Density Surface Models for Cetaceans Along the U.S. East Coast and Gulf of Mexico Using Multiple Platforms and Dynamic Predictors

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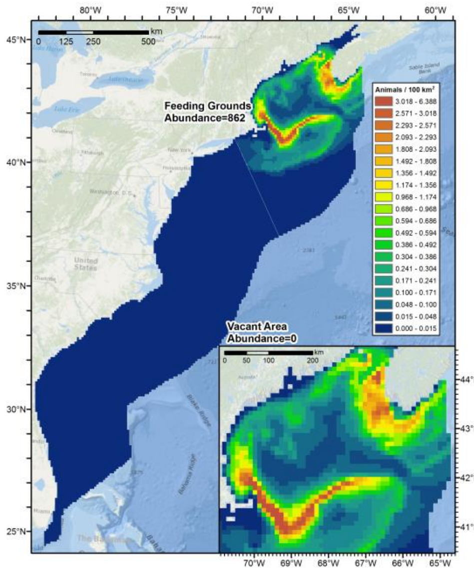
Duke Marine Geospatial Ecology Lab

9 December 2013



Marine Geospatial Ecology Lab
Duke University

NASA

NOAA

NAVFAC Naval Facilities Engineering Command

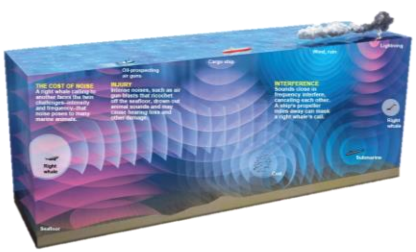
Photo: Whit Welles

Integrating Ocean Observing Data to Enhance Protected Species Spatial Decision Support Systems

NASA Grant / Cooperative Agreement NNX08AK73G

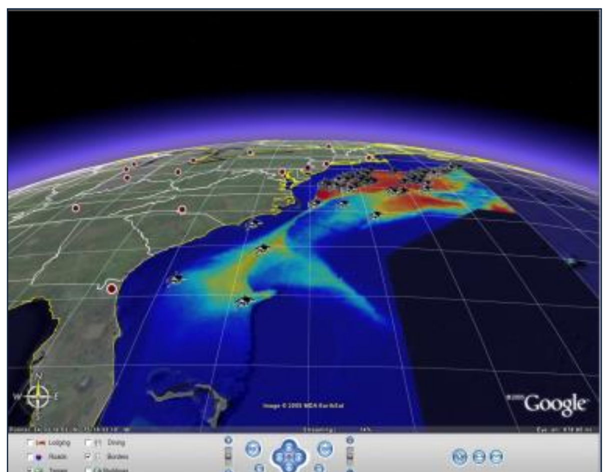
Societal need:

We need to minimize risk to protected marine species from potentially harmful interactions.



Technical need:

Environmental planners and regulators need accurate information on the expected density of cetacean species across space and time.

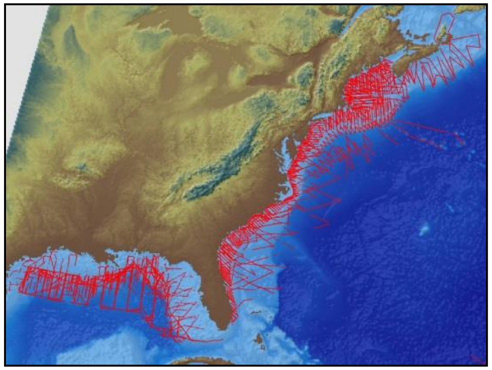


NASA project response:

The Duke Marine Geospatial Ecology Lab (MGEL) and the NOAA Southwest Fisheries Science Center (SWFSC) teamed up to develop a Spatial Decision Support System (SDSS) that provides spatiotemporally-explicit, quantitative predictions of cetacean density.

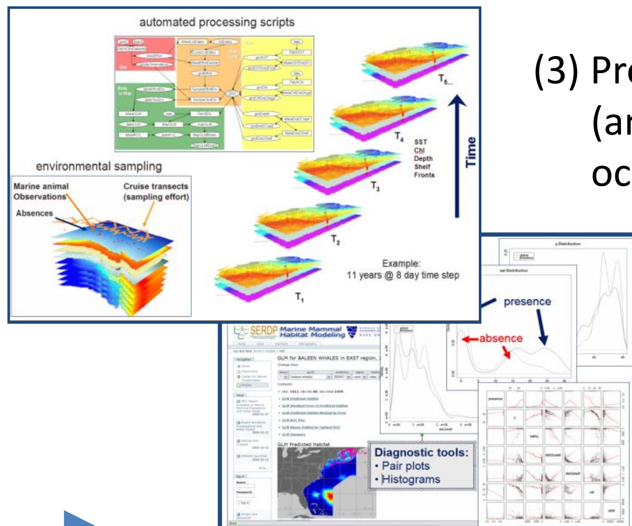
Modeling process in a nutshell

(1) Conduct cetacean surveys

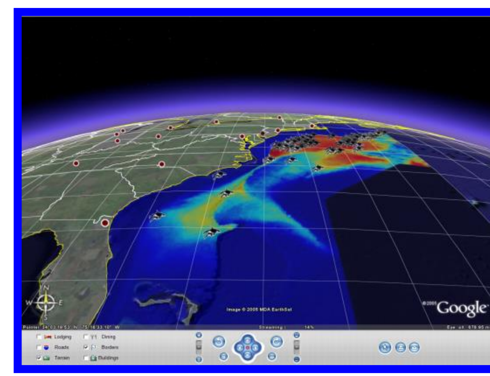


NOAA, UNCW,
and other partners

(2) Aggregate survey tracklines and cetacean sightings and link them to oceanographic observations



(3) Predict cetacean density (animals/km^2) from oceanographic conditions



(4) Publish density predictions for use in marine spatial planning processes

Duke MGEL
(Atlantic and Gulf of Mexico)

NOAA SWFSC
(Pacific)

Topic of this presentation

Data flow for 2013 models

Marine Mammal Surveys

NOAA NMFS NEFSC
- Atlantic surveys 1991-2008
- NARWSS flights 1999-2012

NOAA NMFS SEFSC
- Atlantic surveys 1992-2005
- GoMex surveys 1992-2009

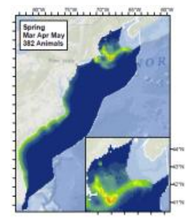
UNC Wilmington
- Navy surveys 1998-2012
- RIWH surveys 2005-2008

Analysis at Duke

Private Database

OBIS SEAMAP

Density Models



NOAA provides Duke with some data they are not yet ready to put into OBIS-SEAMAP for public use

