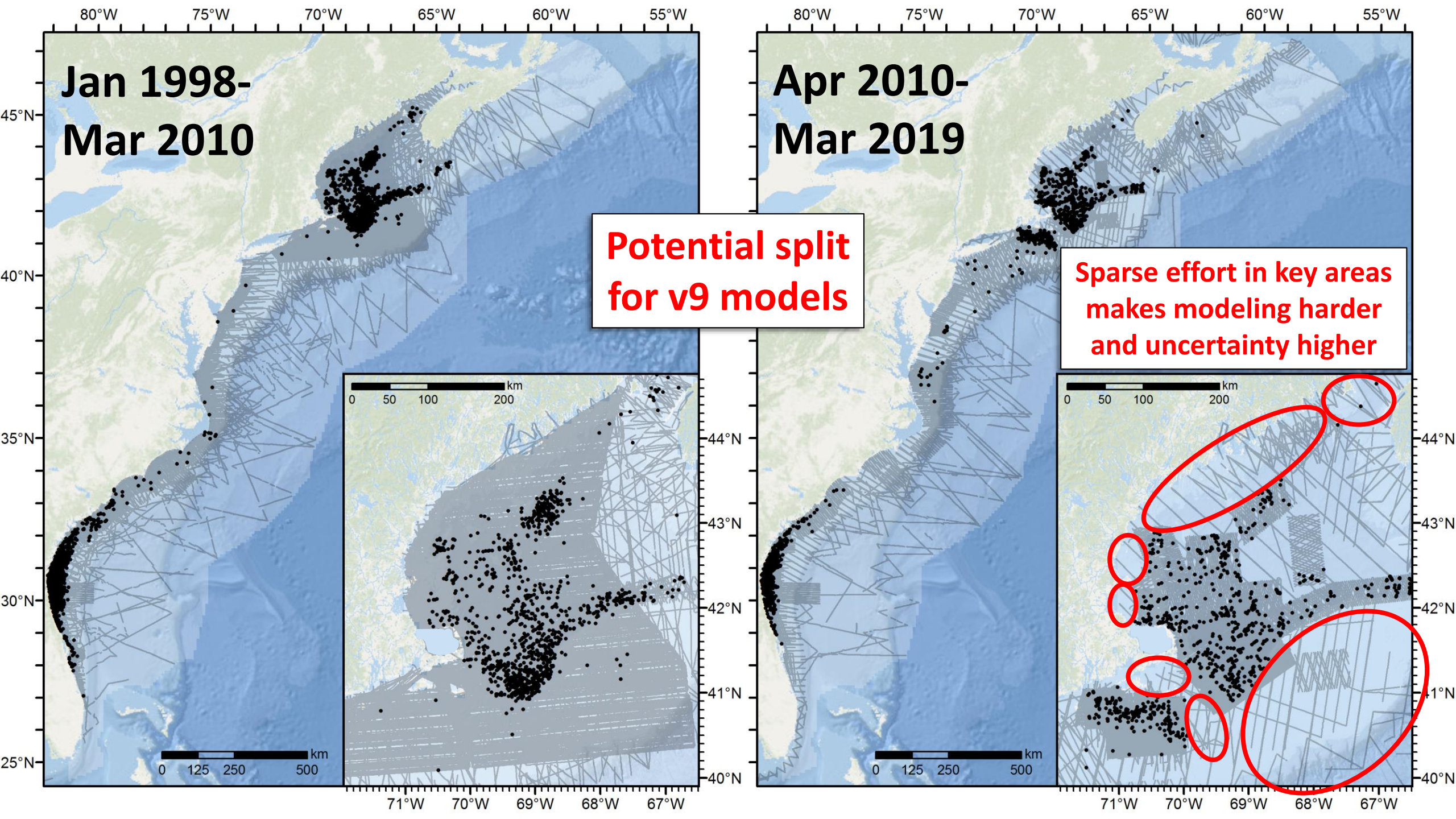

1998-2016
2017-2018
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0
125
250
500
50
100
200


1998-2016
NOAA
AMAPPS
2016
No right whales sighted
2017-2018
NOAA
AMAPPS
2017
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0 125 250 500
0 50 100 200


