VESSEL TRAFFIC-MANAGEMENT SCENARIOS BASED ON RECOMMENDED MEASURES TO REDUCE SHIP STRIKES OF NORTHERN RIGHT WHALES

A report submitted to the NMFS Northeast Implementation Team

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Executive Summary

The National Marine Fisheries Service (NMFS) developed a strategy to reduce ship strikes of northern right whales right along the U.S. East Coast from Maine to Florida. We examined the impact on vessels to comply with proposed vessel operating restrictions calling at major ports. The basis for the proposed operating restrictions are in the report, *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales,* 23 August 2001 (Russell & Knowlton, *et al*). The authors had collaborated earlier with researchers at the Woods Hole Oceanographic Institution's Marine Policy Center who conducted an analysis, *Economic Aspects of Right Whale Ship Management Measures, March 2002* (Kite-Powell and Hoagland) and developed preliminary vessel traffic management scenarios based on the management measures recommended in our report. Subsequent to the publication of the Russell and Knowlton report and the Kite-Powell and Hoagland economic assessment, it became clear that the preliminary vessel traffic-management scenarios used in the economic assessment do not adequately reflect or describe the impact the recommended measures would have on shipping.

This report lays out analytical approaches for providing solid estimates for the impacts measured in additional time it would take for vessels to comply with proposed vessel operating restrictions. In this paper we examine how vessels slow down and speed back up prior to entering a seasonally or dynamically managed area. We examine how vessels enter port to embark a pilot. We then model how much net additional time a vessel would take to transit through a seasonally or dynamically managed area to account for how a vessel currently operates and would operate under speed and /or routing restrictions. We retrospectively applied a sighting trigger to impose a dynamic management area (DMA) when right whales were sighted in high concentrations to compute an annualized expected duration (number of days) and annual average number of vessel miles per DMA for which operating restrictions would have been in force had measures been in place. We reviewed the geographic extent and duration of all proposed SMAs on the basis of our recent work, *Right Whale Sightings and Survey Effort in the Mid Atlantic Region: Migratory Corridor, Time Frame, and Proximity to Port Entrances* (Knowlton, Beaudin Ring, and Russell, 2002), and *GIS Presentation of Survey Tracklines, Right Whale Sightings and Right Whale Movements: 1978-2000, (*Knowlton, Beaudin Ring, Kenney, and Russell, 2002). Finally, we examined the impact of restrictions in Cape Cod Bay and Massachusetts Bay on vessels using Cape Cod Canal, but not calling Boston or Gulf of Maine ports. The summary of findings is presented in tabular format by geographic area, as most areas could be impacted by more than one operating restriction.

Major findings:

- In proposed seasonal management areas from the port of New York and New Jersey south to and including the port of Jacksonville Florida, preliminary estimates over-estimated the impact of speed restrictions on a single voyage by as much as 10%-93%. This was a function of the severity of the proposed measure, the port, and type of vessel. For example, for a large container ship calling at the port of Jacksonville, FL under the most restrictive speed restriction measures, we found that our revised estimates are 26% lower; for the least restrictive measures our revised estimates are 18% lower.

- In our review of mid Atlantic migratory corridor data, we found that our original rough estimates of a 60-day annual duration are probably low; our revised estimates range from 84-210 days, 40%-250% longer, depending on the port. .

- We studied all available right whale sighting data and retrospectively applied the dynamic management trigger mechanism. We believe that for the most part, where possible, most masters would choose to route around most dynamic management areas. For a large container vessel regularly calling Boston via the Great South Channel traveling at 20 knots, our revised estimates are 17% lower than our original estimates based on a 12-knot speed restriction. The revised estimates for DMAs are substantially lower for all other port entrances

Background

Potential management options to reduce the risk of vessel collisions with right whales, including international and domestic regulations, which would restrict vessel operations through speed restrictions, ship routing and other measures, have been framed by the National Marine Fisheries Service's Ship Strike Committee. Through a series of meetings with the shipping industry, conservation groups, maritime operating agencies, natural resource management agencies, and scientific and technical advisors of the Northeast and Southeast Implementation Teams (for the recovery of right whales and humpback whales), the ship strike committee developed a report, *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales*, 23 August 2001 (Russell & Knowlton, *et al*). [This report is posted on the Internet at http://www.nero.nmfs.gov/whaletrp/.] We understand that the National Marine Fisheries Service (NMFS) reviewed this report and developed a strategy that proposes vessel-operating restrictions similar to those proposed in this report.[1]