Model Users

Survey Data Providers

Cetacean & Sound Mapping

NAVFAC Naval Facilities Engineering Command

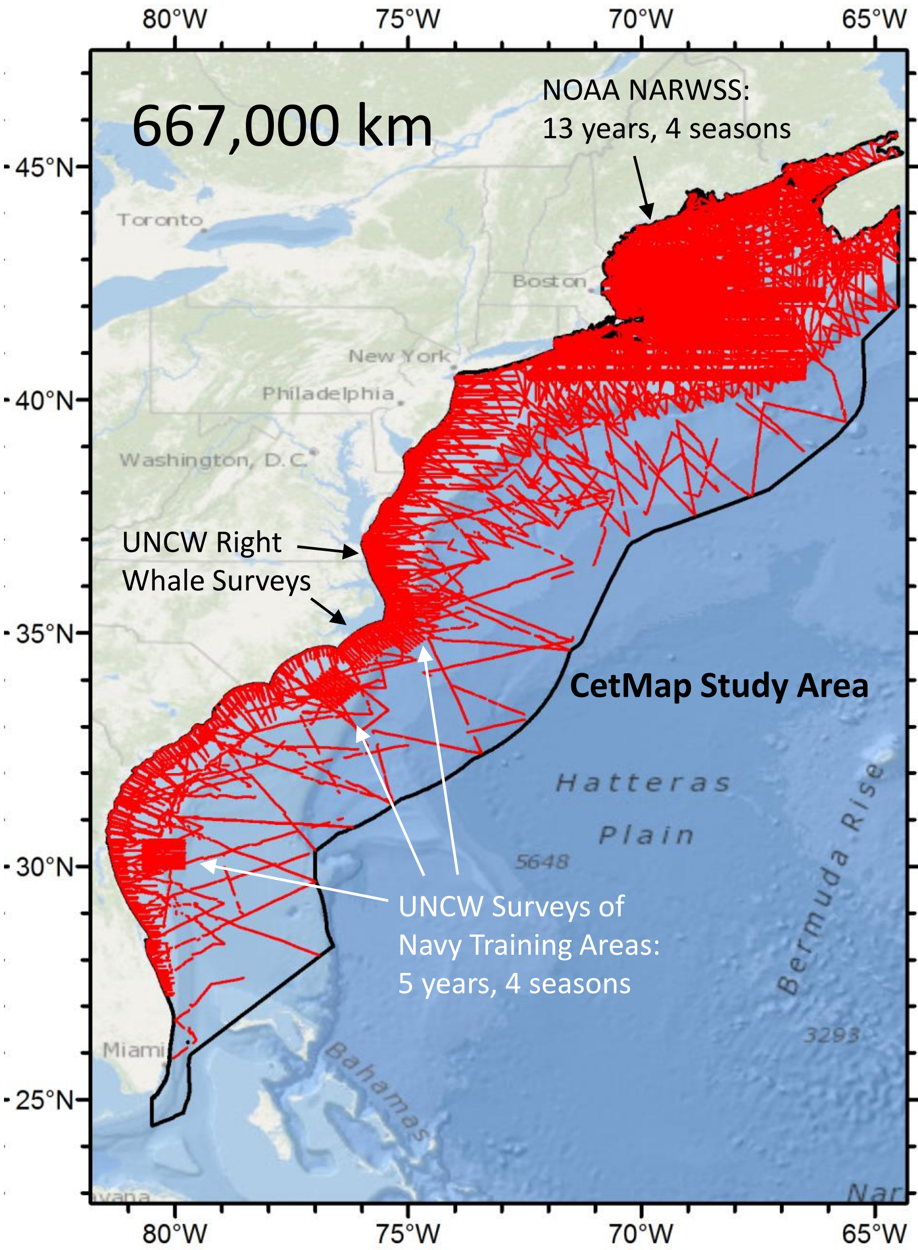
BOEM Bureau of Ocean Energy Management

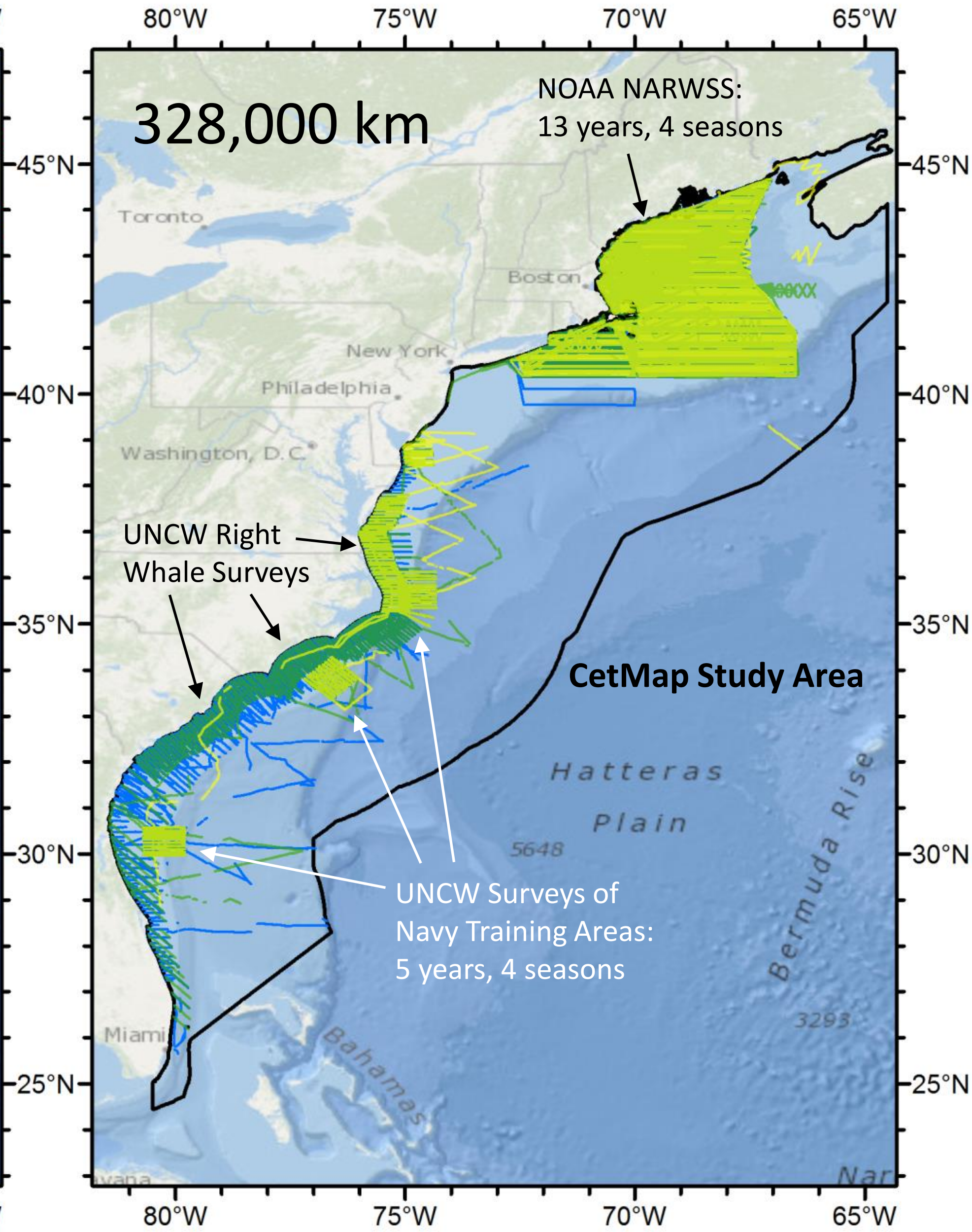
MARINECADASTRE.GOV

Many others have expressed interest

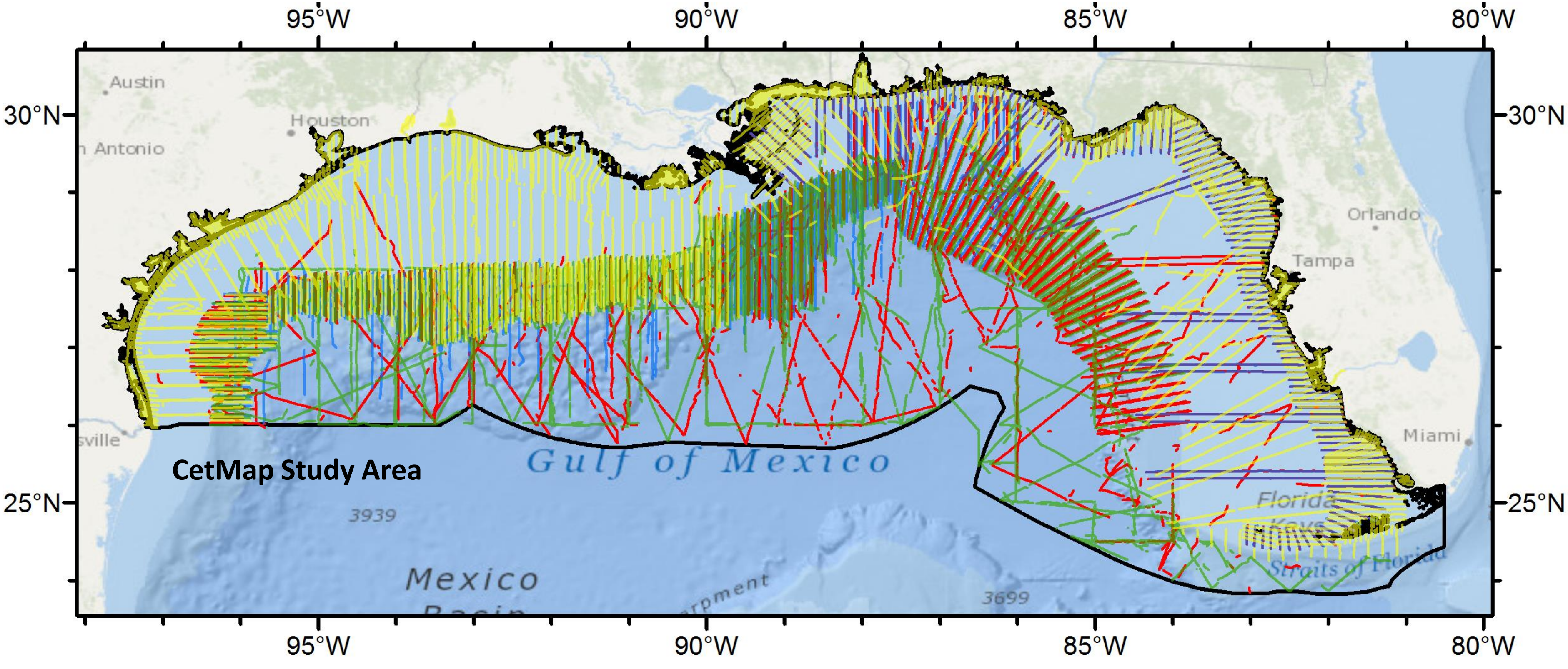
Atlantic Surveys

Summer (Red), Fall (Yellow), Winter (Blue), Spring (Green)





