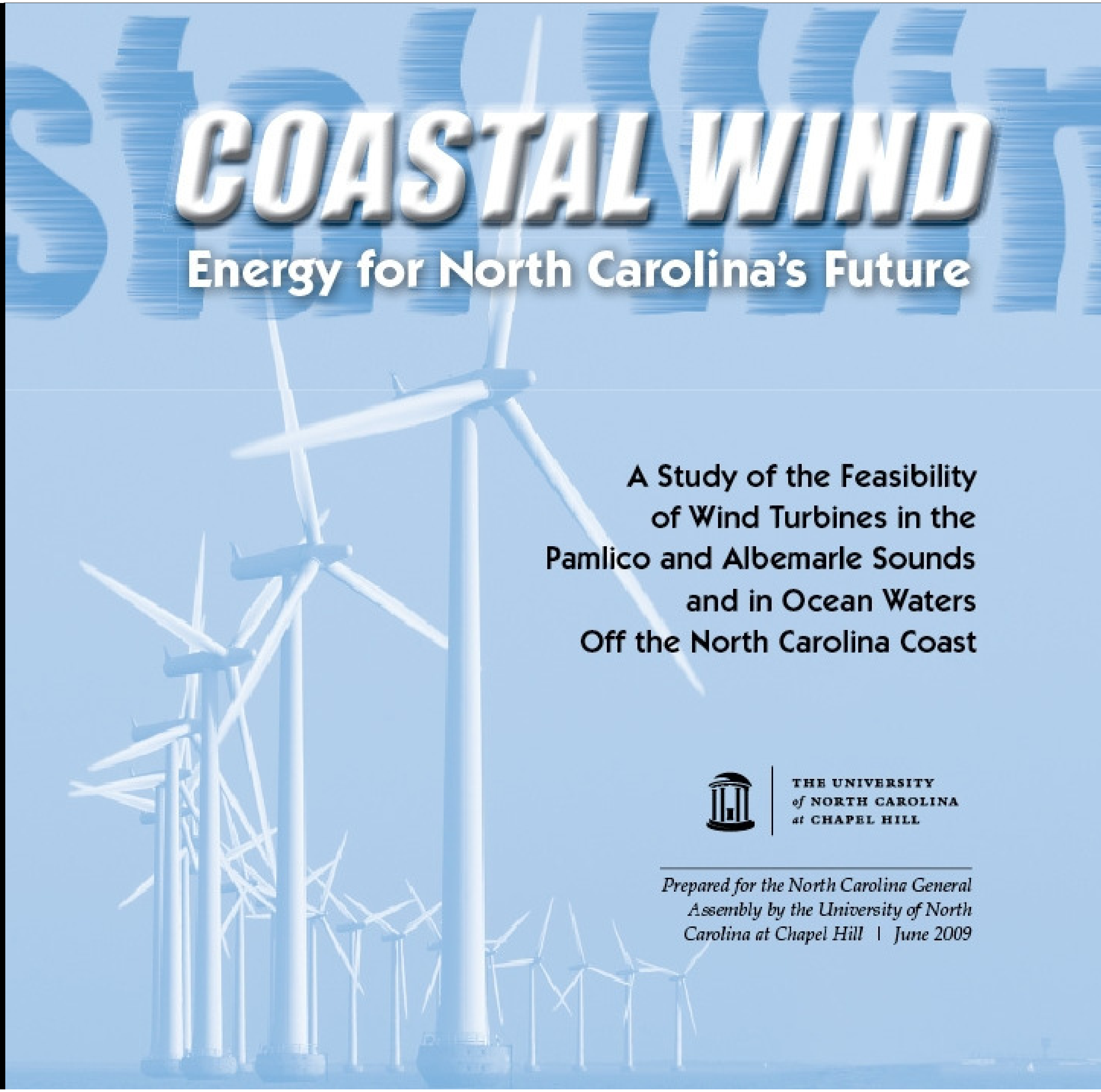


COASTAL WIND

Energy for North Carolina's Future

A Study of the Feasibility of Wind Turbines in the Pamlico and Albemarle Sounds and in Ocean Waters Off the North Carolina Coast

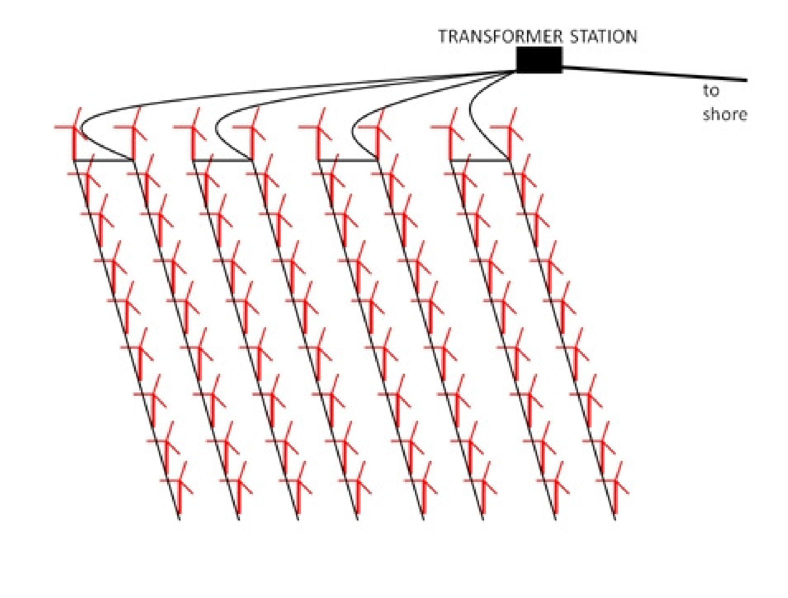
THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Prepared for the North Carolina General Assembly by the University of North Carolina at Chapel Hill | June 2009

Coastal Wind Energy Study

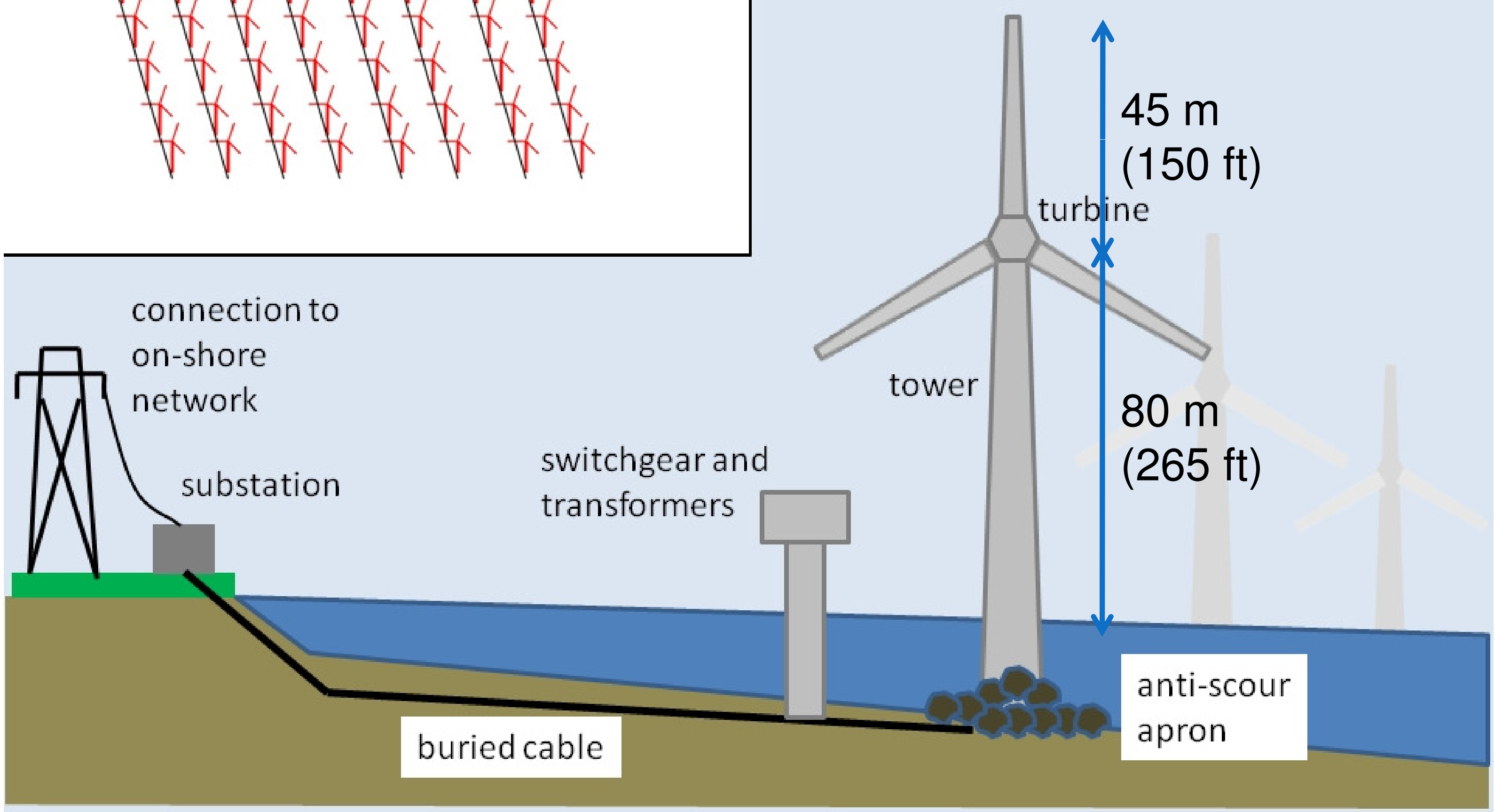
- Requested by the North Carolina General Assembly
- University of North Carolina at Chapel Hill designated to conduct the study
  - C. Elfland, Associate Vice Chancellor for Campus Services, project leader
- Study area
  - Pamlico and Albemarle Sounds
  - Offshore over waters less than 30 meters in depth (wind to 50 meters in depth)

Potential wind farm layout



Dimensions:

1) ~700 m between turbines*
2)MMS leases are 3 mi by 3 mi
3)49 turbines per lease block



Coastal Wind Energy Study

Study Components (from legislation)