These operating restrictions would apply to all vessels operating in high-risk areas along the U.S. east coast from Port Canaveral, Florida to and including Savannah, Georgia, to Charleston, South Carolina, North Carolina ports, the entrances to Chesapeake and Delaware Bays, the NY, NJ approaches, Block Island Sound, the Great South Channel, Cape Cod Bay, and the Gulf of Maine to the Bay of Fundy. There are two types of management areas that are proposed along the eastern seaboard – Seasonal Management Areas (SMA) and Dynamic Management Areas (DMA). SMAs are those areas where management measures would be imposed over a pre-defined timeframe and geographic area that are based on the best historical information about right whale movements and distribution. DMAs are those areas where measures would be imposed based on the identified presence (via visual or acoustic surveillance) of a minimum number of animals within that area.

The risk reduction measures outlined in the Russell and Knowlton report would cause economic impacts on the regulated industries that ultimately extend down the supply chain to consumers. It is therefore important for regulators to understand the complexity of the shipping industry and to consider the potential economic impact before implementing management options. To this

[1] Kathy Wang, NMFS Southeast Region at the May 2003 Southeast Implementation Team meeting, and Pat Gerrior, NMFS Northeast Region at the June 2003 Northeast Implementation Team meeting.

end researchers at the Woods Hole Oceanographic Institution's Marine Policy Center conducted an analysis, *Economic Aspects of Right Whale Ship Management Measures, March 2002* (Kite-Powell and Hoagland), based on the recommendations in the Russell and Knowlton report.

An important part of the "Framework" for economic analysis conducted by Kite-Powell and Hoagland was premised on vessel "Traffic-Management Scenarios" developed in consultation with Bruce Russell. These scenarios were used to determine how much additional time the recommended vessel operating restrictions would add to a vessel's transit through a high-risk area. In turn, the economic models developed by Kite-Powell and Hoagland compute compliance costs as a function of, among other factors, vessel category or type and associated published vessel operating rates.

Subsequent to the publication of the Russell and Knowlton report and the Kite-Powell and Hoagland economic assessment, it became clear that these preliminary vessel traffic-management scenarios do not adequately reflect or describe the impact the recommended measures would have on shipping. In our meetings and other discussions with the shipping industry we learned more about how vessels operate. For example, many vessels take as long as one hour to slow from "sea speed" to "maneuvering speed", which we did not directly factor into the vessel traffic management scenarios we provided Drs. Kite-Powell and Hoagland for their analysis. We also did not account for vessels slowing to embark a pilot prior to entering port. Our estimates on the geographic extent and duration of many of the management errors were not based on comprehensive analyses of the data. Those of us who are close to this work understood that the traffic management scenarios were preliminary and that they would be used by Drs. Kite-Powell and Hoagland to assist NMFS and the shipping industry in developing a sense of the magnitude of the impacts of the proposed measures on shipping. The following is a summary of the problems in our preliminary estimates that we address in this paper:

1a) We originally assumed that a vessel entering an area could slow immediately to the prescribed speed restriction when entering both seasonal management areas (SMAs) as well as dynamic management areas (DMAs). Feedback for the shipping industry advised that most vessels take as many as 60 minutes to decelerate from sea speed to maneuvering speed and as many as 60 minutes to accelerate back up to sea speed. This assumption results in an underestimation of costs as vessels would have to start slowing down well before they reach the management area.

1b) We also originally assumed that when entering port, a vessel in the absence of proposed speed restrictions did not reduce speed (or speed up on an outbound transit) until it crossed the harbor baseline or closing line. This assumption results in an over estimation of costs as many vessels requiring state pilotage must reduce speed to embark/debark a pilot at speeds ranging from 6-10 knots anywhere from 3-12 or so miles offshore, and then do not return to sea speed when approaching shore. These two assumptions offset to a certain degree but should be factored in all SMAs (approaches to Boston off Race Point, all mid Atlantic ports, and the Southeast U.S. ports within the critical habitat).

2) Specific SMAs in the approaches to the ports of Georgetown, South Carolina and Morehead City, North Carolina were not recommended in the Russell and Knowlton report and

consequently in the Kite-Powell and Hoagland report. This was an oversight. Both ports work significant deep draft trade, and are now included in our analyses for mid Atlantic ports.