Gulf of Mexico Surveys



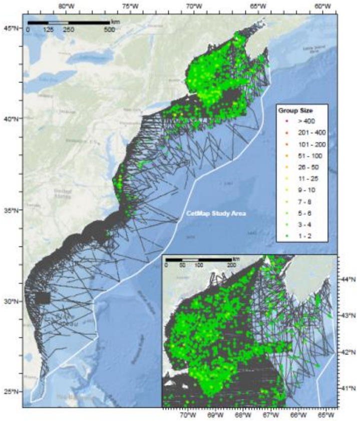
183,000 km

NOAA surveys from 1992-2009

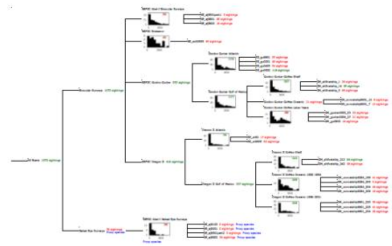
66% during 1992-1998

Summer (Red), Fall (Yellow), Winter (Blue), Spring (Green)

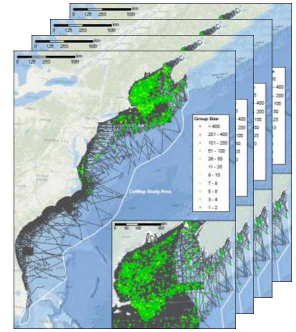
Modeling Workflow



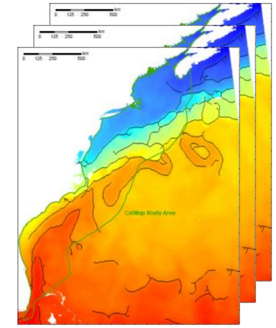
Segment tracklines; extract sightings



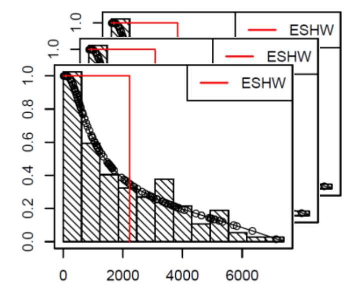
Group similar surveys for fitting detection functions



Split into seasons



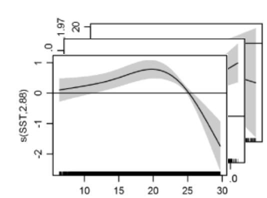
Sample oceanographic predictors for segments



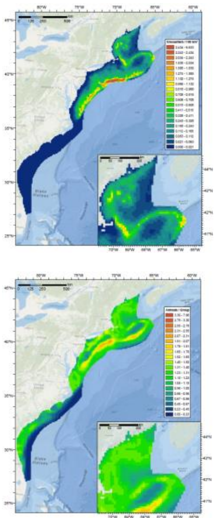
Fit detection functions and predict ESW

$$E(n_j) = exp\left[\log_e\left\{l_j(\hat{\mu}_{left_j} + \hat{\mu}_{right_j}) \cdot \hat{g}(0)\right\} + \beta_0 + \sum_{k=1}^{K} f_k(z_{jk})\right], \quad j = 1, \ldots, T$$

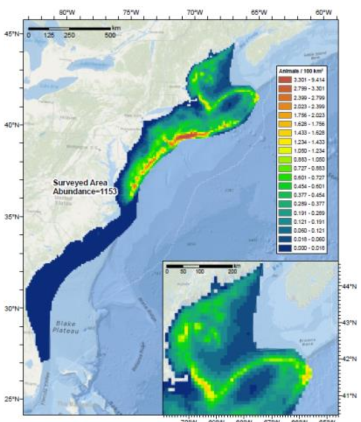
$$E(s) = exp\left[\beta_0 + \sum_{k=1}^{K} f_k(z_{jk})\right], \quad j = 1, \ldots, S$$



Fit GAMs for encounter rate and group size



Predict encounter rate and group size from oceanographic images



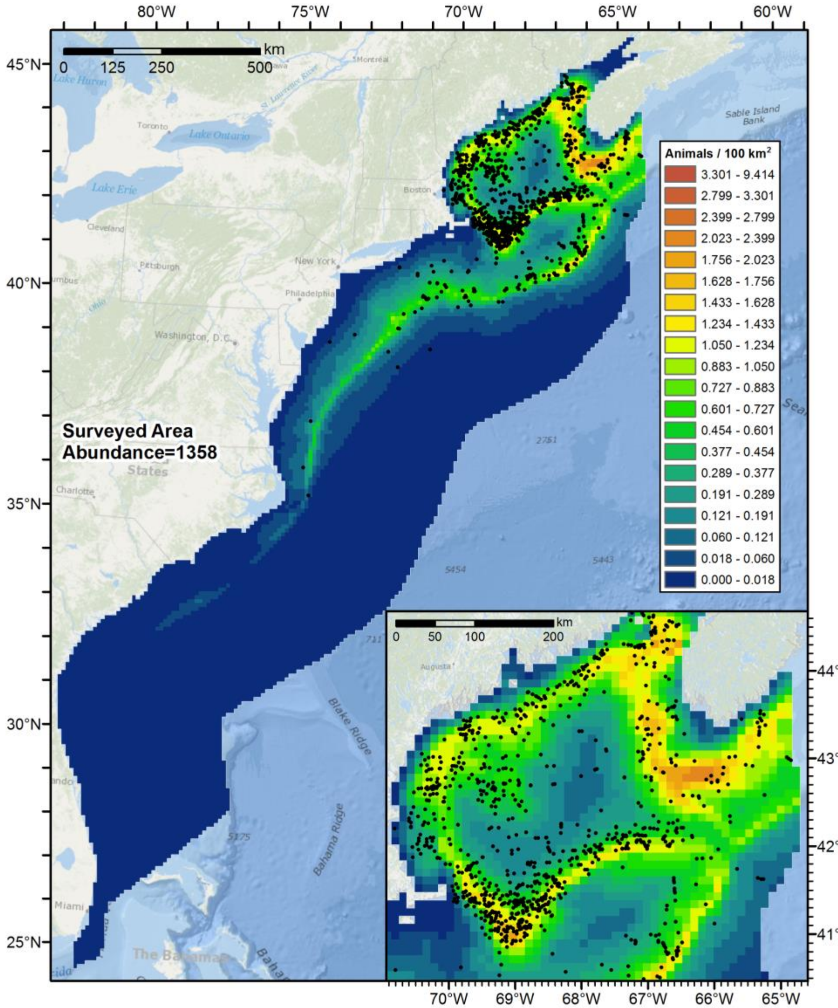
Create density map

Dynamic oceanographic predictors

Variable	Type	Description
SST	Dynamic	Sea surface temperature (deg C).
Chlorophyll	Dynamic	Chlorophyll-*a* concentration (mg m^{-3}). Although cetaceans do not consume chlorophyll directly, many cetacean prey species do, so it can be a proxy for the presence of those species.
VGPM	Dynamic	Primary productivity (mg C m^{-2} day^{-1}). This is an alternative covariate to chlorophyll for biological activity that accounts for the effects of insolation, water temperature, and the depth of the mixed layer on phytoplankton productivity.
TKE	Dynamic	Total kinetic energy of ocean currents (cm^2 s^{-2}). This covariate varies according to water velocity and allowed the models to consider ocean currents such as the Gulf Stream.
EKE	Dynamic	Eddy kinetic energy of ocean currents (cm^2 s^{-2}). This covariate takes high values inside eddy rings, which have been found to be important pelagic habitat.
DistToSSTFront	Dynamic	Distance (m) to closest 1 deg C SST front.
WindSpeed	Dynamic	Wind speed (m s^{-1}) at 10 m over the ocean surface. We used this covariate mainly as a proxy for the roughness of the sea surface, which Good (2006) found to be correlated with north Atlantic right whale calving habitat.
WindStressCurl	Dynamic	Wind stress curl (N m^{-2} per 10^4 km). This covariate is correlated with wind-driven upwelling and downwelling; areas of upwelling and downwelling may represent important habitat.