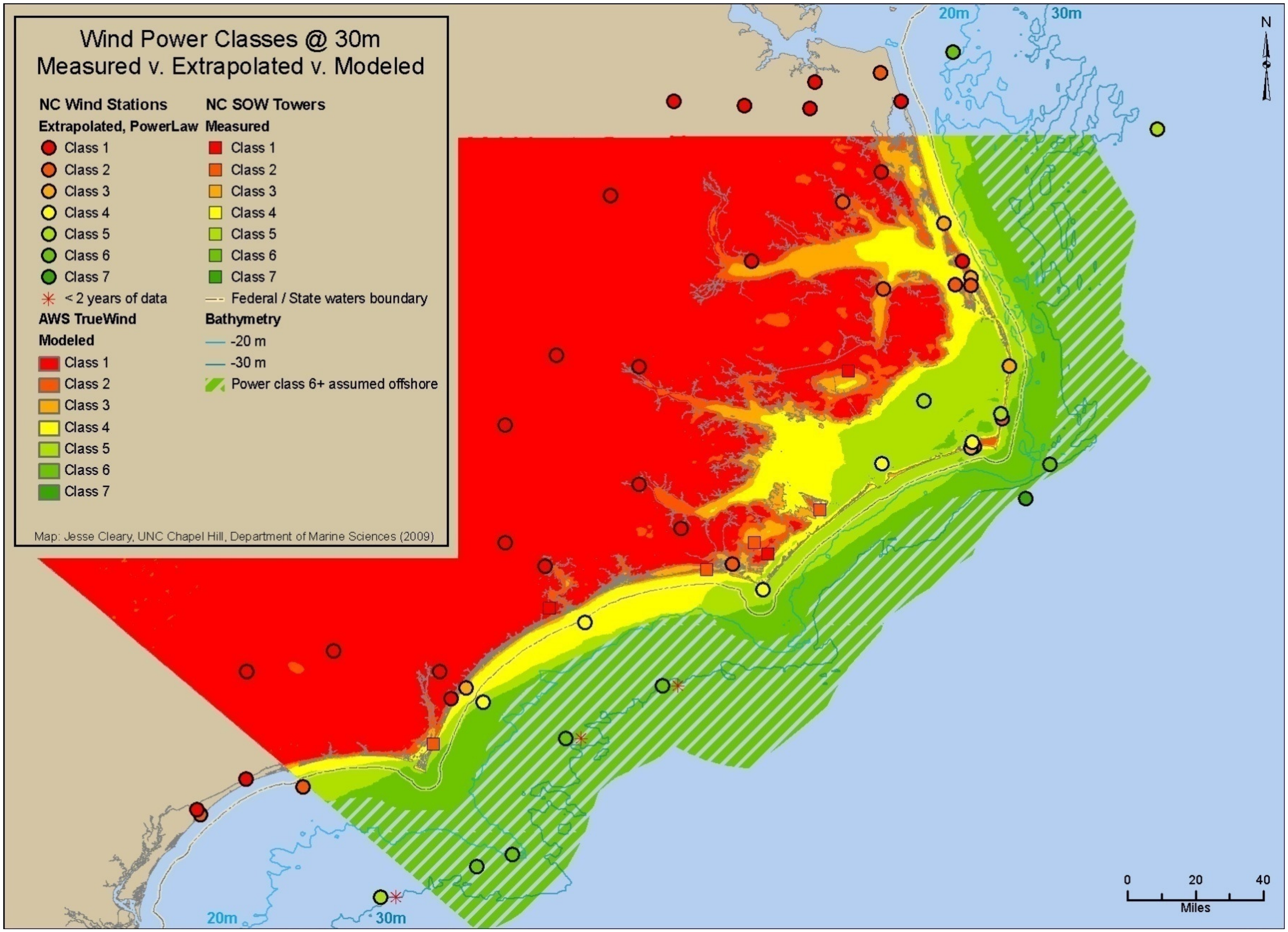
- Wind resource evaluation
- Ecological impacts, synergies, use conflicts
- Foundation concepts
- Geologic framework
- Utility transmission infrastructure
- Utility-related statutory and regulatory barriers
- Legal framework, issues, and policy concerns
- Carbon reduction
- Preliminary economic analysis

Wind Resource Evaluation

H. Seim (Marine Sciences, UNC Chapel Hill)
G. Lackmann (RENCI, NC State)

- Compare existing wind power estimates from AWS Truewind with available low-level (largely 10 meter) wind observations
- Extrapolate low level winds to height – use NC SOW meteorological tower data to examine power-law and log layer fits
- Collect new observations with a sodar wind profiler
- Initiate archive and evaluation of regional wind models being run by NC Climatology Office and RENCI

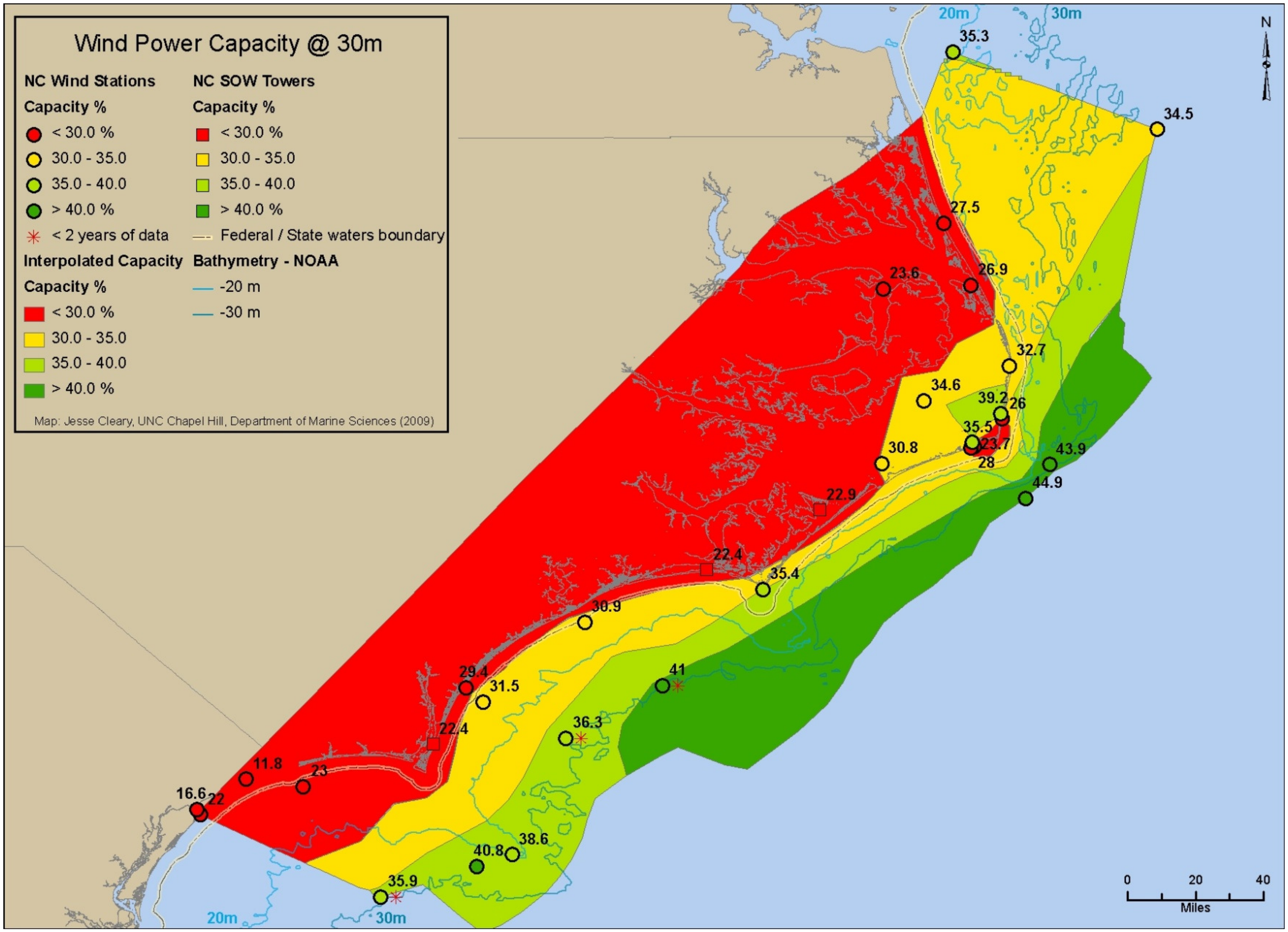
Wind Power Class



Capacity Factor

- Power generation is dependent on the generator used
- Simple but realistic approach is to use power curve for common wind turbine to convert wind speed to power
- Power curves for 3-3.6 MW turbines are all similar – kick-in speed of 3-5 m/s, rated power at 15 m/s, no output above 25 m/s.
- Capacity factor is simply the average output from a generator divided by its maximum output, expressed as a percentage.
- Used measured-over-water wind records to estimate capacity factor

Capacity Factor Map



Ecological impacts, synergies, use conflicts

C. Peterson (Marine Sciences, UNC Chapel Hill)
S. Fegley (Marine Sciences, UNC Chapel Hill)
J. Meiners (Marine Sciences, UNC Chapel Hill)

- Risk to birds, bats, and butterflies and the loss or fragmentation of their terrestrial habitat
- Risk to marine mammals, sea turtles, fish, and bottom-dwelling invertebrates
- Synergies with other ecosystem services
- Conflicts with military, mining, cultural, and ocean dumping uses

Procedure for estimating risk

Interview experts, managers, bird watchers, fishermen, and duck hunters:

- 54 in-person interviews
- 5 phone interviews

Review relevant literature:

- 21 environmental assessments
- 21 government reports
- 40 peer-reviewed articles
- 14 unpublished manuscripts

Accumulate and organize pertinent information:

- distributions and temporal patterns of organisms
- possible presence of endangered, threatened, or species of concern
- specific behavioral responses to structures, noises, and visual cues
- distribution of fishery habitat and fishing activities

Estimation of risk:

- examine accumulated information for patterns and specific concerns
- use general ecological data and paradigms to reduce uncertainty
- consult with experts again on preliminary assessments