1998-2016
SEUS EWS
2016/17
2017-2018
NARWSS
2017,2018
SEUS EWS
2017/18,
2018/19
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0
125
250
500
50
100
200


1998-2016
NLPSC
2011-2015
VAMSC
2016
These programs all performed monthly surveys
2017-2018
NYS-DEC
MMS-WEA
VAMSC
HDR,
UNCW
UNCW
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0
50
100
200
0
125
250
500


Jan 1998-
Mar 2010
Apr 2010-
Mar 2019
Potential split
for v9 models
?
Clear
decrease
Clear
increase
?
?
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0
125
250
500
50
100
200


Jan 1998-
Mar 2010
Apr 2010-
Mar 2019
Potential split
for v9 models
Sparse effort in key areas
makes modeling harder
and uncertainty higher
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W
km
0
125
250
500
50
100
200

Future plans and interests

- Incorporate autocorrelative term, to better capture persistent aggregations
- Incorporate *Calanus* zooplankton covariate (seeking collaborators)
- Collaborate with Canadians on joint U.S.-Canada models
- Incorporate passive acoustics and opportunistic data
- Develop near real time forecasts of right whale density for dynamic management problems

Thank you!

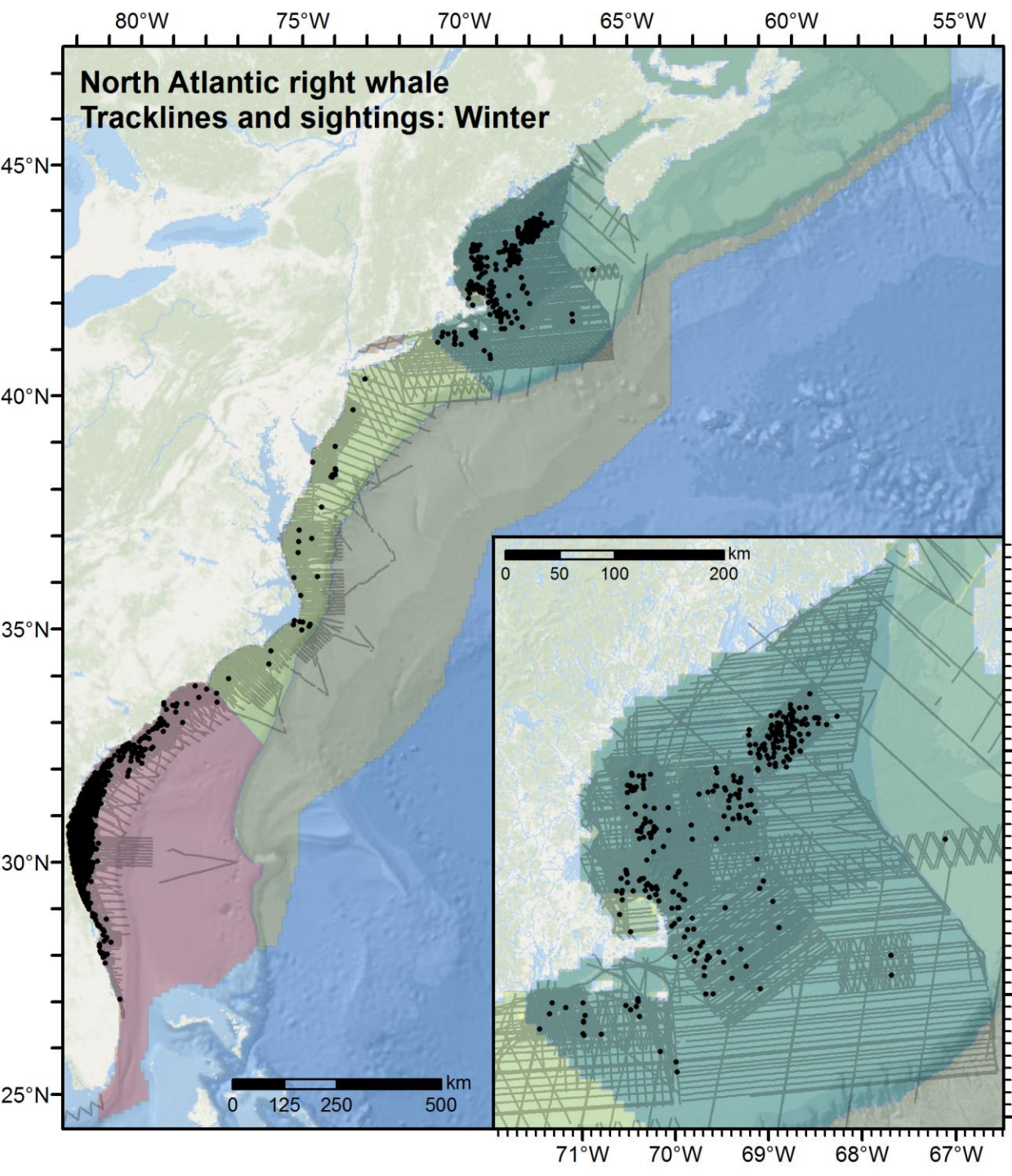
- Contact me: jason.roberts@duke.edu
- Main publication: Roberts et al. (2016) in *Scientific Reports*