Table 1: Oceanographic covariates used in spatial models of group size and encounter rate.

Fin Whales - Summer

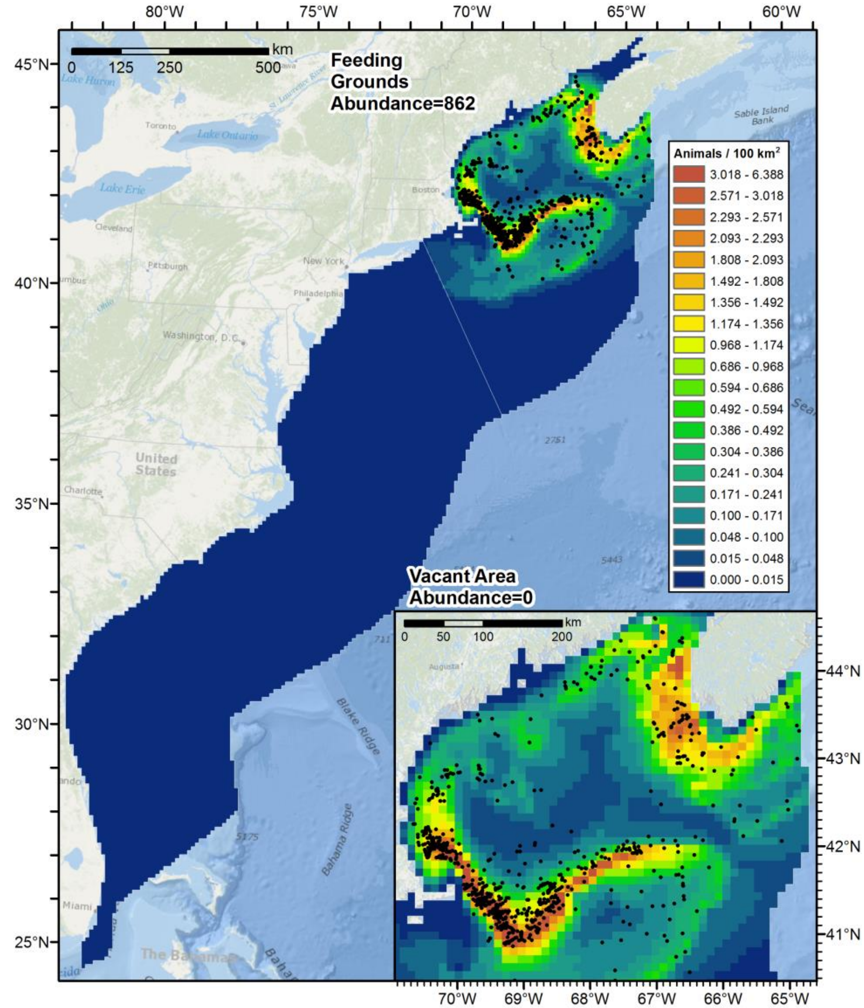


Our abundance estimate: **1358**

NOAA 2012 SAR estimate: **1595** (CV 0.33)

NOAA estimate from Jun-Aug 2011 line-trans. survey of N. Carolina to lower Bay of Fundy

Humpback Whales - Summer

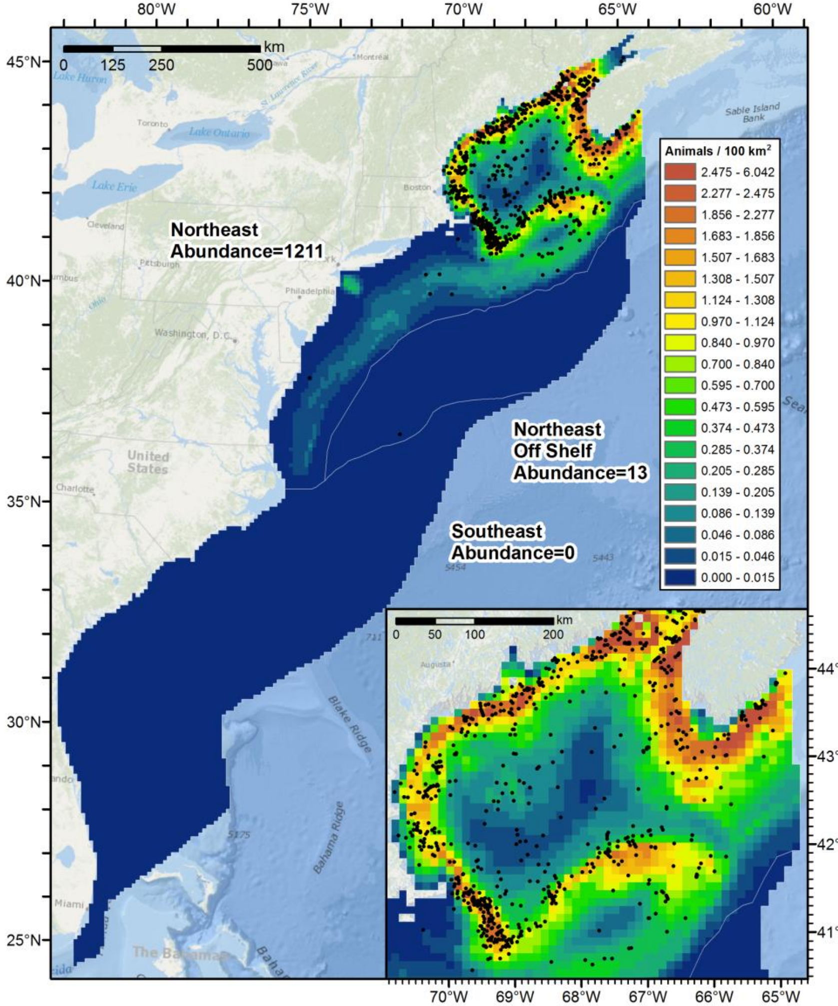


Our abundance estimate: **862**

NOAA 2012 SAR estimate: **823**

NOAA estimate taken from Jun-Oct 2008 photo ID study (Robbins et al.)

Minke Whales - Summer

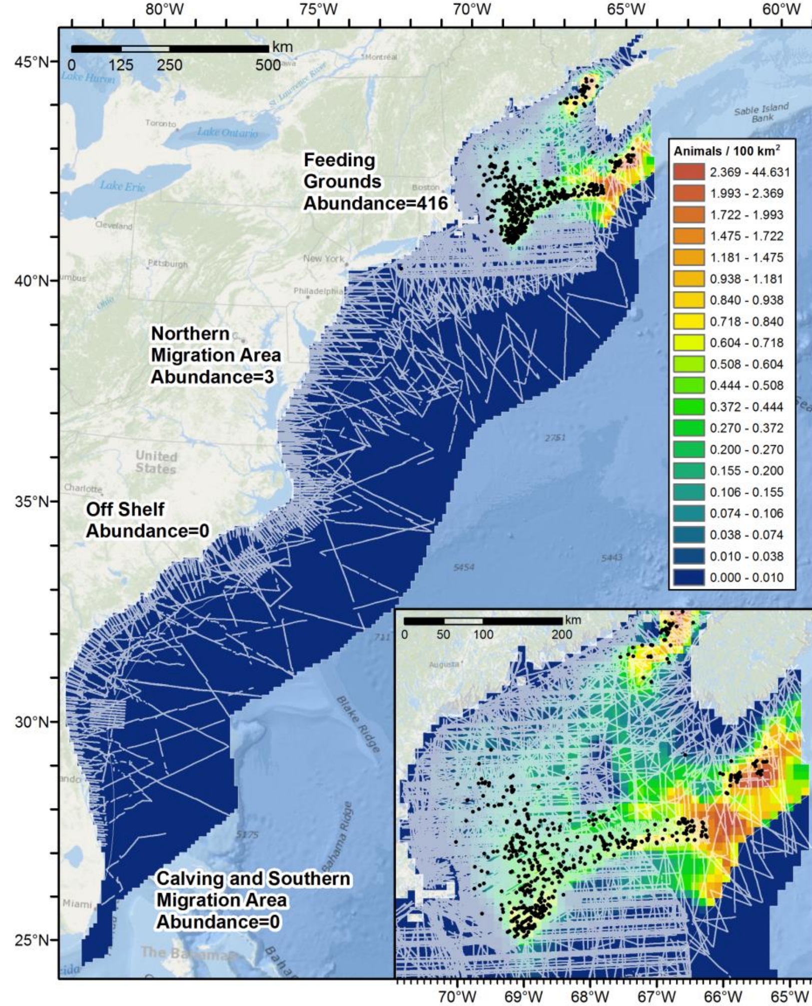


Our abundance estimate: **1224**

NOAA 2012 SAR estimate: **2591** (CV 0.81)