3) The geographic extent of proposed SMAs in the mid Atlantic originally assumed that the radial extent would be from 20-30 nautical miles offshore. This was based on a preliminary analysis of data available at that time. This information has been further refined based on a more thorough analysis of mid Atlantic data.

4) In the mid Atlantic region, the scenarios used by Kite-Powell and Hoagland for each port were 60 days per year. This was based on our preliminary examination of only a small portion of the historical data. (All historical data were not available at the time of our initial analyses). This information has been further refined based on a more thorough analysis of mid Atlantic data.

5) The geographic extent of the SMA off Race Point, MA assumed 30 nautical miles along the Boston approach sea-lane. This was based on our original estimates of 25-40 nautical miles. This information has been further refined based on a more thorough analysis of Cape Cod Bay to Great South Channel movement data.

6) All estimates for DMA scenarios for Block Island Sound, the Great South Channel, and the Gulf of Maine were based on our deliberate over estimates of the extreme imposition of DMA measures based on the trigger mechanism defined in the Russell and Knowlton report; no comprehensive retrospective analysis of historical data was conducted. This report provides a retrospective analysis of the data to determine when and where DMAs would have been imposed if measures had been in place.

7) The preliminary scenarios did not specifically consider DMAs in the approaches to the ports of New York and New Jersey. Recent sightings suggest that right whales may take up residence (i.e. forage and feed) in this area. We do know that aggregations of right whales have on occasion been sighted in the NY/NJ approaches, but there is not enough data available to pose any recommendations.

8) Information provided by the Northeast Pilots (personal communication, Pat Gerrior, NMFS) indicate that there are deep draft vessels using the Cape Cod Canal that would be affected by the proposed SMA (regulated navigation area (area to be avoided)) on the east side of Cape Cod Bay, and the proposed SMA in the Boston sea lane approaches off Race Point. The potential impacts are discussed.

9) Our original traffic-management scenarios for the ports within the Southeast US critical habitats (Brunswick, GA, Fernandina Beach, and Jacksonville, FL) did not address the potential for vessel routing options. At this writing, none of the analyses on the potential for vessel routing options (Hauke Kite-Powell, Woods Hole Oceanographic Institution and Lance Garrison, NMFS Southeast Science Center) are complete. Also not complete at this writing are Lance Garrison's research on the time, duration, and seaward extent of the SMA for the Southeast U.S. Therefore, our findings for this region are limited to speed restrictions. Recommended traffic-management scenarios for the time, duration and geographic extent would remain unchanged.

With guidance from Dr. Kite-Powell, we input several of our revised scenarios into the economic models to examine the consequences of the revised scenarios on the economic aspects of the recommended measures. Fortunately, the models are quite simple with respect to the importance of the parameters of the vessel traffic-management scenarios; though it did take some "tinkering" to factor the net additional transit time. The two factors input to the model, net additional transit time and annualized duration of the measures, each have one to one impacts on the economic costs predicted by the economic models. For example, a doubling of net additional transit time, or the doubling the annualized duration (annualized time frame, e.g., 60 days per year) would double the costs. Doubling the net additional transit time, and halving the duration would wash. Doubling each would quadruple the net costs. The net additional transit time is a function of: the proposed speed restriction; a vessel's sea speed; the time it takes for a vessel to decelerate from sea speed to maneuvering speed (and conversely to accelerate back to sea speed) for SMAs in port approaches; the size of the SMA; and the location of the pilot buoy. This last factor, the location of the pilot buoy, accounts for the requirement that most large vessels must already slow when coming into port to embark a mandated pilot.

We had originally thought we would input the revised scenario information into the economic model and present our findings. Rather, we only present our scenarios and compare/contrast these with those used in the Kite-Powell and Hoagland study. To actually input the net additional transit time would require modification to the economic model, which is best left to the authors of that study.

Analytical Approach and Results

1. Application of Speed Restrictions

a) Accounting for vessels' need to take as much as one hour to slow from sea speed to maneuvering speed before entering a right whale management area.