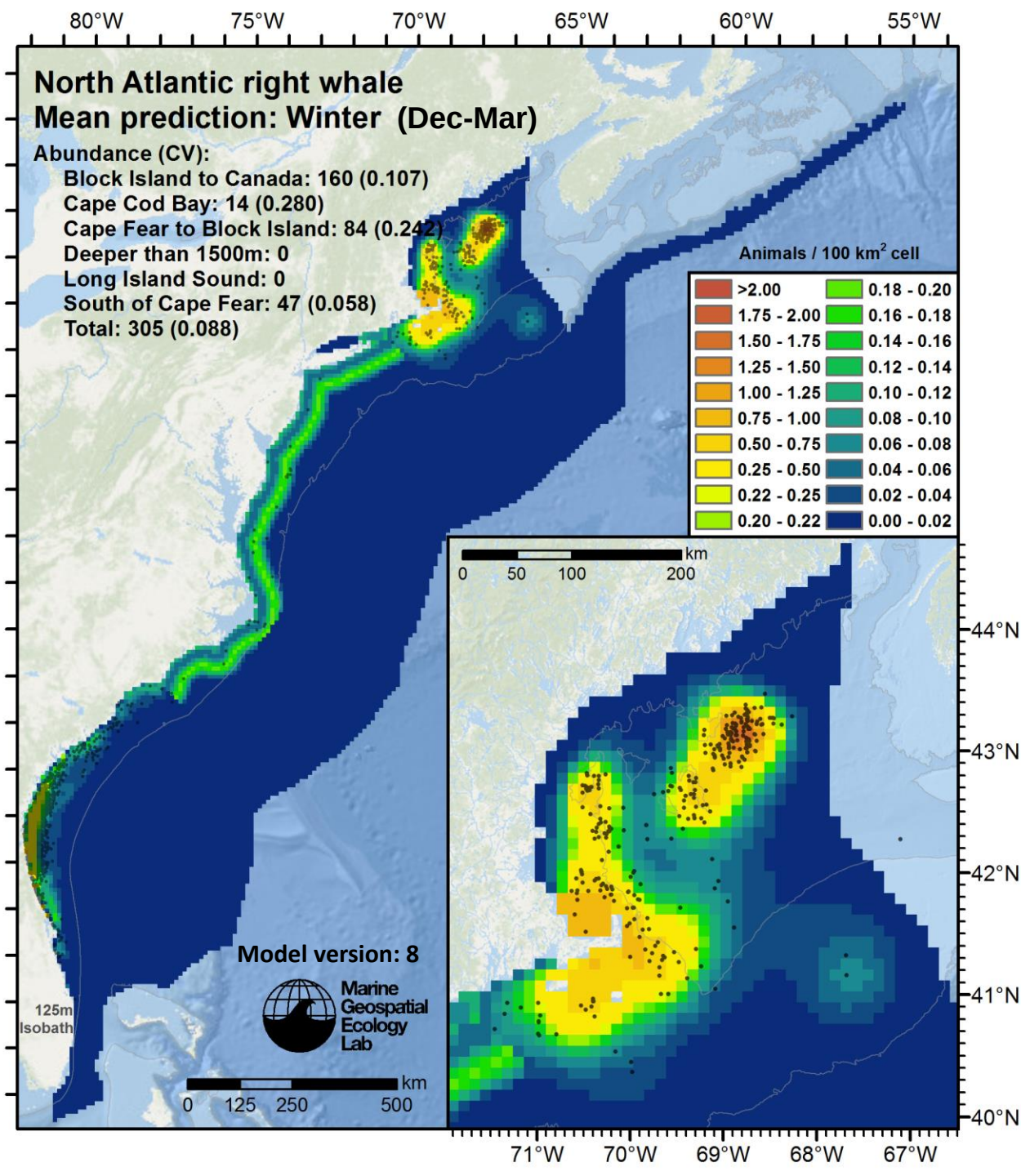
- Attend NOAA's Peer Review of the Right Whale Decision Support Tool
  - November 19-21 in Woods Hole, MA; open to the public; webinar available
  - Density model review is November 20 at 9:10-11:15 AM
  - https://www.fisheries.noaa.gov/event/peer-review-right-whale-decision-support-tool