NOAA estimate from Jun-Aug 2011 line-trans. survey of N. Carolina to lower Bay of Fundy

N. Atlantic Right Whales - Summer

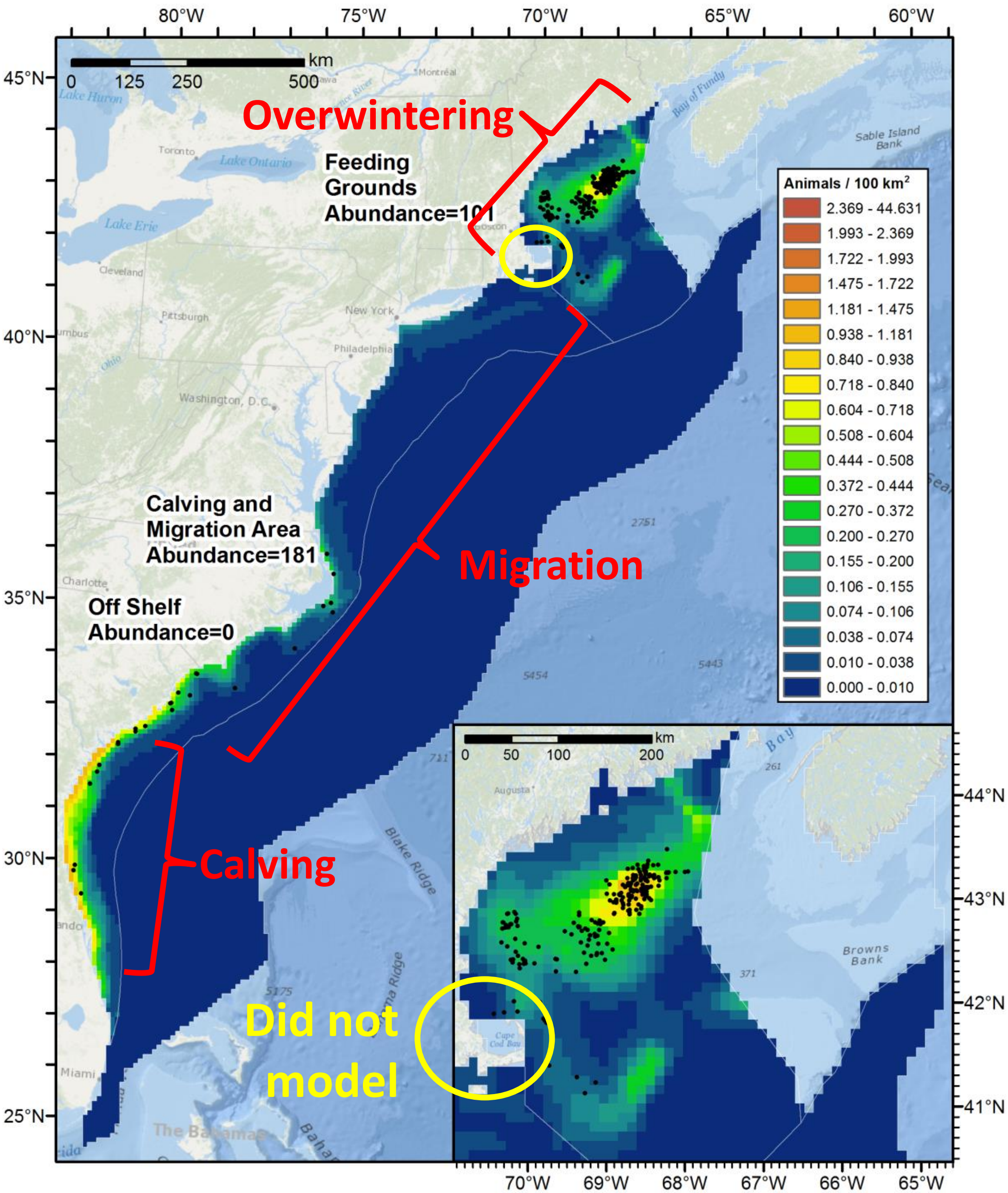


Our abundance estimate: **419**

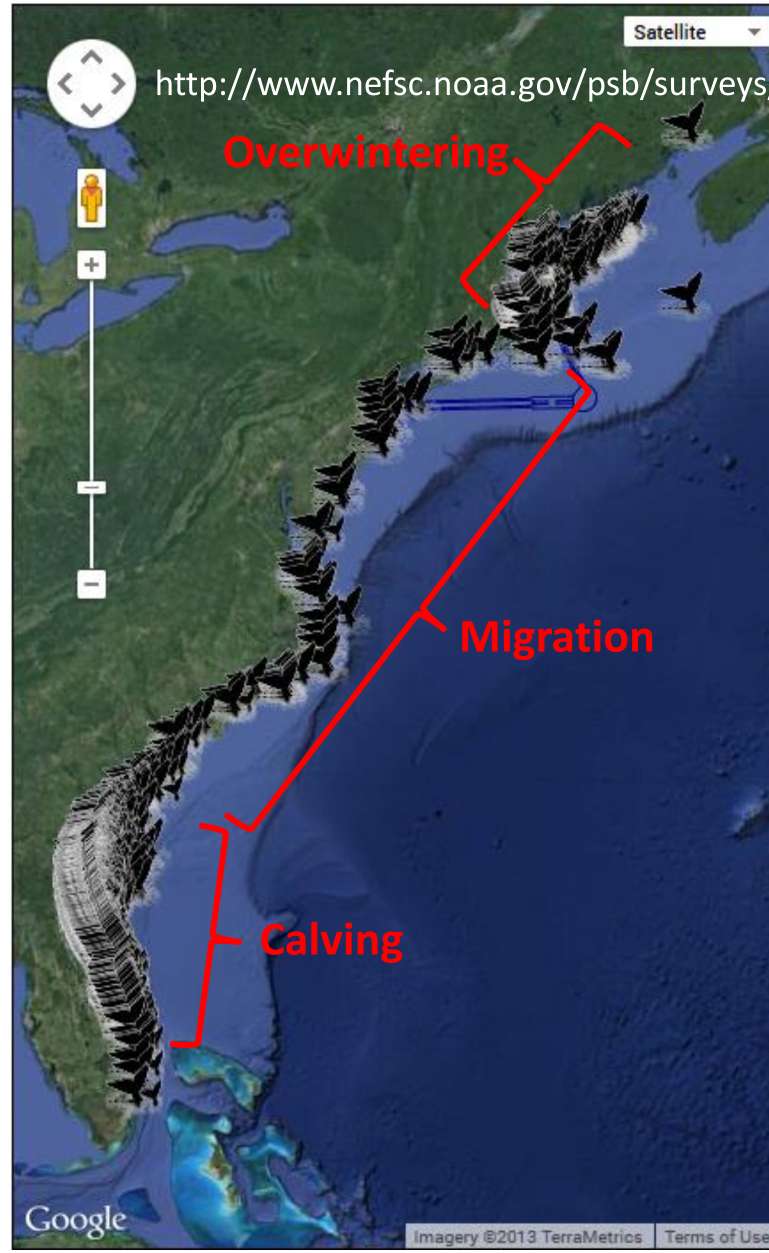
NOAA 2012 SAR estimate: **444**

NOAA estimate taken from 2009 photo ID census of individual whales

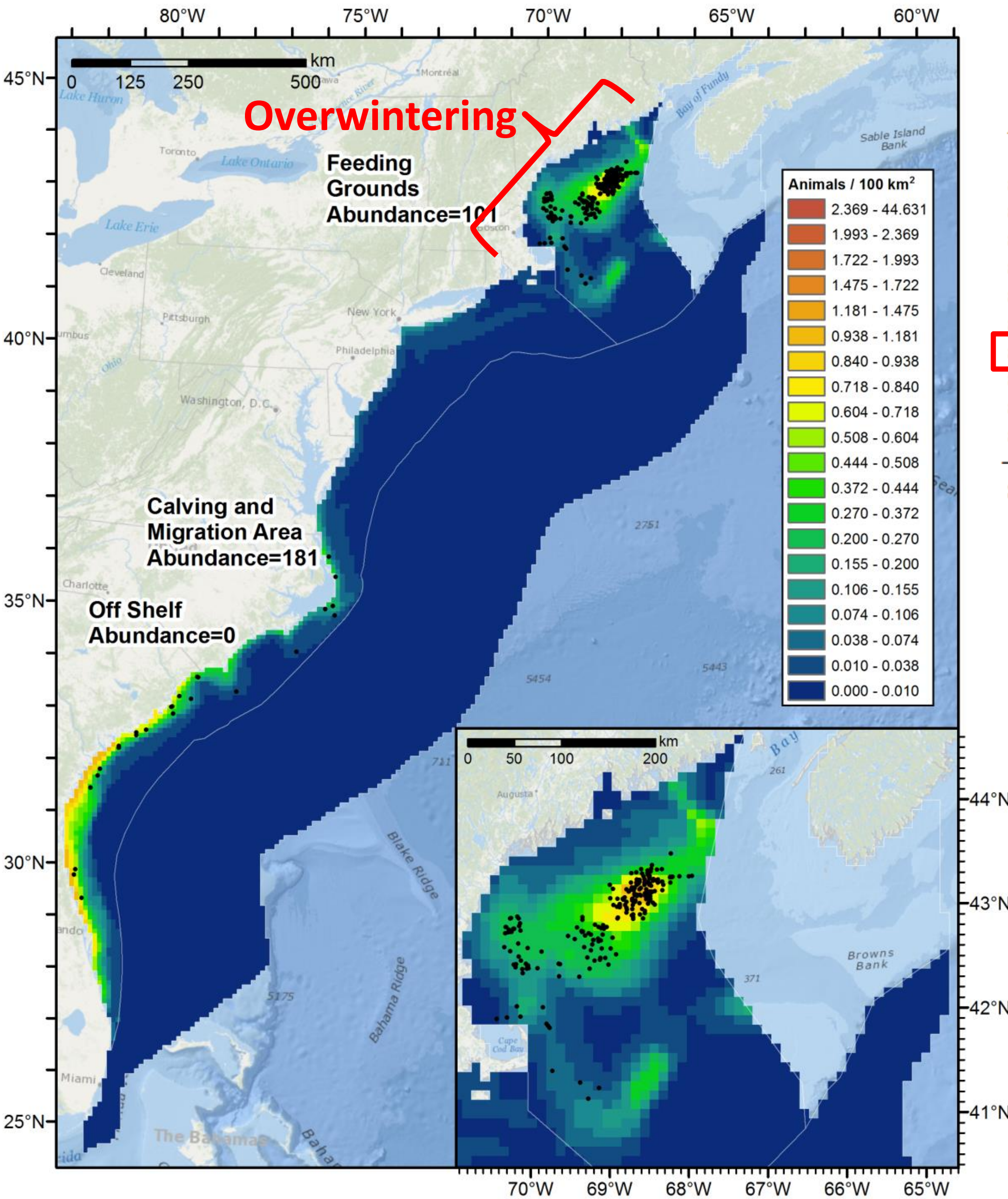
N. Atlantic Right Whales - Winter



NOAA Right Whale Sightings January, All Years

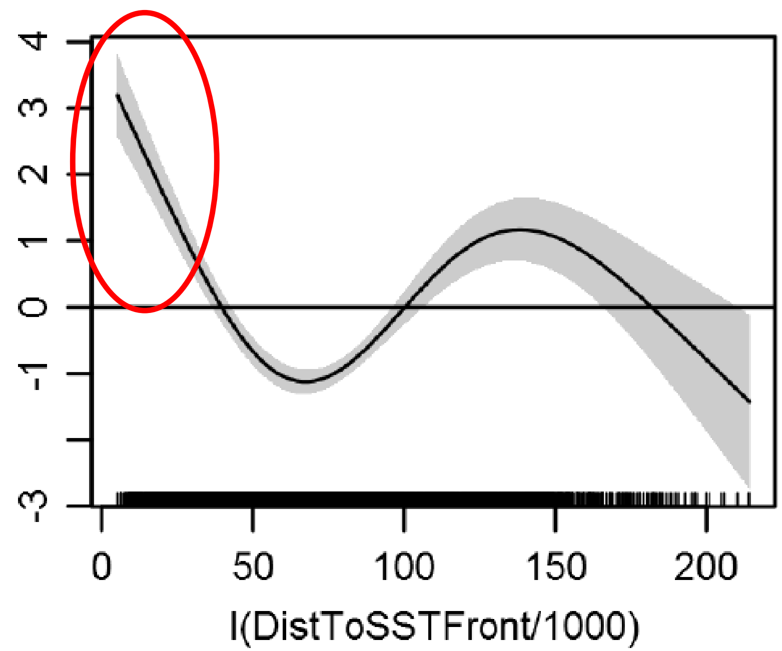


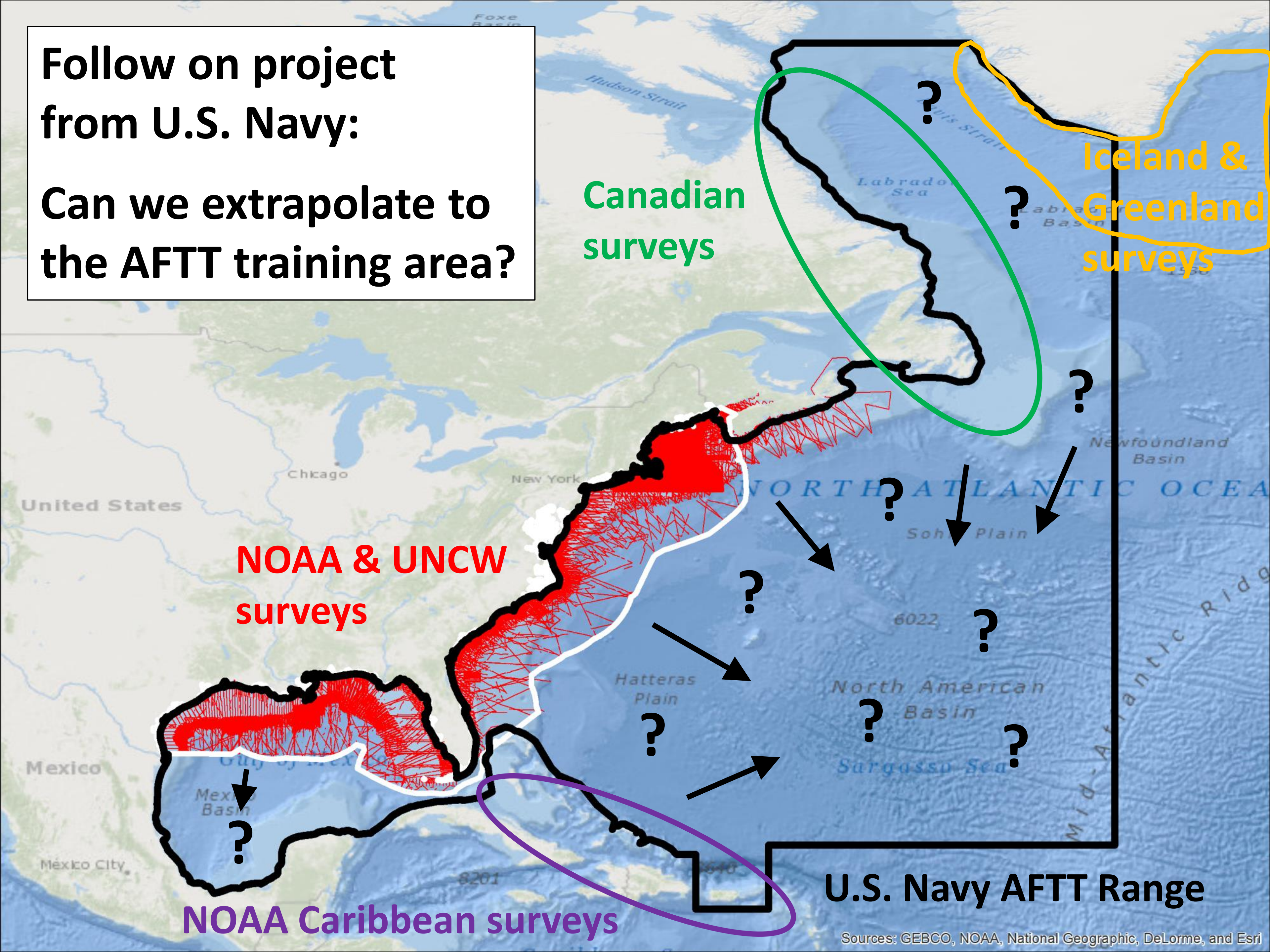
N. Atlantic Right Whales - Winter



DistToSSTFront had highest F score in overwintering area

```
Approximate significance of smooth terms:
                              edf Ref.df      F  p-value
s(lat)                     2.3981      3  5.372 0.000189 ***