Analytical Approach

We originally assumed that a vessel could slow immediately to the prescribed speed restriction when entering seasonal management areas (SMA) as well as dynamic management areas (DMA)[2]. Feedback from the shipping industry advised that most vessels take as many as 60 minutes to decelerate from sea speed to maneuvering speed and as many as 60 minutes to accelerate back up to sea speed. For the purposes of this analysis we are assuming proposed speed restrictions of 10, 12 and 13 knots; these proposed speed restrictions are within the range of maneuvering speed for many of the large commercial vessels transiting right whale waters.

Accounting for a vessel's net time, $\Delta T_{VS\text{-}RS}$, to slow from sea speed to maneuvering speed is quite simple. We must first determine the distance, *RD,* over which a vessel travels to reduce speed from sea speed to maneuvering speed, and then determine the time, $T_{VS,}$ it would take a vessel to travel this distance without having to reduce speed. Note that *MS* is the mean or average speed

[2] We made this assumption understanding that most vessels must slow to take on a pilot and that this would in part offset this additional time. We also deliberately over-estimated the annual duration and average size of DMAs.

over one hour that a vessel makes when reducing speed from sea speed, *VS,* to the proposed speed restriction, *RS:* $MS = (VS + RS) \div 2$.

Variables defined:

VS is the vessel's sea speed.
RS is the proposed speed restriction.
$\Delta T_{VS\text{-}RS}$ is a vessel's net time, to slow from sea speed to maneuvering speed.
RD is the distance, over which a vessel travels to reduce speed from sea speed to maneuvering speed.
D_{DMA} is the radius of the Dynamic Management area.
T_{VS} is the time it would take a vessel to travel this distance without reducing speed.
T_{MS} is the time to slow from sea speed to maneuvering speed.
MS is the mean or average speed over one hour that a vessel makes when reducing sea speed, *VS* from to the proposed speed restriction, *RS.*

$RD = MS \times T_{MS}$

Where, $T_{MS} =$ Time to slow from sea speed to maneuvering speed: assume 1 hour.

$T_{VS} = RD \div VS$

$\Delta T_{VS\text{-}RS} = T_{MS} - T_{VS}$

For example:

If, VS = 20 knots and *RS* = 12 knots,

then, *MS* = 16 knots, and *RD* = 16 nm,

then, $\Delta T_{VS\text{-}RS} = 1hour - (16nm \div 20knots) = .2$ *hours or 12 minutes*[3].

Therefore, a vessel traveling at a sea speed, *VS*, of 20 knots would need to voyage plan for an additional 12 minutes to reduce speed from sea speed to a proposed speed restriction, *RS*, of 12 knots, and 12 minutes to accelerate back to sea speed, absent any other factors. Other factors might include: vessels in bound to a port do not accelerate back to sea speed. Most large commercial vessels inbound to a port must take on a pilot and therefore must reduce speed to take on a pilot. This time would be added to the time needed to transit at reduced speed through the SMA or DMA.

Results

As shown in Table 1, the time necessary to account for a vessel to slow from sea speed to maneuvering speed ranges from: no additional time (tug/barge) to 14 minutes (large container ship or large cruise ship) at a proposed speed restriction of 13 knots; and, to as much as 5

[3] 1 knot equals 1 nautical mile per hour, and 1 nautical mile is 2000 yards.

minutes (tug/barge) to 18 minutes (large container ship or large cruise ship) at a proposed speed restriction of 10 knots. This affects dynamic and seasonal management areas as follows.

Dynamic management: The net additional time necessary to transit a DMA would be the time it would take the vessel to transit the DMA with speed restrictions minus the time it would take the vessel to transit the DMA without speed restrictions, plus 2 times the additional transit time, ΔT_{VS-RS}, for both entering and departing the DMA to return to sea speed: $\Delta T_{NET} = (D_{DMA} \div RS)-(D_{DMA} \div VS)) + ((\Delta T_{VS-RS}) \times 2)$. Note: Masters would assess the total additional time when considering whether it is possible to route around a DMA versus steam at a reduced speed through the DMA. Our recommended vessel traffic-management scenarios do not account for a master choosing to route around versus steam slowly through a DMA. Our recommended vessel traffic-management scenarios also assume that a vessel would be transiting the full diameter of the DMA.