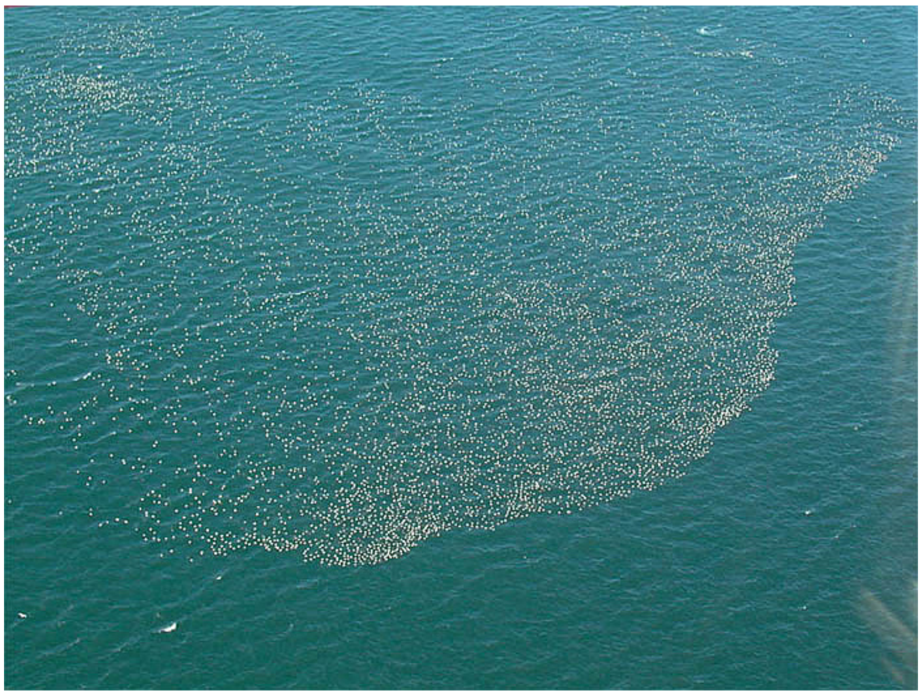
Bird and Bat Risk Distribution

- Risk assessment – combines abundance and behavior
  - Mortality risk from encounter with blades
  - Turbine avoidance increases fitness risks from loss of foraging habitat or by inducing longer flight paths (especially for overwintering ducks)

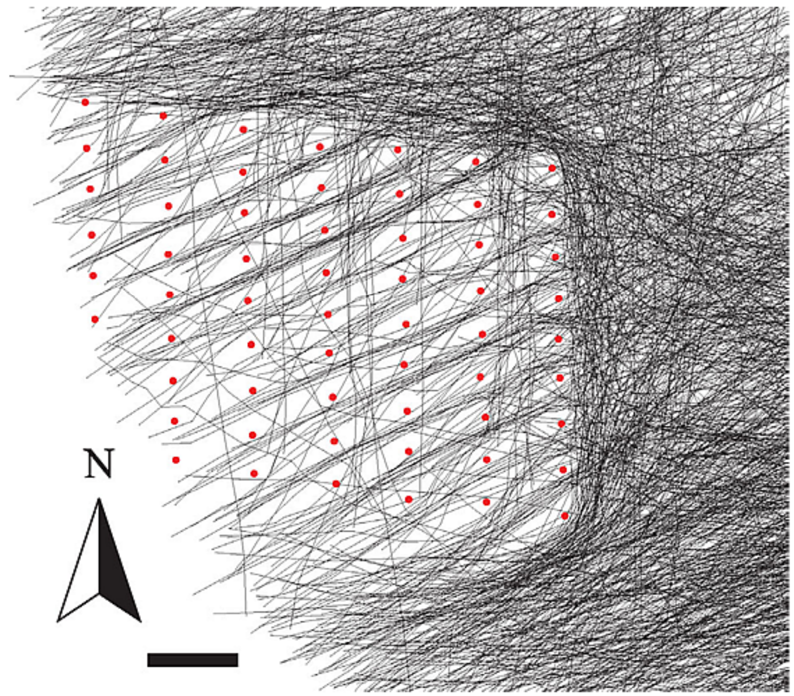

Scott Hecker, National Audubon


Al Perry

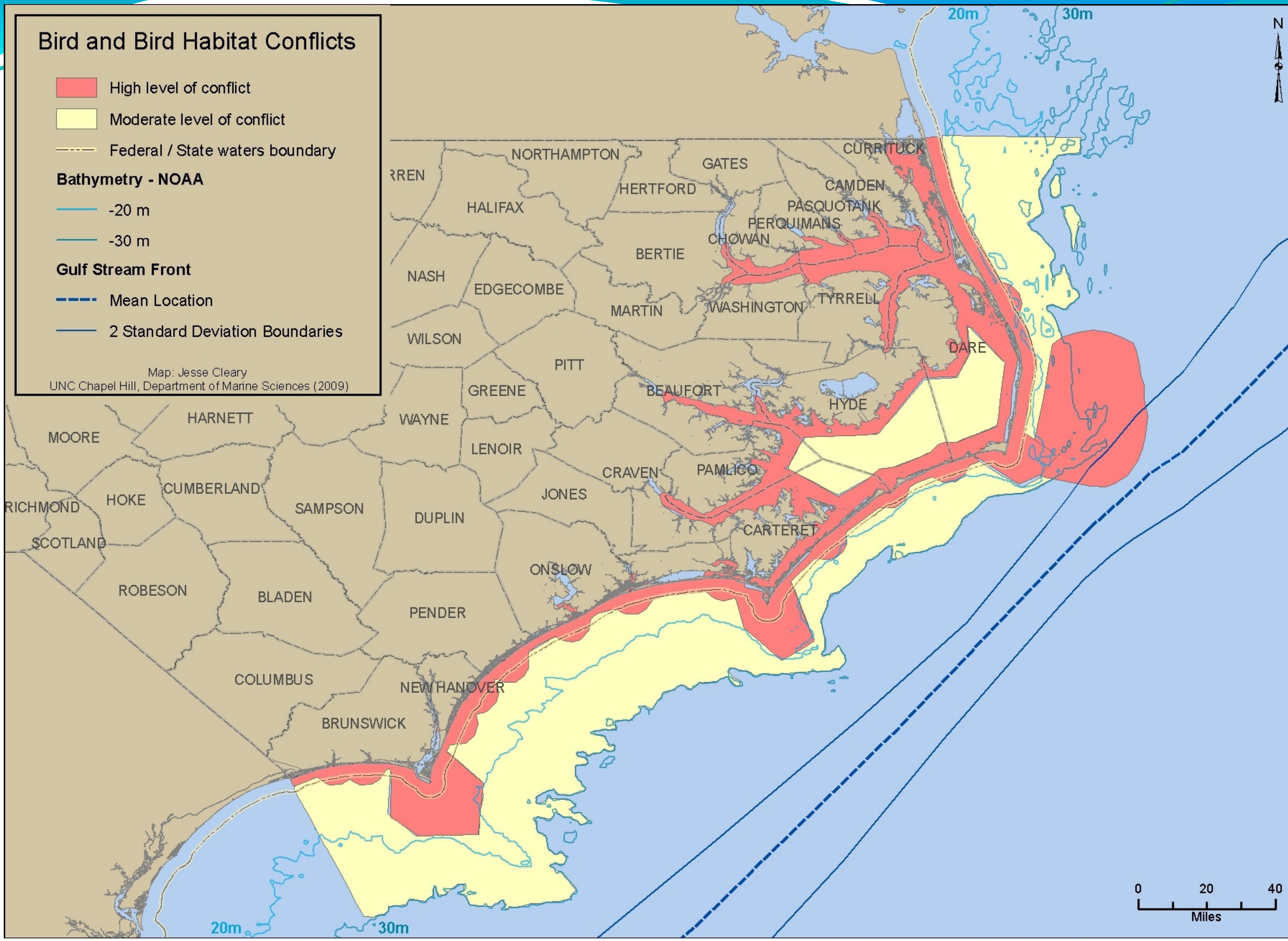
Behavioral responses
(an example)



Aerial photograph of a flock (a “raft”) of 20,000 common eiders – photograph by Simon Perkins, Mass Audubon



Compilation of radar tracks for common eiders and geese flying near and through an offshore, Danish wind mill farm (individual mills are represented by red dots – Desholm and Kahlert 2005). These results are controversial; the wind mills interfere with the radar used to document flight paths.