s(I(DistToShore/1000))     0.9386      3  2.310 0.004668 **
s(I(DistToGOM125m/1000))   2.0041      3 13.659 1.55e-10 ***
s(SST)                     2.8445      3 12.014 1.85e-08 ***
s(log10(TKE))              2.1958      3 19.069 9.59e-16 ***
s(log10(EKE))              2.6719      3 21.848  < 2e-16 ***
s(I(DistToSSTFront/1000))  2.9707      3 55.176  < 2e-16 ***
s(log10(VGPM))             2.5721      3 21.892  < 2e-16 ***
s(WindSpeed)               2.8117      3 16.315 1.23e-11 ***
s(WindStressCurl)          2.8737      3 15.016 1.12e-10 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

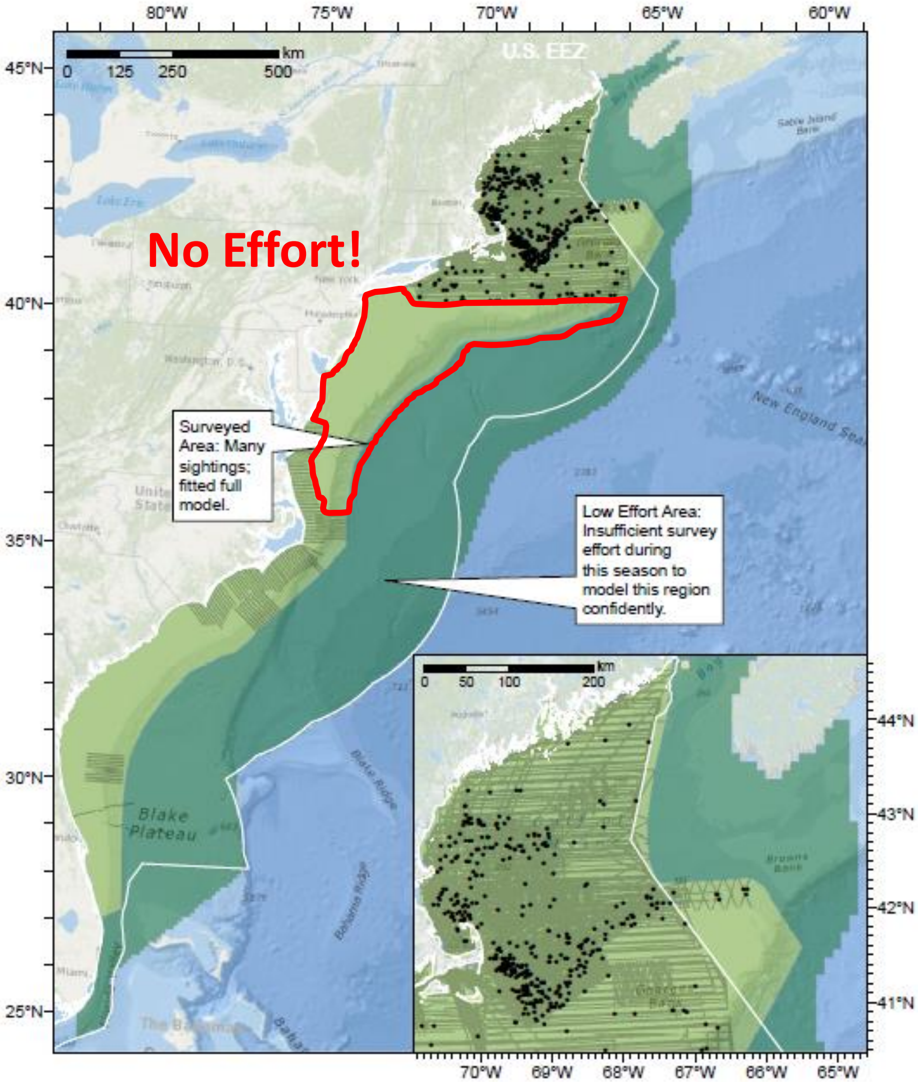




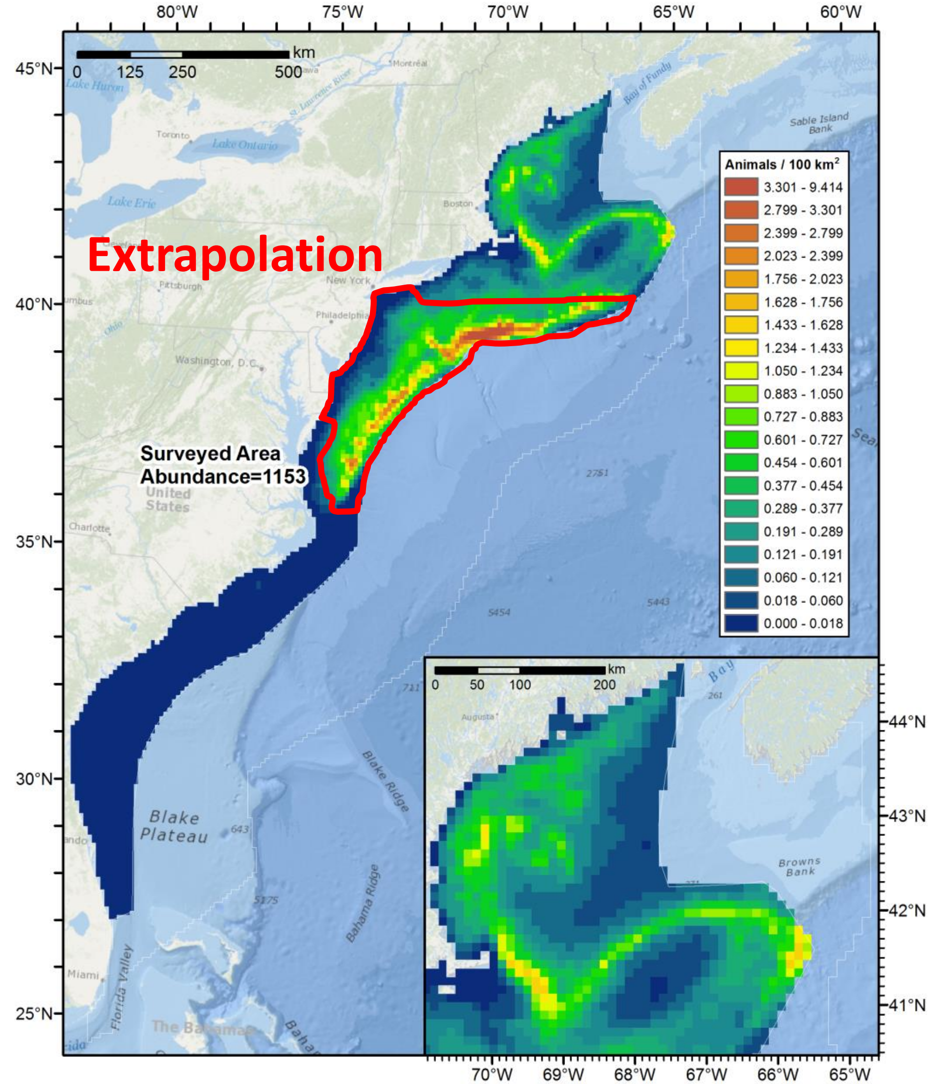
Follow on project from U.S. Navy:
Can we extrapolate to the AFTT training area?
Canadian surveys
Iceland & Greenland surveys
NOAA & UNCW surveys
NOAA Caribbean surveys