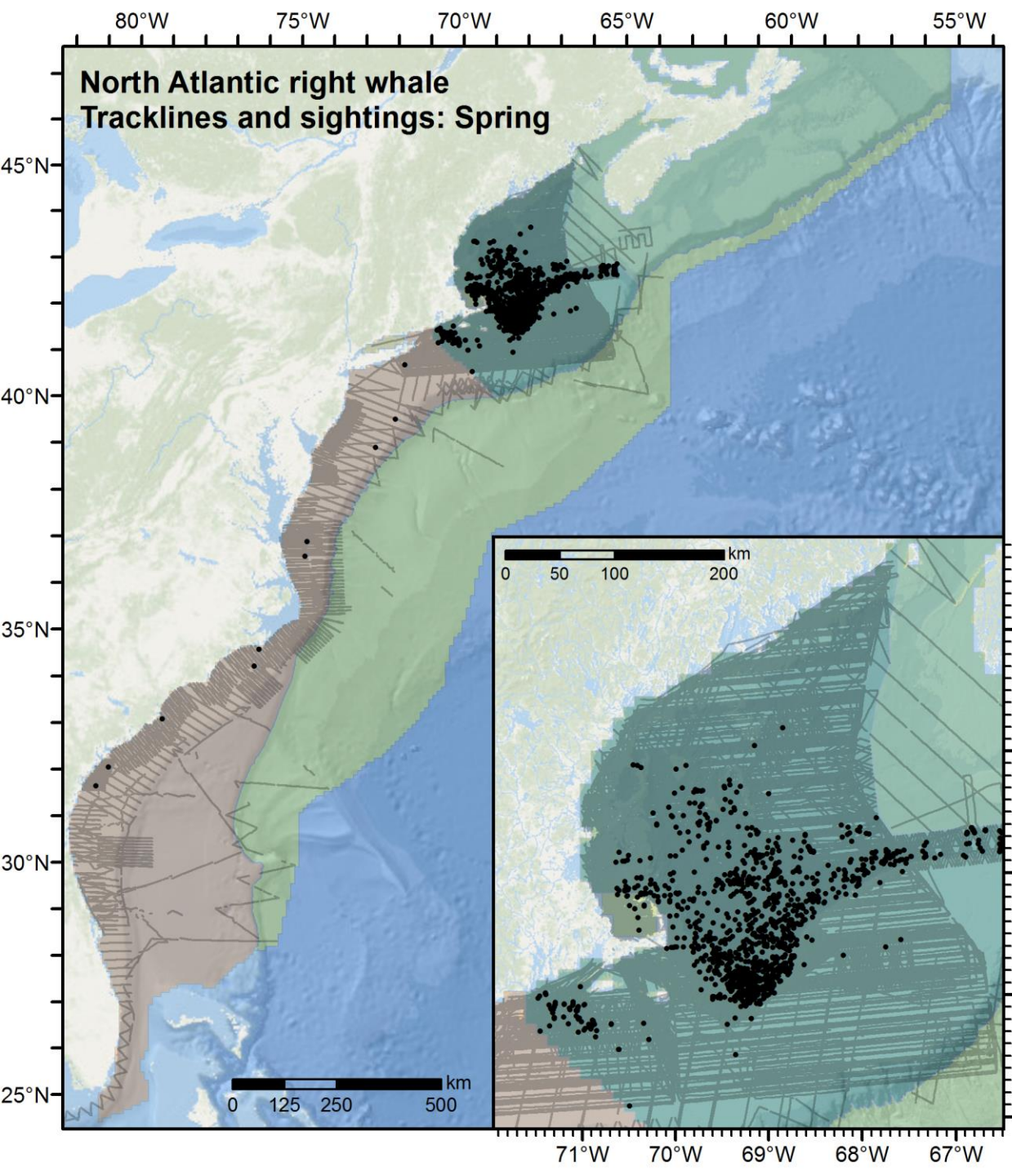
NOAA FISHERIES