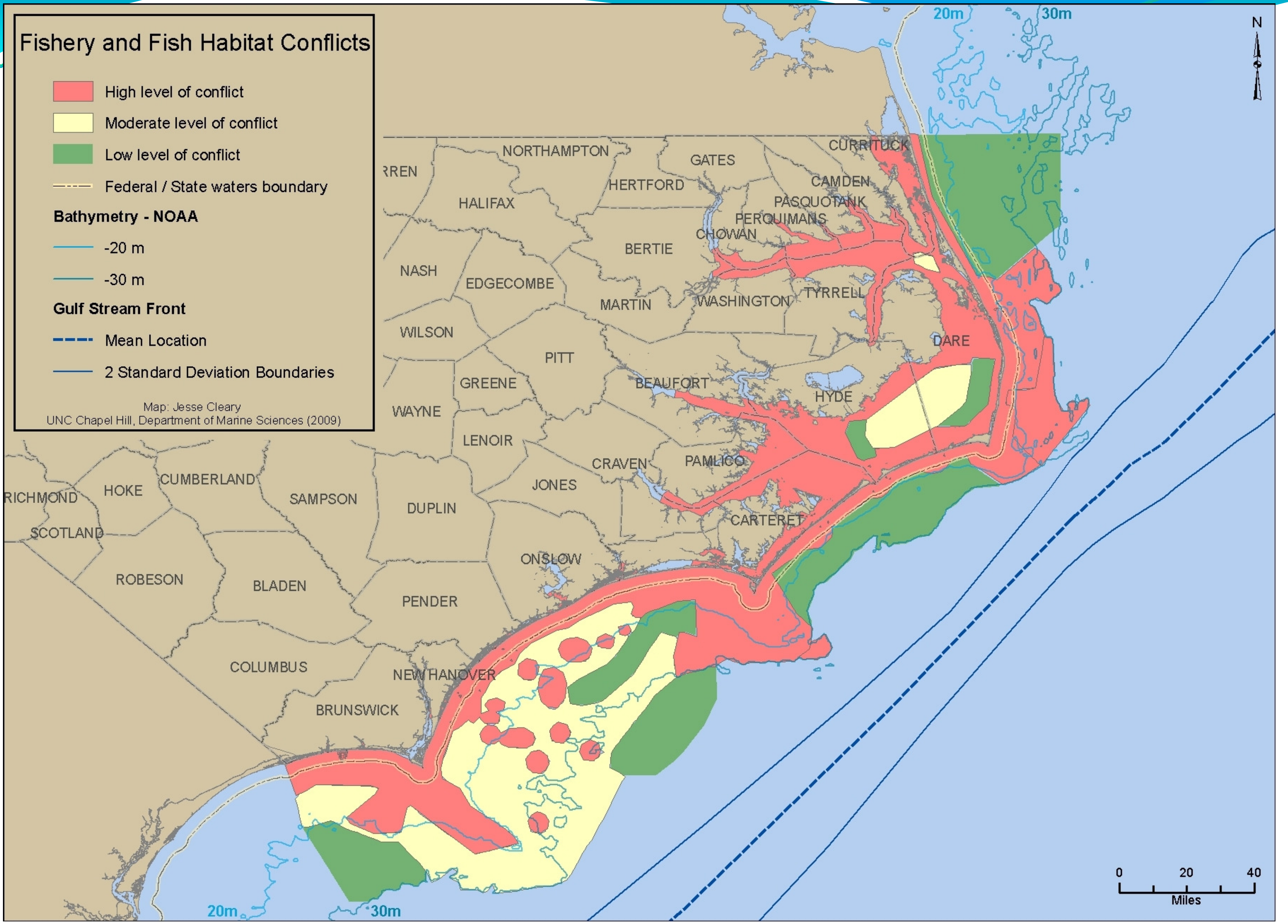
Bird and Bird Habitat Conflicts
High level of conflict
Moderate level of conflict
Federal / State waters boundary
Bathymetry - NOAA
-20 m
-30 m
Gulf Stream Front
Mean Location
2 Standard Deviation Boundaries
Map: Jesse Cleary
UNC Chapel Hill, Department of Marine Sciences (2009)
20m
30m
N
NORTHAMPTON
GATES
CURRITUCK
CAMDEN
HERTFORD
PASQUOTANK
PERQUIMANS
CHOWAN
HALIFAX
BERTIE
NASH
EDGECOMBE
MARTIN
WASHINGTON
TYRRELL
DARE
WILSON
PITT
GREENE
BEAUFORT
HYDE
HARNETT
WAYNE
MOORE
LENOIR
CRAVEN
PAMLICO
CUMBERLAND
JONES
RICHMOND
HOKE
SAMPSON
DUPLIN
CARTERET
SCOTLAND
ONSLOW
ROBESON
BLADEN
PENDER
COLUMBUS
NEW HANOVER
BRUNSWICK
0
20
40
Miles

Measures to Reduce Risk to Birds and Bats

- Do not use continuous lighting
- Reduce or eliminate perches
- Avoid white colors. Paint wind mill vanes in high contrast patterns
- Pilot studies and impact studies after installation and operation of the first wind farm will demonstrate whether other mitigation procedures are needed

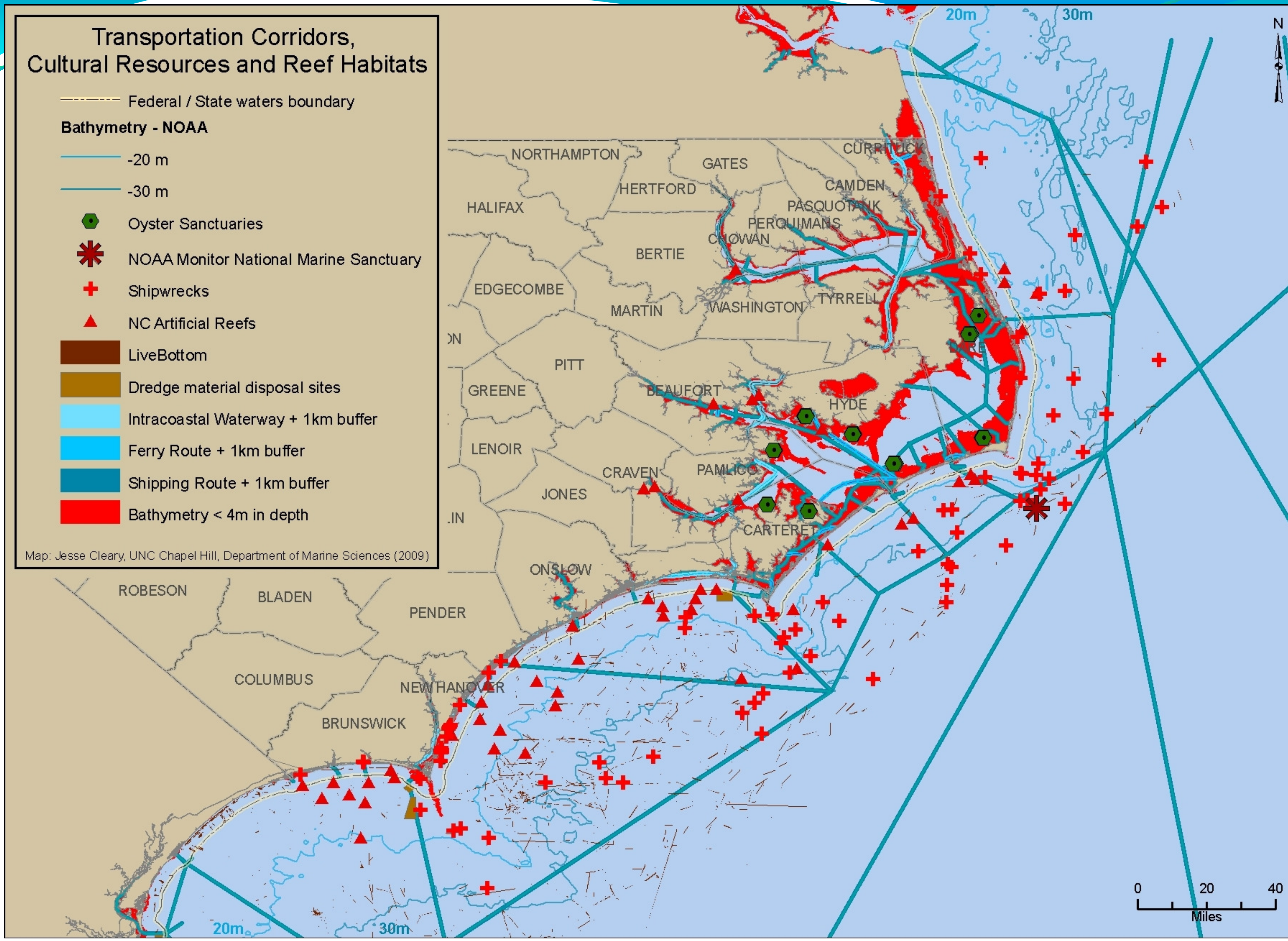
Critical Fish Habitats and Fishing Uses

- Primary, secondary nurseries, migration paths, strategic habitats, submerged aquatic vegetation, shell bottom, oyster reefs (sounds), and live reefs (ocean)
- Larval fish and blue crab migration corridors (may require seasonal constraint on construction)
- Intense fishing uses
  - Trawling (shrimp, crabs, flounder)
  - Dredging (scallops, oysters)
  - Long hauling (various fishes)
- High productivity regions
  - Gulf Stream, three Capes, all inlets, the “Point”
  - All inlets with 5 mile radius from centerpoint


Fishery and Fish Habitat Conflicts
High level of conflict
Moderate level of conflict
Low level of conflict
Federal / State waters boundary
Bathymetry - NOAA
-20 m
-30 m
Gulf Stream Front
Mean Location
2 Standard Deviation Boundaries
Map: Jesse Cleary
UNC Chapel Hill, Department of Marine Sciences (2009)
NORTHAMPTON
GATES
CURRITUCK
CAMDEN
HERTFORD
PASQUOTANK
PERQUIMANS
CHOWAN
HALIFAX
BERTIE
NASH
EDGECOMBE
MARTIN
WASHINGTON
TYRRELL
WILSON
DARE
PITT
GREENE
BEAUFORT
HYDE
WAYNE
LENOIR
CRAVEN
PAMLICO
JONES
CARTERET
RICHMOND
HOKE
CUMBERLAND
SAMPSON
DUPLIN
SCOTLAND
ONSLOW
ROBESON
BLADEN
PENDER
COLUMBUS
NEW HANOVER
BRUNSWICK
20m
30m
N
0
20
40
Miles

Navigation Corridors, Cultural Resources, Reef Habitats

- All marked navigation channels (ferries, shipping, intercoastal waterway), 1 km buffer on each side
- Shipwrecks, including Monitor National Marine Sanctuary
- Artificial reefs, live bottom and oyster sanctuaries
- Dumping sites
- Areas of National Park Service sensitivity to viewscape impacts (e.g., near lighthouses)