For a vessel entering a proposed SMA within the mid Atlantic region and Southeast U.S. critical habitat, the additional transit time, ΔT_{VS-RS}, for entering and later when departing would be added to the additional time a vessel would take to transit the SMA at the proposed restricted speed. For vessels cutting across any proposed SMA, (e.g., coastwise traffic not calling at a port with an SMA in-force), additional transit time, ΔT_{VS-RS}, would be added for both entering and departing the SMA (i.e., additional transit time x 2). Note: Masters would assess the total additional time when considering whether it is more cost effective to route around an SMA, versus steam at a reduced speed through a SMA. Our recommended vessel traffic-management scenarios do not account for a master to route around versus steam slowly across an SMA.

For a vessel transiting through the proposed SMA around the Boston approach sea-lanes off Race Point, additional consideration of how vessels transit this area is necessary. For vessels enroute Boston sailing from the east, the additional transit time, ΔT_{VS-RS}, to enter the SMA and later depart Boston and exit the SMA would be added to the additional time a vessel would take to transit the SMA at the proposed speed restriction. Because the western edge of the SMA is within the immediate approaches to the area where vessels take on a pilot, inbound vessels would not return to sea speed. Also, outbound vessels would not increase speed to sea speed until they clear the SMA. For vessels transiting across the SMA (northerly or southerly), for example coming from or going to the Cape Cod Canal, additional transit time ΔT_{VS-RS}, would be added for both entering and departing the SMA (i.e., additional transit time x 2). We expect that these vessels would route around this SMA, that is to the west of the SMA, before heading north and east.

Table 1

Vessel Type or Category	Average Vessel Speed, knots	Additional Transit Time, ΔT_{VS-RS}, in minutes, for a vessel to slow from sea speed to maneuvering speed		
		10 Knot speed restriction	12 Knot speed restriction	13 Knot speed restriction
Dry bulk---- handy	14	9	4	2
handymax	14	9	4	2
Panamax	14.5	9	5	3
Cape	14.5	9	5	3
tanker--product	14	9	4	2
Aframax	15	10	6	4
Suezmax	14.5	9	5	3
VLCC				
Containership-- 1000TEU	15	10	6	4
1500TEU	15	10	6	4
2000TEU	24	18	15	14
3000TEU	24	18	15	14
4000TEU	24	18	15	14
LNG	20	15	12	11
Car Carrier	16	11	8	6
Cruise ship	25	18	16	14
tug/barge--freight	12	5	0	0
--tank	12	5	0	0

Table 1 shows the average sea speed for various vessel types calling at US East Coast Ports (Kite-Powell and Hoagland, March 2002); and the additional transit time, ΔT_{VS-RS}, as a function of proposed speed restrictions, for vessels to slow from sea speed to maneuvering speed. A vessel departing a DMA would also incur this additional time when departing the DMA. For most ports only a subset of this vessel types call.

b) **Accounting for the requirement for vessels to take on a pilot when entering port: mid Atlantic ports and ports within the Southeast U.S. critical habitat**

Analytical Approach

We also originally assumed that when entering port, vessels, in the absence of proposed speed restrictions, do not reduce speed (or speed up on an outbound transit) until they cross the harbor at the baseline or closure line. This assumption results in an over estimation of costs as many vessels that require pilotage must reduce speed to embark/debark a state or federal pilot at speeds ranging 6-10 knots anywhere from 3-12 or so miles offshore. This location is often referred to as the "pilot buoy." These vessels then do not return to sea speed when entering, but likely to a speed of at most, between 10-12 knots. By and large, only tug/barges, large recreational vessels, and vessels engaged in U.S. and coastwise commerce, do not take on a state or federal pilot. *Note that, in our calculations and traffic-management scenarios, we assume that proposed speed restrictions would only impact vessels from the outer limit of the SMA to the pilot buoy.*

Vessels entering Block Island Sound from the south would take on a pilot after transiting the proposed SMA; therefore there is no need to account for this requirement in these calculations.

Calculating the amount of time it takes a vessel to slow to embark the pilot is a simple calculation; the time ΔT_{PB}, is a function of the vessel speed at the pilot buoy, VS_{PB}, and the sea speed of the vessel, VS. However this is only part of the equation to determine the net additional time, ΔT_{NET}, it would take for a vessel to comply with the speed restriction, RS. There are several variables that make this calculation more difficult:

- The location of the pilot buoys varies from port to port, as does the speed at which vessels must slow to embark the pilot.
- The speed at the pilot buoy, VS_{PB}, (see Table 2), is less than proposed speed restrictions, RS.
- Most importantly, the location of the pilot buoy, PD, which varies from port to port, relative to the outer limit of the proposed seasonal management area, D_{SMA} (see Table 2), impacts where vessels would currently begin slowing from sea speed to maneuvering speed.