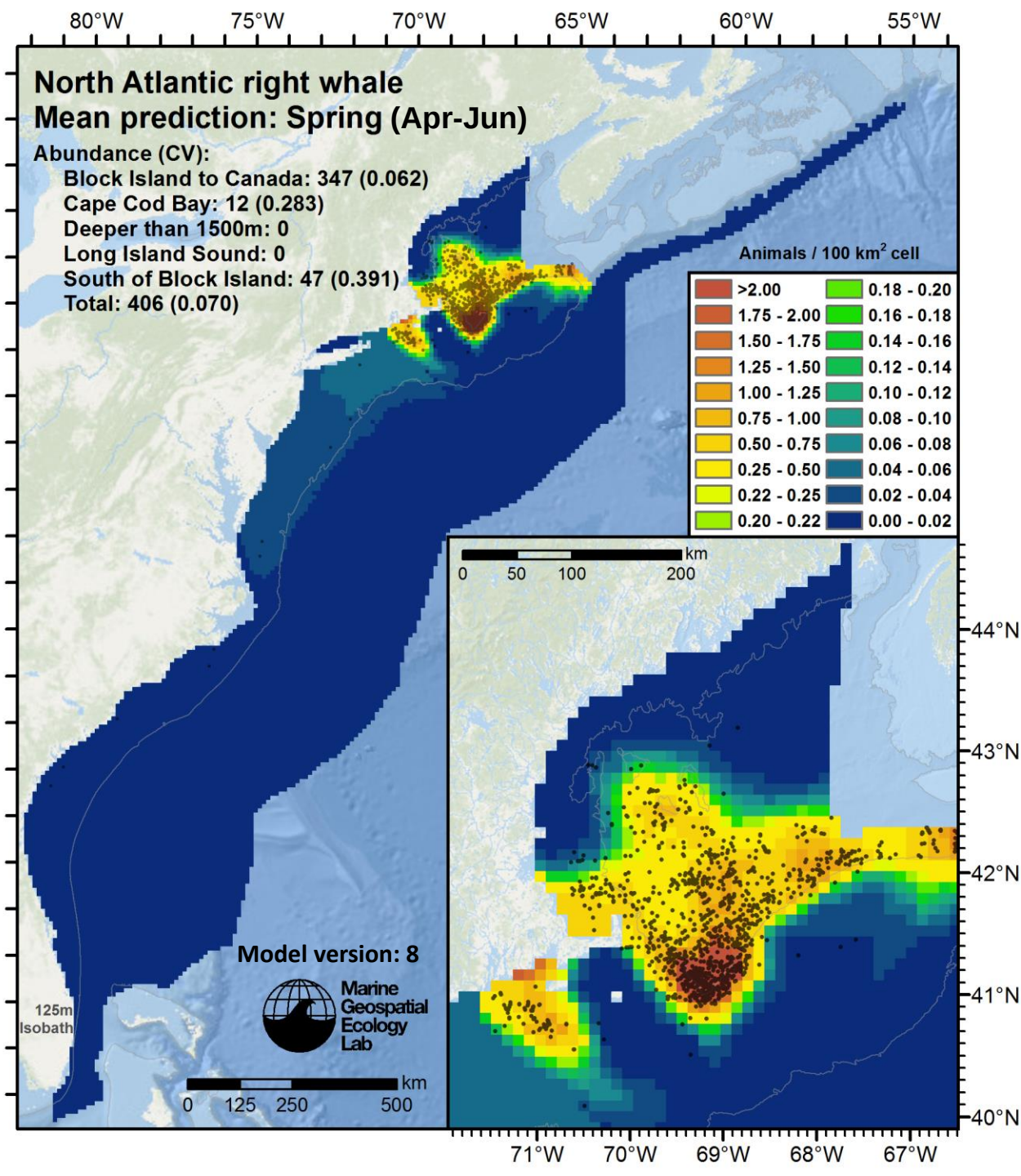
The Center for Independent Experts