Transportation Corridors, Cultural Resources and Reef Habitats
Federal / State waters boundary
Bathymetry - NOAA
-20 m
-30 m
Oyster Sanctuaries
NOAA Monitor National Marine Sanctuary
Shipwrecks
NC Artificial Reefs
LiveBottom
Dredge material disposal sites
Intracoastal Waterway + 1km buffer
Ferry Route + 1km buffer
Shipping Route + 1km buffer
Bathymetry < 4m in depth
Map: Jesse Cleary, UNC Chapel Hill, Department of Marine Sciences (2009)
NORTHAMPTON
GATES
CURRITUCK
HERTFORD
CAMDEN
HALIFAX
PASQUOTANK
PERQUIMANS
CHOWAN
BERTIE
EDGECOMBE
MARTIN
WASHINGTON
TYRRELL
PITT
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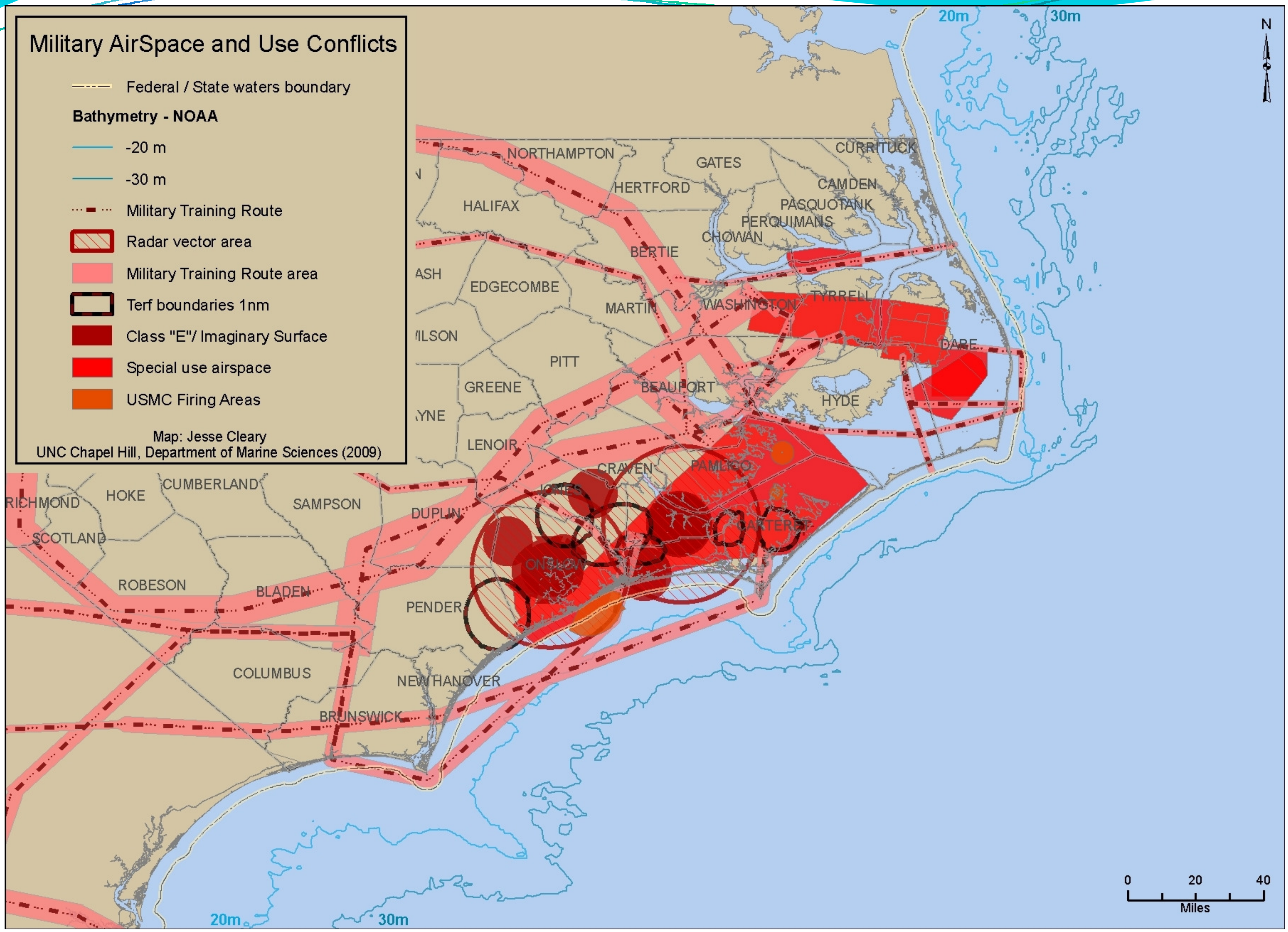
HYDE
LENOIR
CRAVEN
PAMLICO
JONES
CARTERET
ONSLOW
ROBESON
BLADEN
PENDER
COLUMBUS
NEW HANOVER
BRUNSWICK
20m
30m
N
0
20
40
Miles

Military Conflicts

- Special use airspace
- Training routes
- Radar vector areas
- USMC firing ranges


Military AirSpace and Use Conflicts
Federal / State waters boundary
Bathymetry - NOAA
-20 m
-30 m
Military Training Route
Radar vector area
Military Training Route area
Terf boundaries 1nm
Class "E"/ Imaginary Surface
Special use airspace
USMC Firing Areas
Map: Jesse Cleary
UNC Chapel Hill, Department of Marine Sciences (2009)
20m
30m
N
NORTHAMPTON
GATES
CURRITUCK
HERTFORD
CAMDEN
HALIFAX
PASQUOTANK
PERQUIMANS
CHOWAN
BERTIE
EDGECOMBE
TYRRELL
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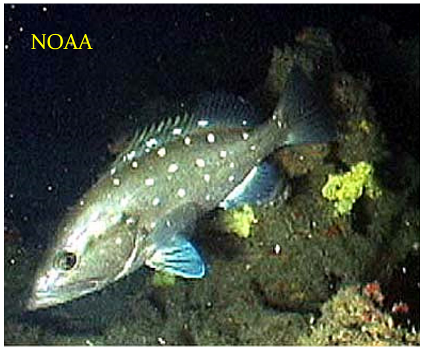
SCOTLAND
ONSLOW
CARTERET
ROBESON
BLADEN
PENDER
COLUMBUS
NEW HANOVER
BRUNSWICK
0
20
40
Miles

Synergies – Positive Interactions

- A stone scour apron surrounds the monopile base (12-m radius with stones rising 2-3 m above bottom)
  - Excellent foundation for artificial oyster reef in sounds
  - Excellent foundation for live-bottom reef in coastal ocean
- Wind farms may induce upwelling downstream
  - Could mitigate seasonal hypoxia and anoxia events in sounds
  - In the coastal ocean could enhance local primary production



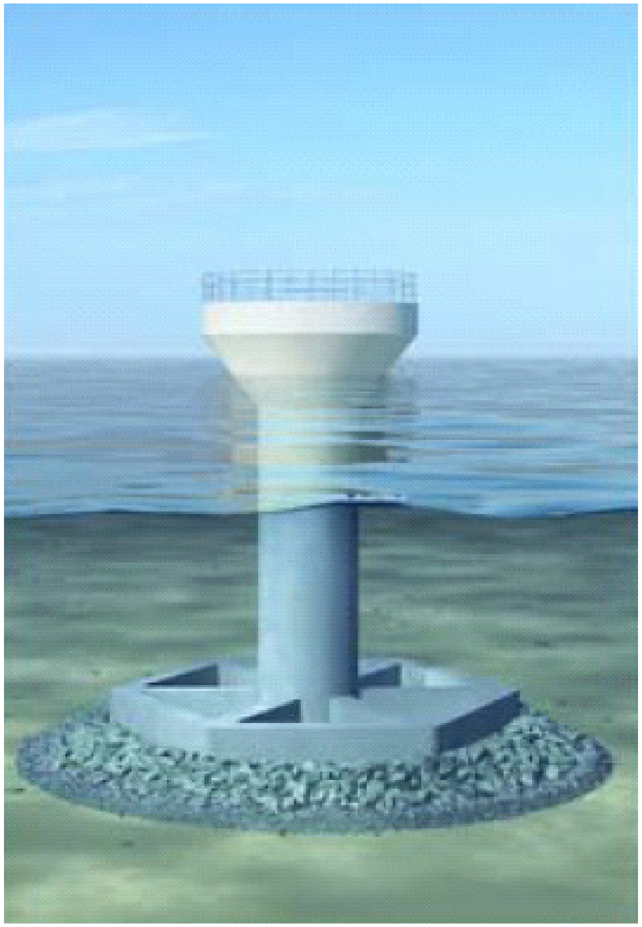
Foundation Concepts

J. Schuett (Affiliated Engineers, Chapel Hill)
S. Petersen (Ramboll Wind, Denmark)
K. Jensen, (Ramboll Wind, Denmark)

- Structural systems
- Appropriateness for sound and coastal ocean bottom geology

Foundation Alternatives

Monopile foundation with transition piece and scour protection. Flange height above sea level approximately 20 meters. 200-300
tons



Open gravity-based structure without ballast and at water depth of approximately 20 meters. The design shown includes an ice deflection cone. 2000-5000 tons