U.S. Navy AFTT Range
Hudson Strait
Labrador Sea
Newfoundland Basin
Sohm Plain
6022
Hatteras Plain
North American Basin
Sargasso Sea
Chicago
New York
United States
Mexico
Mexico City
8201
Sources: GEBCO, NOAA, National Geographic, DeLorme, and Esri

Fin Whales - Spring

Effort and Sightings



Modeled Density



Fin Whales - Spring

CETAP Sightings 1978-1982

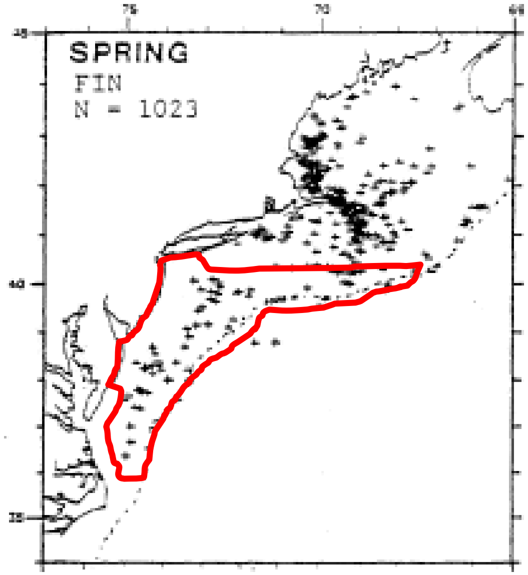
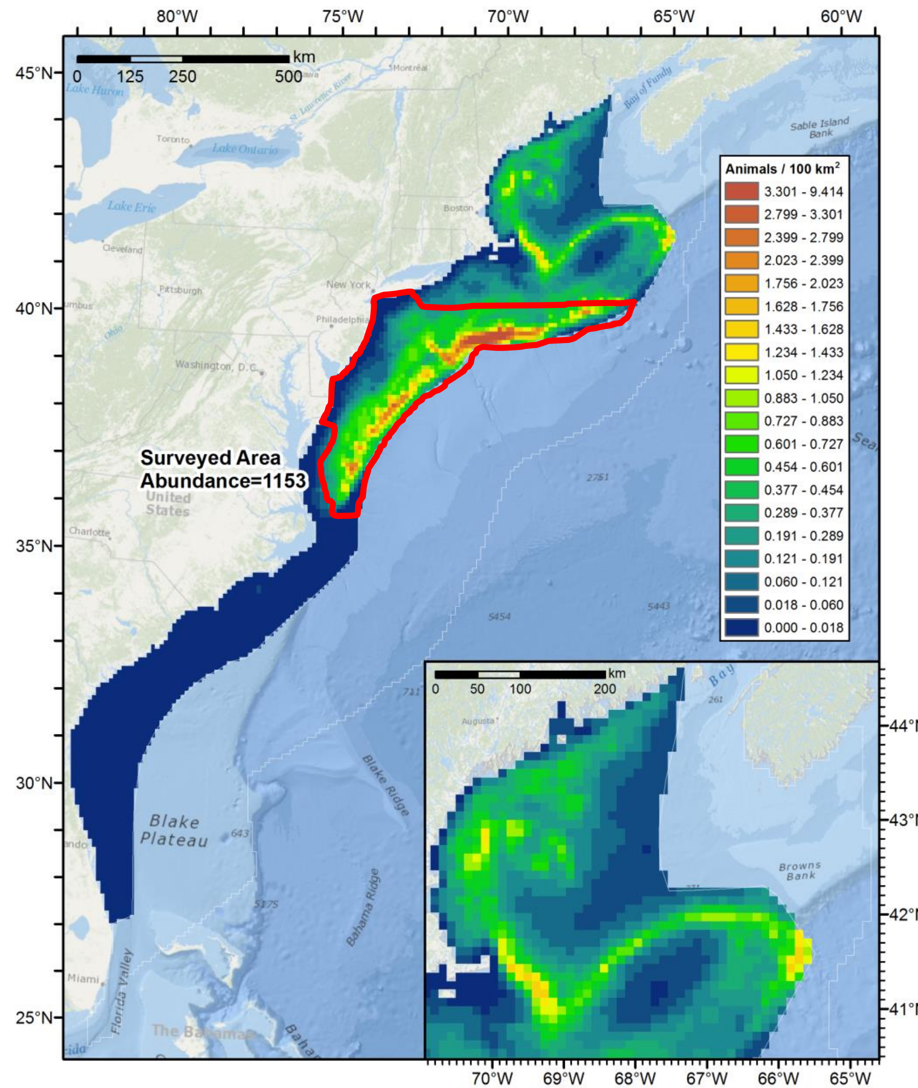
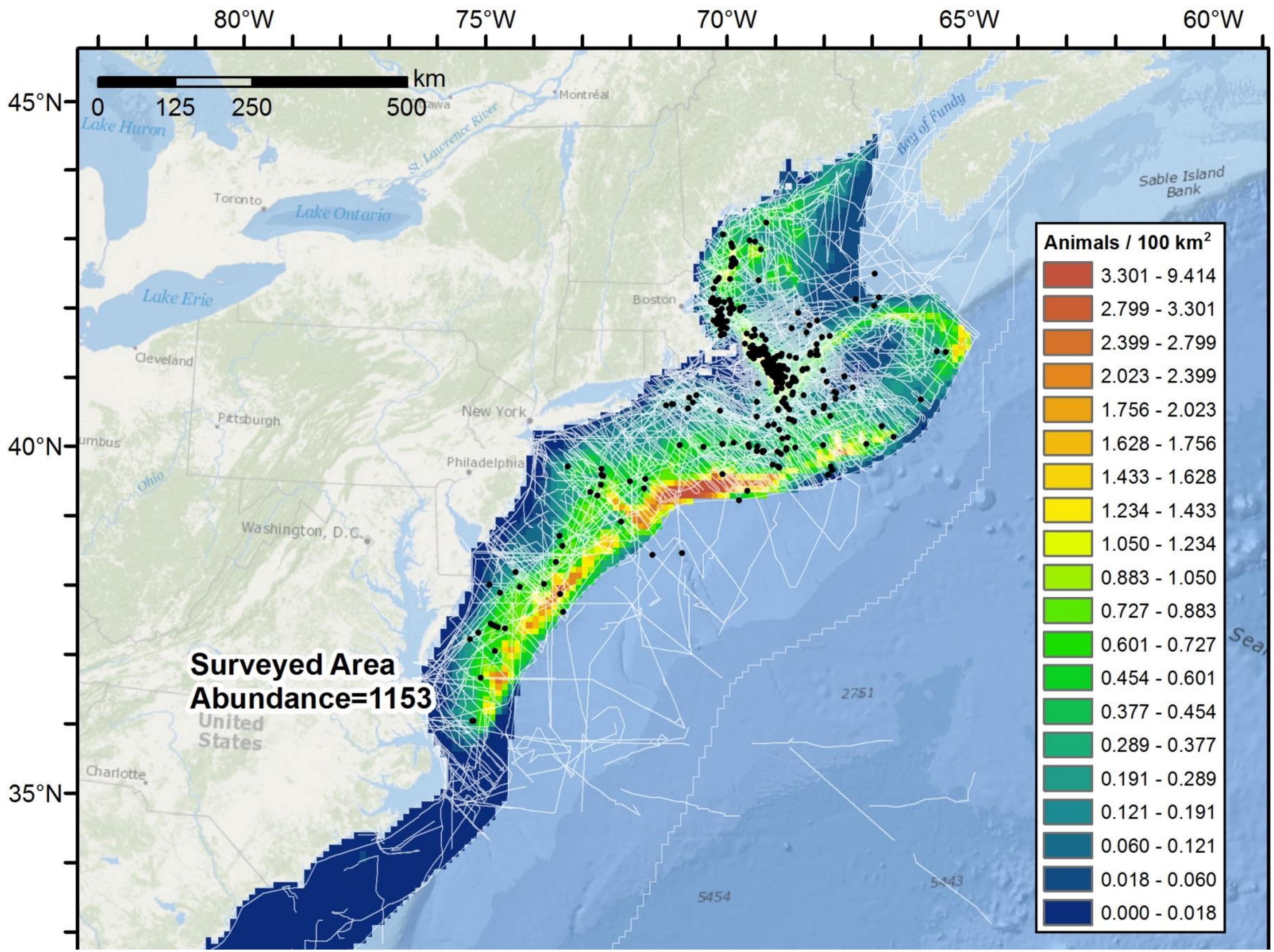


Photo: Aqqa Rosing-Asvid

Modeled Density



Fin Whales - Spring: CETAP Comparison



Summary

- Abundance estimates from the summer-season models were consistent with NOAA’s stratum-based estimates
- Models based on oceanographic predictors yielded density surfaces that visually matched sighting patterns
  - Formal validation and confidence estimation still needed
- Dynamic oceanographic predictors show promise
  - We are refitting the models with contemporaneous predictors to test their performance vs. climatological predictors
- Oceanographic predictors may allow extrapolation of density to poorly surveyed regions
  - Focus of follow-on project

Acknowledgements

- Thanks to the observers, crews, and everyone responsible for conducting the surveys
- Thanks for sharing surveys, providing advice, and reviewing results: Debi Palka, Lance Garrison, Bill McLellan, Tim Cole, Christin Khan, Peter Corkeron, Karin Forney, Elizabeth Becker, Megan Ferguson, Richard Pace, Jolie Harrison, Sofie Van Parijs, Erin LaBrecque, Anu Kumar, Andrew DiMatteo
- Thanks to our funders:

Thanks for attending!

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