To determine the additional time, ΔT_{NET}, it would take for a vessel to comply with the speed restriction, RS, we must first determine the time it would take a vessel to enter port with speed restrictions, ΔT_{RS}, which includes accounting for the vessel slowing to take on a pilot. This equals the time, $\Delta T_{VS\text{-}RS}$, for a vessel to slow from sea speed to maneuvering speed, plus the time, T_{RS}, it takes for a vessel to travel at the proposed speed restriction from the outer limit of the SMA to the location, D'_{PB}, at which the vessel must begin slowing to take on the pilot, plus one hour to slow from the speed restriction, RS to the speed at the pilot buoy, VS_{PB}. In some scenarios the value T_{RS} is by definition zero; this occurs when the location, D'_{PB}, at which a vessel needs to start slowing to take on the pilot is beyond the outer limit, D_{SMA}, of the seasonal management area, and the vessel is already within the range of maneuvering speed.

Variables defined:

VS is the vessel's sea speed.
$VS_{PB,}$ is the vessel speed at the pilot buoy.
RS is the proposed speed restriction.
MS is the mean or average speed over one hour that a vessel makes when reducing from sea speed, VS to the proposed speed restriction, RS.
RD is the distance over which a vessel travels to reduce speed from sea speed to maneuvering speed.
PD is the distance from the harbor entrance to the pilot buoy,
D_{SMA} is the outer limit of the seasonal management area, SMA.
D'_{PB} is the distance from the outer limit of the SMA to the location at which the vessel must begin slowing to take on the pilot.
$\Delta T_{VS\text{-}RS}$ is a vessel's net time to slow from sea speed to maneuvering speed.
T_{VS} is the time it would take a vessel to travel this distance without having to reduce speed.
T_{MS} is the time to slow from sea speed to maneuvering speed.
ΔT_{PB} is the additional time it takes a vessel to slow to embark the pilot.
ΔT_{NET} is the additional time it would take for a vessel to comply with the speed restriction, RS.
ΔT_{RS} is the additional time it takes for a vessel to travel at the proposed speed restriction from the outer limit of the SMA to the location, $D'_{PB},$ at which the vessel must begin slowing to take on the pilot.
$T_{W/O}$ is the time it takes for a vessel to enter port without speed restrictions.
T'_{VS} is the time it takes for a vessel to travel from the outer limit of the SMA without a speed restriction to the location at which the vessel must begin slowing to take on the pilot.

$\Delta T_{NET} = \Delta T_{RS} - T_{W/O}$

$\Delta T_{RS} = \Delta T_{VS\text{-}RS} + T_{RS}$ + 1 hour

- Where $T_{RS} = (D_{SMA} - D'_{PB}) \div RS;$ $IF\ D'_{PB} > D_{SMA}$, then T_{RS} = ZERO
- Where $D'_{PB} = PD + ((RS + VS_{PB}) \div 2)$

Second, in order to determine the time, $T_{W/O}$, it takes for a vessel to enter port without speed restrictions, we must determine the time, $T'_{VS,}$ it takes for a vessel to travel from the outer limit of the SMA without a speed restriction to the location at which the vessel must begin slowing to take on the pilot; and then add to this the time, T_{MS} (always one hour), it takes for a vessel to reduce speed to take on the pilot at the pilot buoy, PD. This must be determined for two reasons. First the distance, D_{PB}, over which the vessel is currently traveling to reduce speed to take on the pilot, would overlap all or part of the distance, RD, over which the vessel travels to reduce speed to enter the SMA. And second, the distance, D_{PB}, may also overlap all or part of the distance, D_{SMA}, over which the speed restriction applies, that is, from the outer limit of the SMA to the pilot buoy. For reasons similar to the computation for a vessel with speed restrictions discussed above, in some scenarios the value T'_{VS} is by definition zero; this occurs when the location, $D_{PB,}$

at which a vessel needs to start slowing to take on the pilot is beyond the outer limit, D_{SMA}, of the SMA, and the vessel is already within the range of maneuvering speed.