Foundation Alternatives

Installation vessels need at least 4 meters water depth

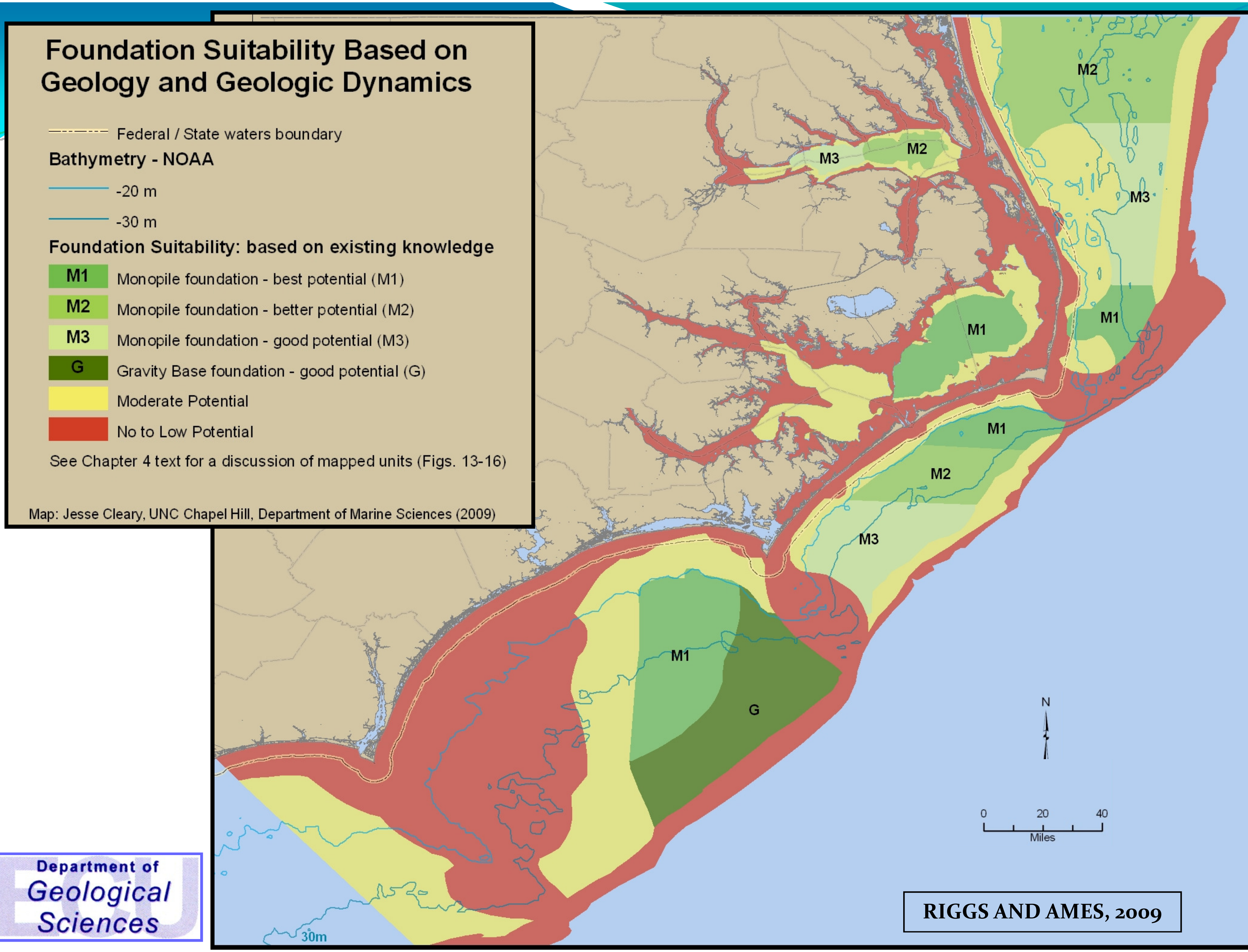
Geology

S. Riggs (Geological Sciences, East Carolina)

D. Ames (Geologic Sciences, East Carolina)

- Sound and ocean bottom geology
- Suitability for various types of wind turbine foundations

Foundation Suitability Based on Geology and Geologic Dynamics



Department of Geological Sciences

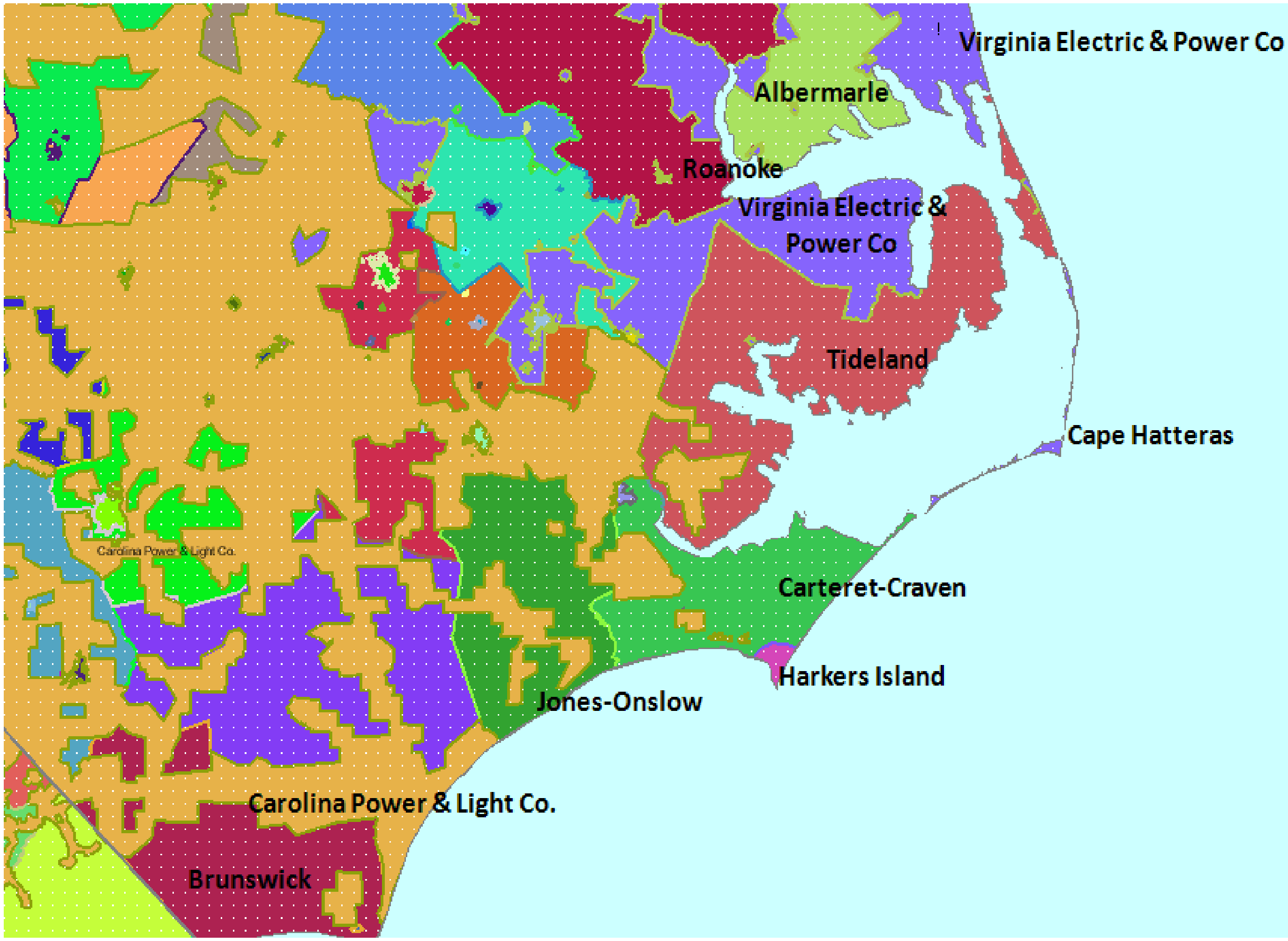
Utility Transmission Infrastructure

K. Higgins, Energy Strategies, Salt Lake City

Caitlin Collins, Energy Strategies, Salt Lake City

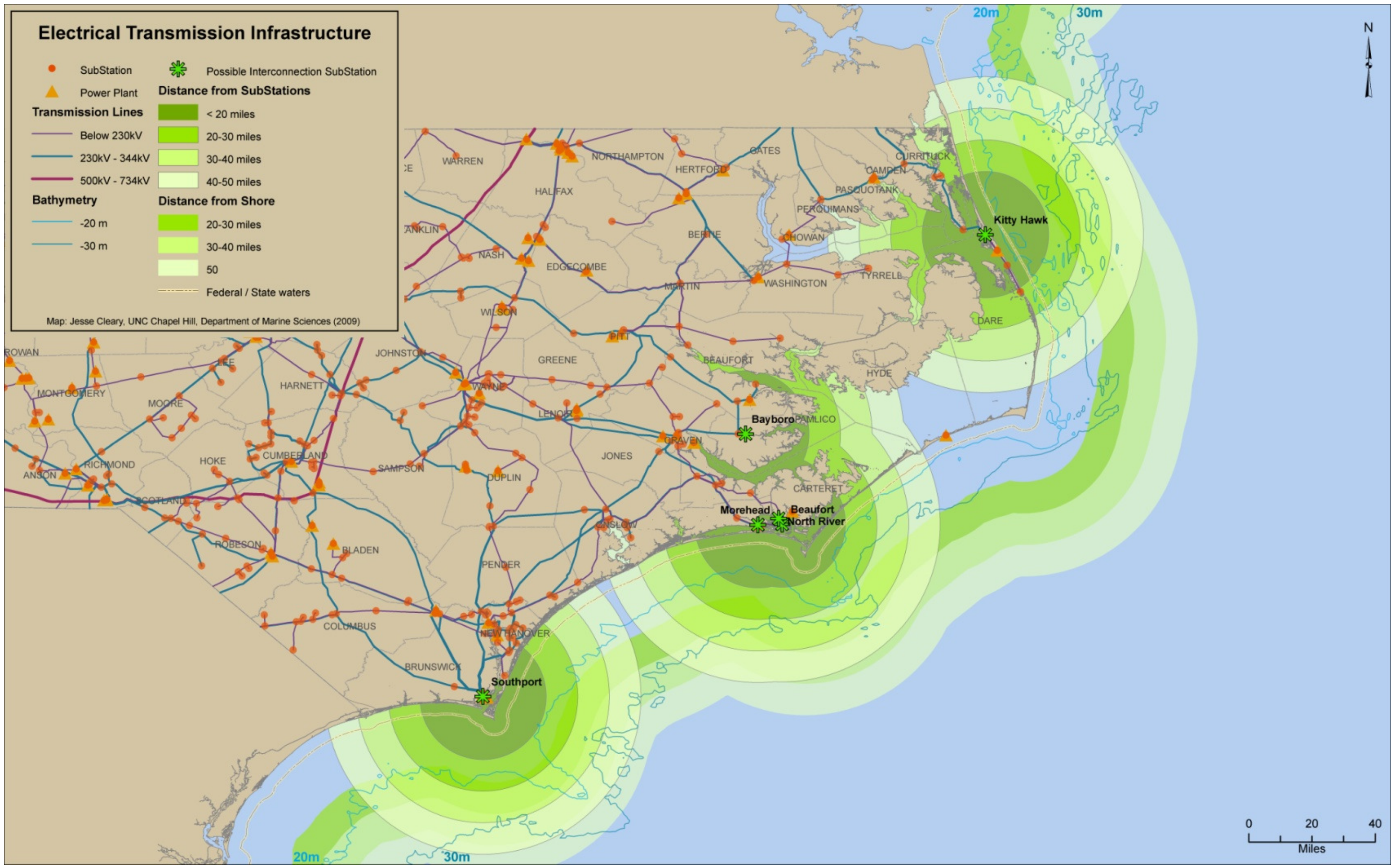
- Assessment of the transmission infrastructure along the coast of North Carolina
- Ability of transmission infrastructure to absorb large-scale offshore wind projects