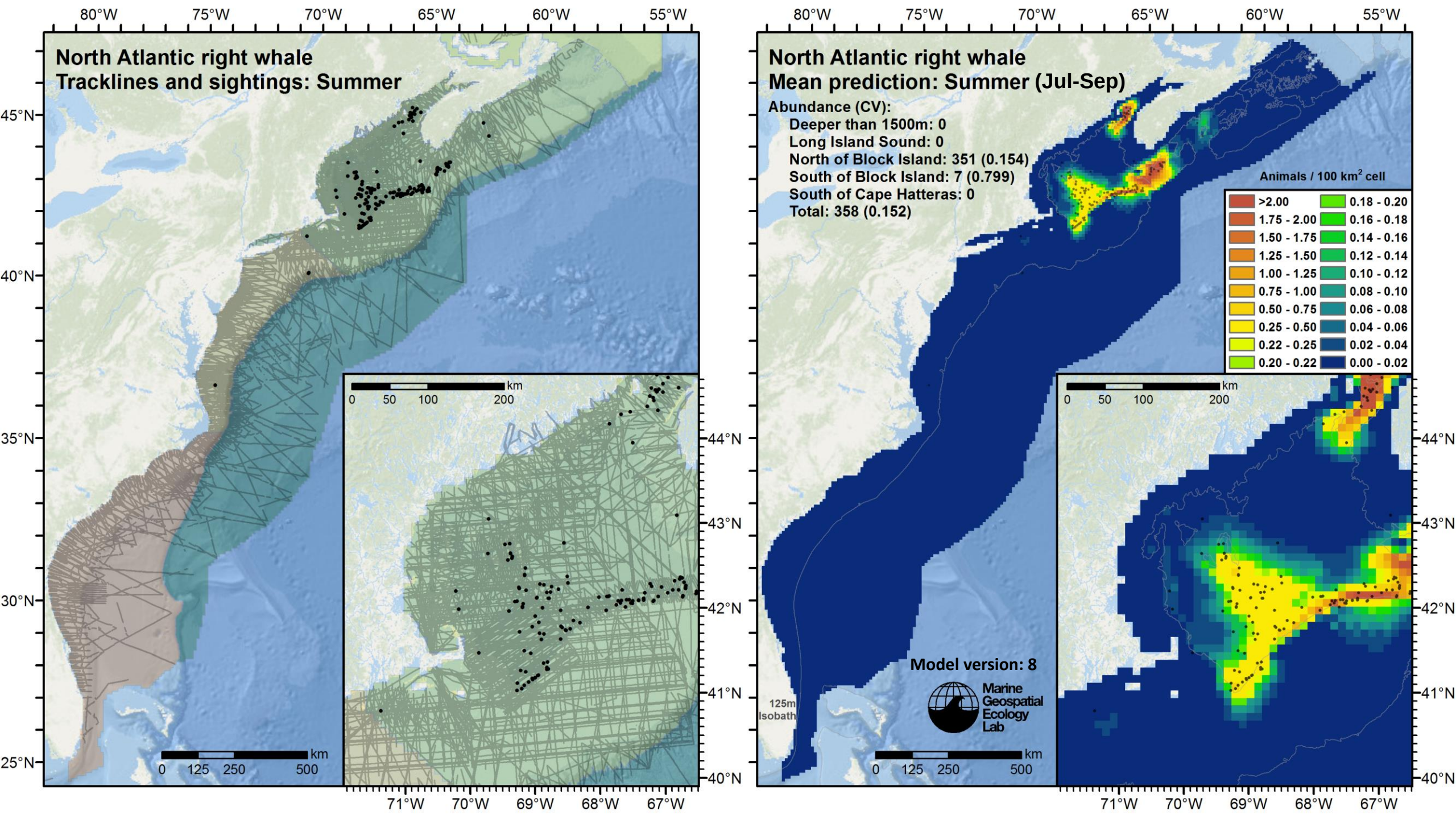
Backup slides, if animation doesn’t work