$T_{W/O} = T'_{VS} + T_{MS}$

- *Where* $T'_{VS} = (D_{SMA} - D_{PB}) \div VS$; *IF* $D_{PB} > D_{SMA}$, then T'_{VS} = ZERO
- Where $D_{PB} = (PD + (VS + VS_{PB}) \div 2) * T_{MS}$.
- Where, T_{MS} equals the time to slow from sea speed to maneuvering speed: assume 1 hour.

In summary:

$\Delta T_{NET} = \Delta T_{RS} - T_{W/O}$

$\Delta T_{RS} = \Delta T_{VS\text{-}RS} + T_{RS}$ + 1 hour
$T_{W/O} = T'_{VS} +$ 1 hour

Shown in the third column of Table 2 is the maneuvering speed, VS_{PB}, which regional pilot's associations ask that vessels maintain for boarding a pilot. (Source: U.S. Coast Pilots 2, 3, and 4 and communications with regional pilots' associations). Note that some pilots associations do not specify a speed. It is generally understood that masters should reduce the speed of their vessels' speed to fewer than 8 knots. For the purposes of this analysis we used 8 knots for all port approaches in our calculations.

In the fourth column of Table 2, note that for Fernandina Beach, FL there are two distances specified for the location of the "pilot buoy" relative to the harbor baseline or closing line. Some inbound vessels defer embarking a pilot until they are in an area about 4 nm from the harbor entrance. For purposes of this report, we assumed that the location of the pilot buoy is 10.9 nm for all vessels approaching Nassau Terminals at Fernandina Beach, FL

Table 2

Port Entrance	Pilot embarkation	Speed at Pilot Buoy, VS_{PB}	Location of "Pilot Buoy" relative to harbor baseline or closing line
NY/NJ	**Triangular cruising area west of Ambrose Light**	**No speed specified**	**6.8 nm**
Delaware Bay	**2.5nm SE of Cape Henlopen, DE**	**5 knots**	**2.5 nm**
Chesapeake Bay	**LWB "C"**	**No speed specified**	**2.85 nm**
Wilmington, NC	**1nm east of LBB "2CF"**	**6-8 knots**	**4.1 nm**
Morehead City, NC	**LBB "2BI"**	**5 knots**	**6.7 nm**
Georgetown, SC	**LWB "WB"**	**No speed specified**	**5.6 nm**
Charleston, SC	**LWB "C"**	**8-10 knots**	**12.5 nm**
Savannah, GA	**LWB "T"**	**8 knots**	**9.7 nm**
Brunswick, GA	**LWB "STS"**	**5-9 knots**	**6.7 nm**
Fernandina Beach, FL	**LB "STM"**	**6 knots**	**10.9nm (& 4nm)**
Jacksonville, FL	**LWB "STJ"**	**8 knots**	**4.2 nm**

Table 2 shows the location of the pilot embarkation point, typically in the vicinity of a buoy, the so called "pilot buoy;" and the maneuvering speed, VS_{PB}, that the local pilots' association ask that vessels maintain for boarding a pilot. (Source: U.S. Coast Pilots 2, 3, 4 and communications with regional pilots' associations).

Results

We originally assumed that when entering port, vessels, in the absence of proposed speed restrictions, do not reduce speed (or speed up on an outbound transit) until they cross the harbor at the baseline or closure line. This assumption by itself results in an over estimation of the time it takes to comply with the SMA for vessels calling at mid Atlantic ports and ports within the Southeast U.S. critical habitat; many vessels that require pilotage must reduce speed to embark/debark a state or federal pilot. This assumption offsets to a certain degree the need of many vessels' to take as much as one hour to slow from sea speed to maneuvering speed before entering a SMA off these ports. Further, these vessels then do not return to sea speed, but likely to a speed of, at most, between 10-12 knots to the harbor entrance. Therefore, we have also assumed in our calculations and traffic-management scenarios that proposed speed restrictions would only impact vessels from the outer limit of the SMA to the pilot buoy. The net additional time, ΔT_{NET}, a vessel would take to comply with the SMA is not a simple calculation and requires the input of vessel speed, restricted speed, location of pilot buoy, and buffer distance. Tables 3a-i and 4a-c, Appendix I, summarize the computations of the additional time, ΔT_{NET}, it would take for various vessel types to comply with the proposed seasonal management area (20, 25 and 30 nautical miles) and potential speed restrictions (10, 12, and 13 knots) for mid Atlantic ports (except Block Island Sound) and ports within the Southeast U.S. critical habitat. (Average vessel sea speeds can be found in Table 1, column 2). A null value across all columns indicates that no vessels of the type listed called at the port in CY 1999. Net additional time to comply with the SMA for vessels calling at mid Atlantic ports and ports within the Southeast U.S. critical habitat vary from port to port. Ports with the pilot buoy closest to the harbor would be impacted the most. Table 3c, for the ports of Hampton Roads and Table 3h for the port of Charleston are summarized below as examples of the variability of impacts depending on the pilot buoy location and depending on vessel type and speed (tug/barge – 12 kt sea speed; large container ship – 24 kt sea speed):