Electric Services Territories



Source: Platts Energy Advantage

Transmission Lines and Substations



Synthesis

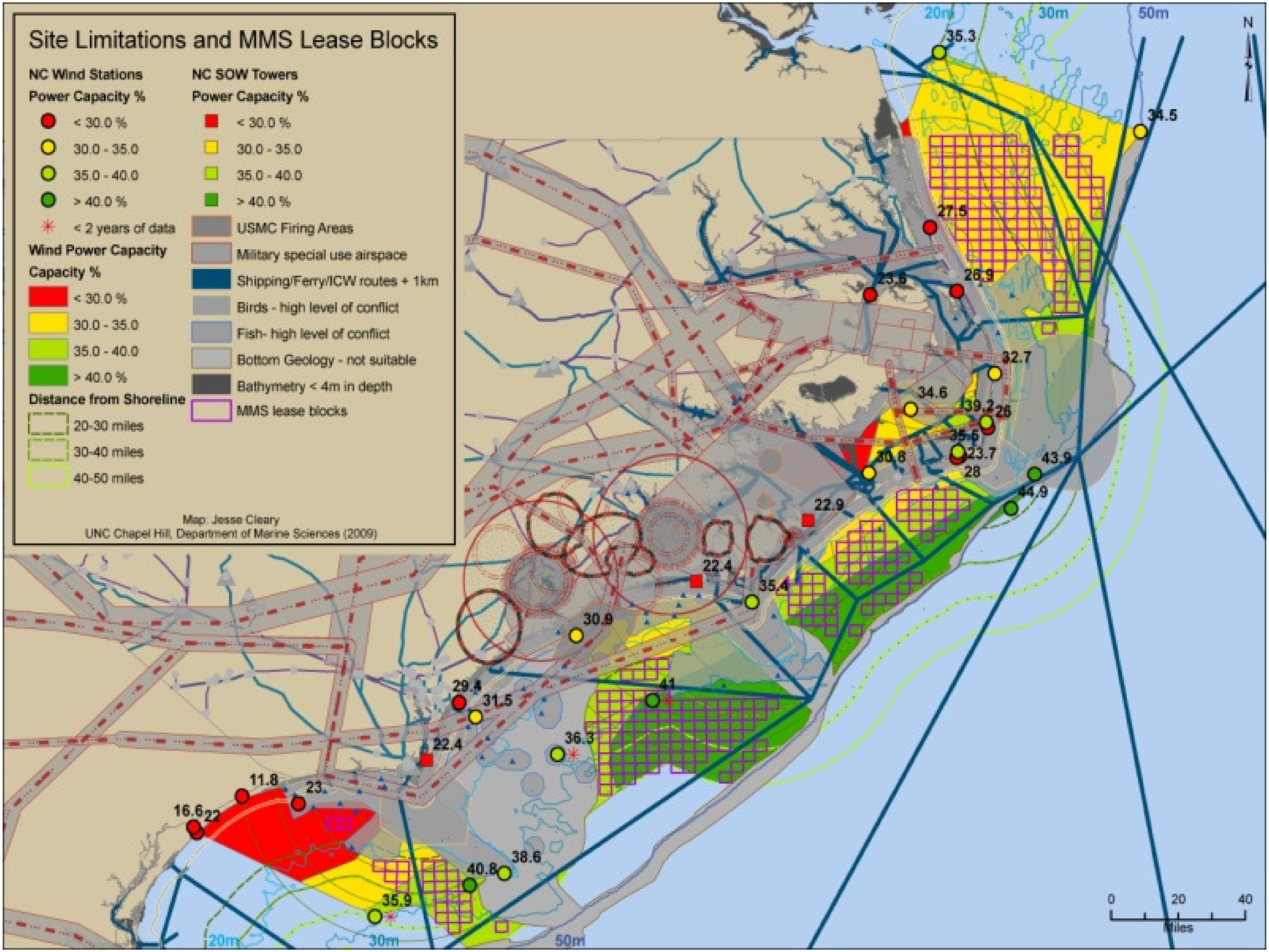
Methodology (Marine Spatial Planning)

- Information from the individual groups was integrated into a geographic information system
- Emphasis was placed on identifying severe constraints likely to preclude any wind energy development
- Areas identified as no-build (e.g. too shallow, reserved for use by the military) and areas identified as having high ecological impact or low suitability for foundation construction were eliminated
- Each constraint equally weighted and an equal degree of certainty as to their extents assumed
- Provides a conservative and introductory look at what areas remain viable for wind power development.

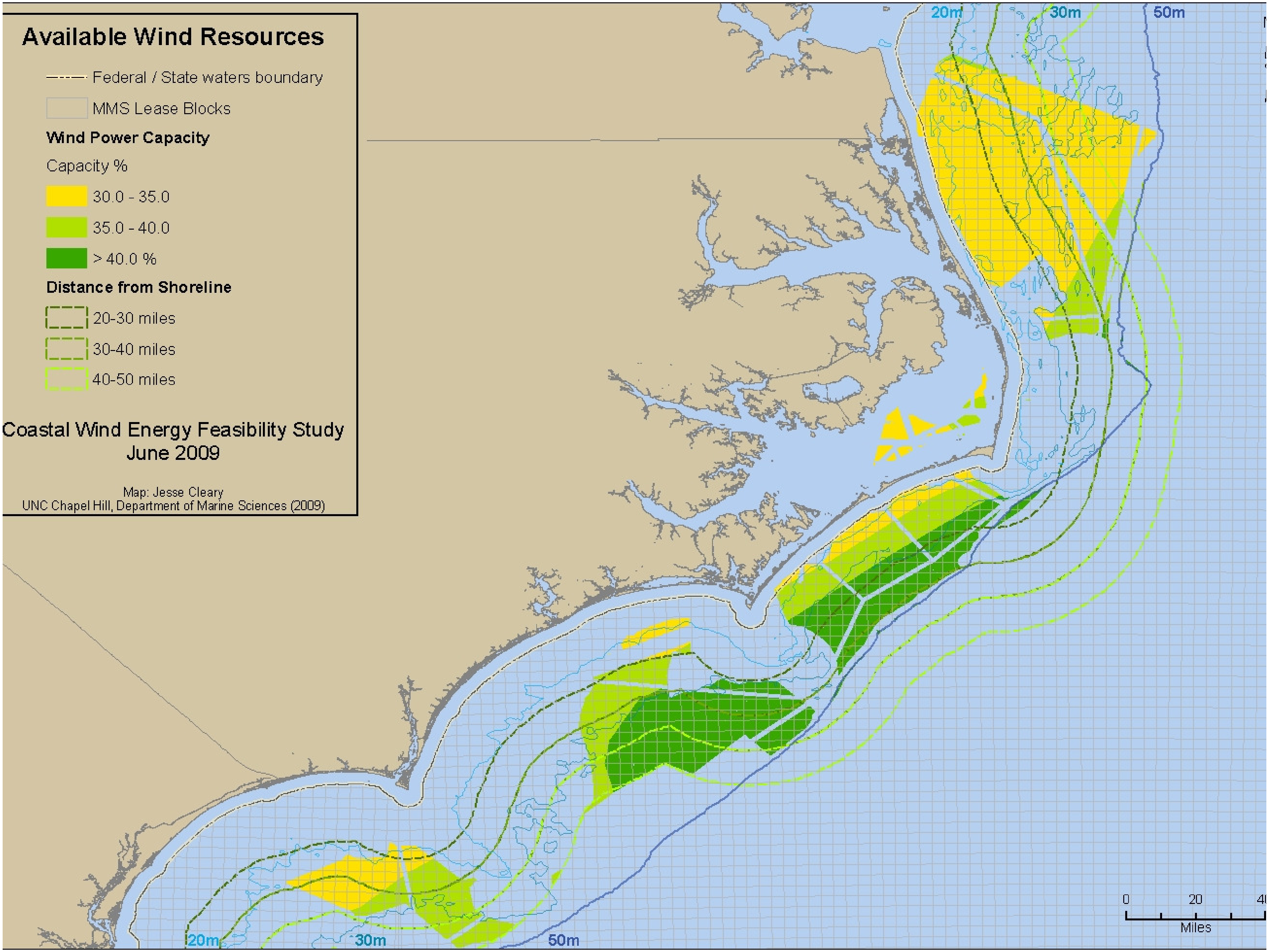
Synthesis

Results

- Limited portion of State waters, restricted to the eastern half of Pamlico Sound, appears feasible for further study
- Large areas offshore are potentially well-suited for wind energy development.



Site Limitations and MMS Lease Blocks
NC Wind Stations
Power Capacity %
< 30.0 %
30.0 - 35.0
35.0 - 40.0
> 40.0 %
< 2 years of data
NC SOW Towers
Power Capacity %
< 30.0 %
30.0 - 35.0
35.0 - 40.0
> 40.0 %
USMC Firing Areas
Military special use airspace
Shipping/Ferry/ICW routes + 1km
Birds - high level of conflict
Fish- high level of conflict
Bottom Geology - not suitable
Bathymetry < 4m in depth
MMS lease blocks
Wind Power Capacity
Capacity %
< 30.0 %
30.0 - 35.0
35.0 - 40.0
> 40.0 %
Distance from Shoreline
20-30 miles
30-40 miles
40-50 miles
Map: Jesse Cleary
UNC Chapel Hill, Department of Marine Sciences (2009)
20m
30m
50m
N
0
20
40
Miles


Available Wind Resources
Federal / State waters boundary
MMS Lease Blocks
Wind Power Capacity
Capacity %
30.0 - 35.0
35.0 - 40.0
> 40.0 %
Distance from Shoreline
20-30 miles
30-40 miles
40-50 miles
Coastal Wind Energy Feasibility Study
June 2009
Map: Jesse Cleary
UNC Chapel Hill, Department of Marine Sciences (2009)
20m
30m
50m
20m
30m
50m
0
20
Miles

Findings

Large areas offshore

- 2800 square miles (311 MMS lease blocks)
  - less than 50 m deep, within 50 miles of the coastline
  - Raleigh and Onslow Bay appear most promising
  - Over the shelf north of Cape Hatteras does not appear as favorable, but lack data
- If all developed, could support 55,000 MW nameplate capacity (average output 130% of total NC use in 2007)
- Developing 45 MMS blocks= 20% of total NC power demand in 2007