North Atlantic right whale
Tracklines and sightings: Winter
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
km
0 125 250 500
km
0 50 100 200
71°W
70°W
69°W
68°W
67°W


North Atlantic right whale
Mean prediction: Winter (Dec-Mar)
Abundance (CV):
Block Island to Canada: 160 (0.107)
Cape Cod Bay: 14 (0.280)
Cape Fear to Block Island: 84 (0.242)
Deeper than 1500m: 0
Long Island Sound: 0
South of Cape Fear: 47 (0.058)
Total: 305 (0.088)
Animals / 100 km² cell
>2.00
1.75 - 2.00
1.50 - 1.75
1.25 - 1.50
1.00 - 1.25
0.75 - 1.00
0.50 - 0.75
0.25 - 0.50
0.22 - 0.25
0.20 - 0.22
0.18 - 0.20
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
0.00 - 0.02
Model version: 8
Marine Geospatial Ecology Lab
125m Isobath
km
0 125 250 500
km
0 50 100 200
80°W
75°W
70°W
65°W
60°W
55°W
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W


North Atlantic right whale
Tracklines and sightings: Spring
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
km
0 125 250 500
km
0 50 100 200
71°W
70°W
69°W
68°W
67°W
44°N
43°N
42°N
41°N
40°N


North Atlantic right whale
Mean prediction: Spring (Apr-Jun)
Abundance (CV):
Block Island to Canada: 347 (0.062)
Cape Cod Bay: 12 (0.283)
Deeper than 1500m: 0
Long Island Sound: 0
South of Block Island: 47 (0.391)
Total: 406 (0.070)
Animals / 100 km² cell
>2.00
1.75 - 2.00
1.50 - 1.75
1.25 - 1.50
1.00 - 1.25
0.75 - 1.00
0.50 - 0.75
0.25 - 0.50
0.22 - 0.25
0.20 - 0.22
0.18 - 0.20
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
0.00 - 0.02
Model version: 8
Marine Geospatial Ecology Lab
125m Isobath
km
0 125 250 500
km
0 50 100 200
80°W
75°W
70°W
65°W
60°W
55°W
44°N
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W


North Atlantic right whale
Tracklines and sightings: Summer
North Atlantic right whale
Mean prediction: Summer (Jul-Sep)
Abundance (CV):
Deeper than 1500m: 0
Long Island Sound: 0
North of Block Island: 351 (0.154)
South of Block Island: 7 (0.799)
South of Cape Hatteras: 0
Total: 358 (0.152)
Animals / 100 km² cell
>2.00
1.75 - 2.00
1.50 - 1.75
1.25 - 1.50
1.00 - 1.25
0.75 - 1.00
0.50 - 0.75
0.25 - 0.50
0.22 - 0.25
0.20 - 0.22
0.18 - 0.20
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
0.00 - 0.02
Model version: 8
Marine Geospatial Ecology Lab
125m Isobath
km
0 125 250 500
0 50 100 200
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
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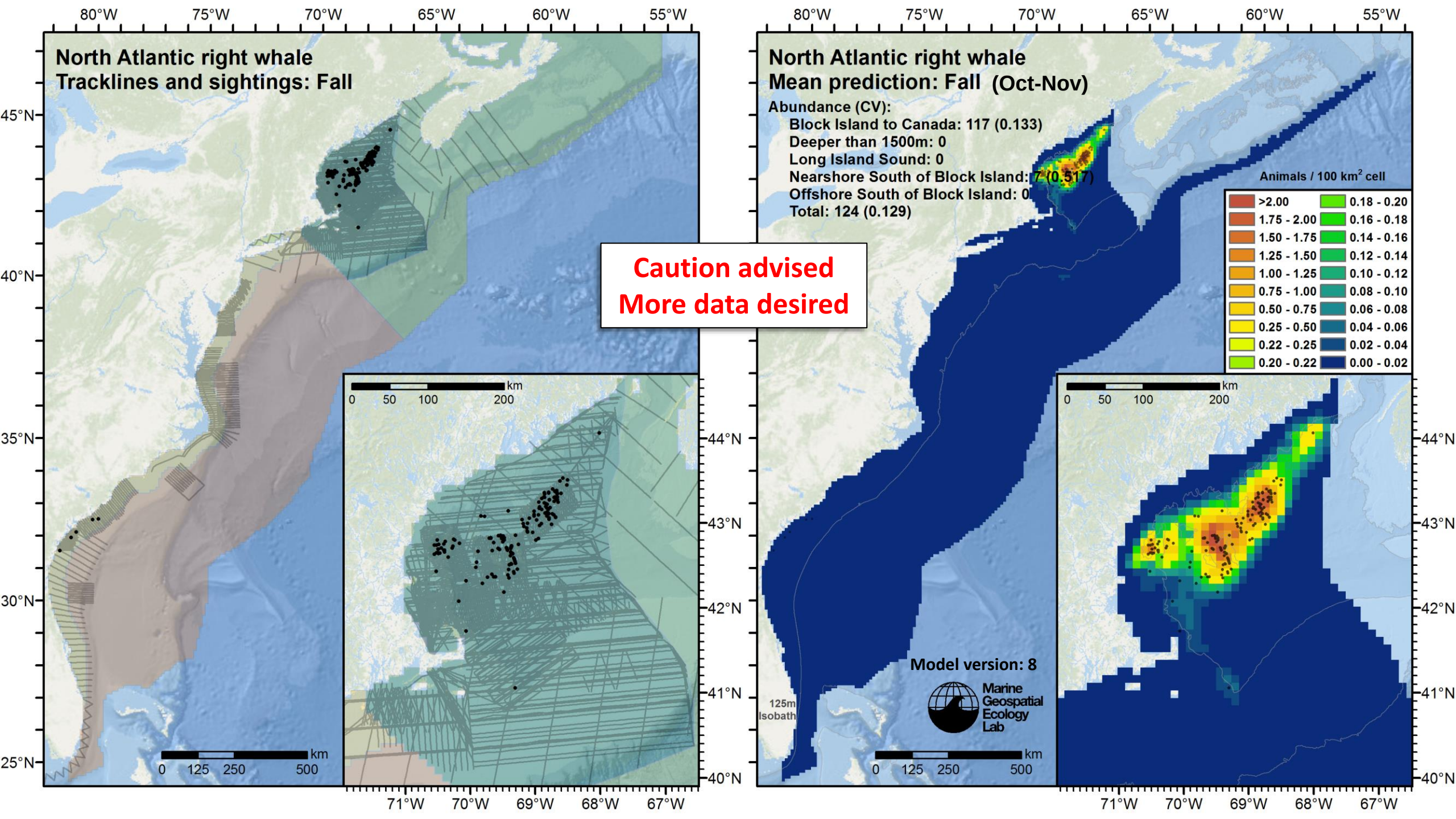
43°N
42°N
41°N
40°N
71°W
70°W
69°W
68°W
67°W


North Atlantic right whale
Tracklines and sightings: Fall
North Atlantic right whale
Mean prediction: Fall (Oct-Nov)
Abundance (CV):
Block Island to Canada: 117 (0.133)
Deeper than 1500m: 0
Long Island Sound: 0
Nearshore South of Block Island: 7 (0.517)
Offshore South of Block Island: 0
Total: 124 (0.129)
Caution advised
More data desired
Animals / 100 km² cell
>2.00
1.75 - 2.00
1.50 - 1.75
1.25 - 1.50
1.00 - 1.25
0.75 - 1.00
0.50 - 0.75
0.25 - 0.50
0.22 - 0.25
0.20 - 0.22
0.18 - 0.20
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
0.00 - 0.02
Model version: 8
Marine Geospatial Ecology Lab
125m Isobath
km
0 125 250 500
0 50 100 200
80°W 75°W 70°W 65°W 60°W 55°W
45°N 40°N 35°N 30°N 25°N
44°N 43°N 42°N 41°N 40°N
71°W 70°W 69°W 68°W 67°W