Benefits to North Carolina

National Renewable Energy Laboratory

20% of the nation's electricity from wind by 2030

- Economic benefit
- Environmental benefit

Economic Impact

10,440 MW New Offshore Development

Direct Impacts

Construction Phase
- 24,500 new jobs
- $2.9 B to local economies

Operational Phase
- 5,600 new long term jobs
- $535 M/yr to local economies

Indirect and Induced Impacts

Construction Phase
- 20,500 new jobs
- $1.9 billion to local economies

Operational Phase
- 3,500 local jobs
- $335 M/yr to local economies

Totals (construction + 20 years)

Total economic benefit = $22.2 billion

New local jobs during construction = 45,000

New local long-term jobs = 9,100

Construction Phase = 1-2 years
Operational Phase = 20+ years

NREL Wind Powering America , Year 2030

Environmental Impact

10,440 MW New Offshore Development

Cumulative Impact through 2030

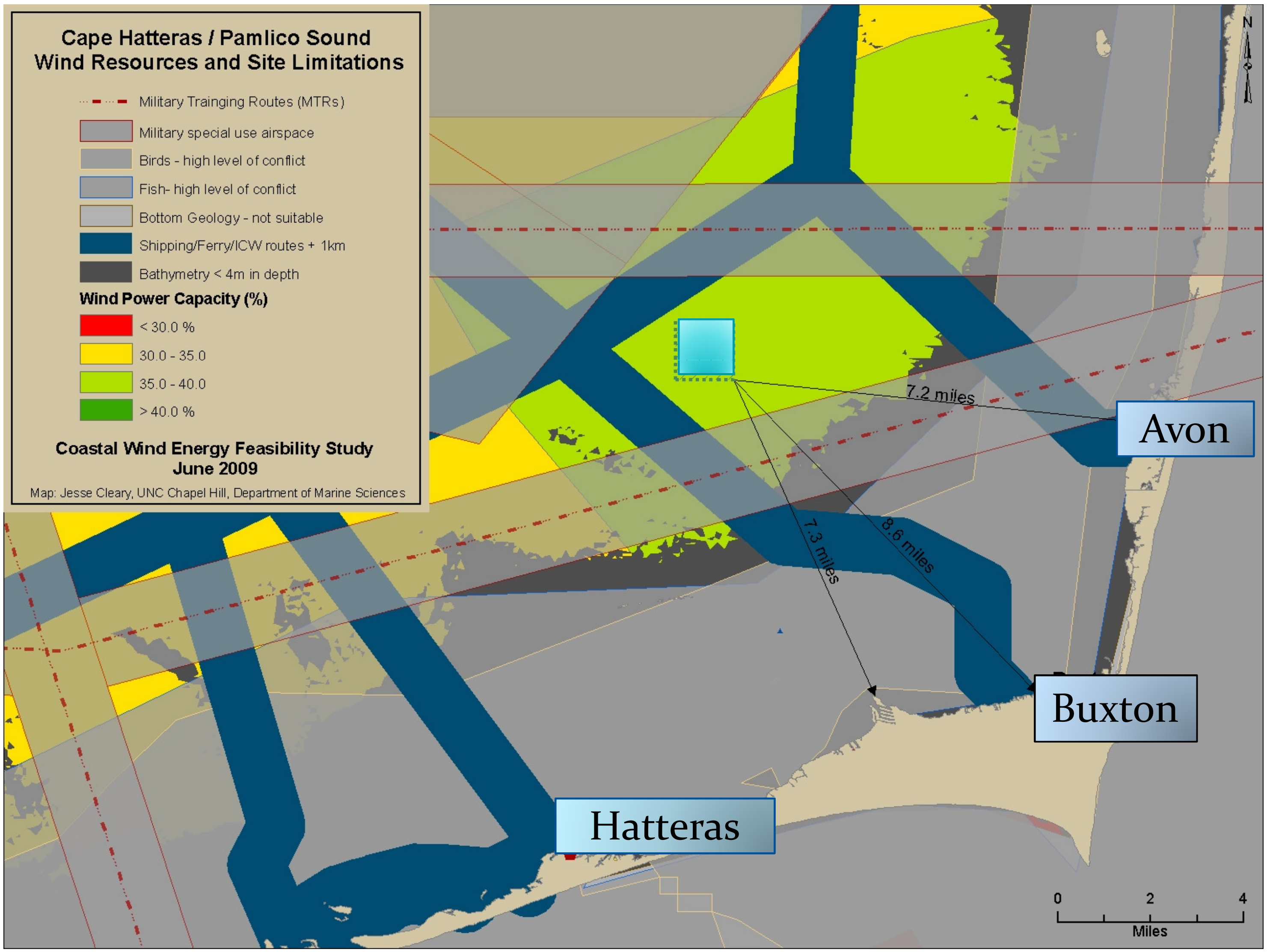
Water Savings	Carbon Savings
74.7 billion gallons	135 million tons

NREL Wind Powering America , Year 2030

Strategic Direction

- Support additional wind research
- Support additional utility transmission research
- Establish state policy toward utility-scale wind farm development
- Leverage the expertise of the public universities
- Develop demonstration turbines
  - No water-based wind turbine pilot projects ongoing in the US at this time
  - Area in the Pamlico Sound identified as potentially suitable

Possible Turbine Demonstration Site



In Eastern Pamlico Sound

3 square mile area to host 1-3 turbines

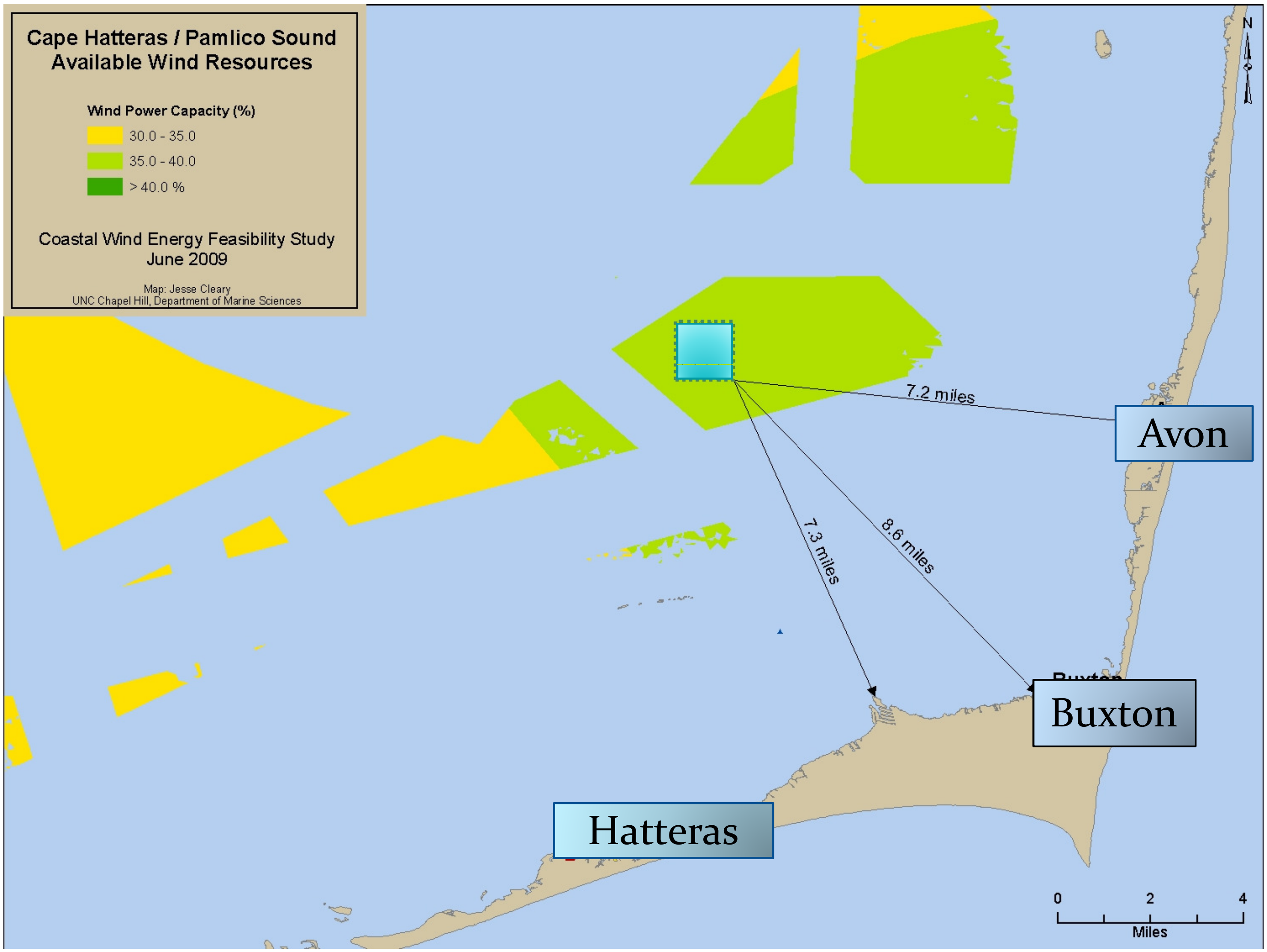
16-20 ft deep

7-10 miles from Outer Banks

Each 3.6 MW turbine will power about 1000 homes

Each turbine will cost $12-15 million (installed)

Possible Turbine Demonstration Site



In Eastern Pamlico Sound

3 square mile area to host 1-3 turbines

16-20 ft deep

7-10 miles from Outer Banks

Each 3.6 MW turbine will power about 1000 homes

Each turbine will cost $12-15 million (installed)

Photo simulation of wind farms
6.8 miles SE of Tybee Island, GA


Photo simulation of wind farms
10.4 miles SE of Tybee Island, GA

Example Pilot Study Topics

- Study actual mortality of birds and bats in the presence of the turbines, test mitigation strategies
- Measure power generation capacity and the influence of varying winds, wind shear and turbulence on it
- Ability of the turbines to withstand storm-force winds
- Enhancement of oyster and mussel growth and water quality from the turbine foundations
- Study of visual impacts and their acceptability, especially National Park Service visitors and local Outer Banks residents

Questions