For the ports of Norfolk, Hampton Roads, VA, the pilot buoy is 2.85 miles from the harbor entrance. The revised calculations show:

- no additional time (tug/barge) to 38 minutes (large container ship) at a proposed speed restriction of 13 knots and a SMA of 20 nautical miles from the baseline or closing line. This compares to our original estimates as follows:
  - Tug/barge: no difference
  - Large container ship: 42 minutes vs. 38 minutes (revised) (~10%) less

- to as many as 23 minutes (tug/barge) to 81 minutes (large container ship) at a proposed speed restriction of 10 knots and an SMA of 30 nautical miles from the baseline or closing line. This compares to our original estimates as follows:
  - Tug/barge: 30 minutes vs. 23 minutes (revised) (~23% less)
  - Large container ship: 105 minutes vs. 81 minutes (revised) (~23% less)

For the port of Charleston, SC., the pilot buoy is 12.5 miles from the harbor entrance. The revised calculations show:

- no additional time (tug/barge) to 3 minutes (large container ship) at a proposed speed restriction of 13 knots and a SMA of 20 nautical miles from the baseline or closing line. This compares to our original estimates as follows:
  - Tug/barge: no difference
  - Large container ship: 42 vs. 3 minutes (revised) (~93% less).

- to as many as 14 minutes (tug/barge) to 48 minutes (large container ship) at a proposed speed restriction of 10 knots and a SMA of 30 nautical miles from the baseline or closing line. This compares to our original estimates as follows:
  - Tug/barge: 30 minutes vs. 14 minutes (revised) (~53% less)

- Large container ship: 105 minutes vs. 48 minutes (revised) (~54% less)

Table 3c

Hampton Roads Chesapeake Bay		*Additional Transit Time, minutes @ RS = 10 Kts*			*Additional Transit Time, minutes @ RS = 12 Kts*			*Additional Transit Time, minutes @ RS = 13 Kts*		
Location of Pilot buoy @ 2.85 nm		**20**	**25**	**30**	**20**	**25**	**30**	**20**	**25**	**30**
Vessel category	**Speed**									
dry bulk—handy	14									
Handymax	14									
Panamax	14.5	34	37	43	22	21	23	16	14	14
Cape	14.5									
tanker—product	14									
Aframax	15									
Suezmax	14.5	34	37	43	22	21	23	16	14	14
VLCC										
container-1000TEU (15kt)	15									
--1500TEU	15									
--2000TEU	24									
--3000TEU	24	55	67	81	43	51	61	38	44	52
--4000TEU	24									
LNG	20									
Car Carrier	16									
Cruise ship	25									
tug/barge--freight	12	22	21	23	0	0	0	0	0	0
--tank	12	22	21	23	0	0	0	0	0	0

Table 3c shows the additional time required with proposed speed restrictions of 10, 12 and 13 knots and proposed geographic extent of the seasonal management areas (SMA) of 20, 25 and 30 nautical miles for vessels calling in the Hampton Road area (Chesapeake Bay).

Table 3h

Charleston, SC

Location of Pilot buoy @ 12.5 nm		*Additional Transit Time, minutes @ RS = 10 Kts*			*Additional Transit Time, minutes @ RS = 12 Kts*			*Additional Transit Time, minutes @ RS = 13 Kts*		
		20	**25**	**30**	**20**	**25**	**30**	**20**	**25**	**30**
Vessel category	**Speed**									
dry bulk—handy	14									
Handymax	14	9	18	23	5	11	12	3	8	8
Panamax	14.5	9	19	25	5	13	14	3	10	10
Cape	14.5									
tanker—product	14	9	18	23	5	11	12	3	8	8
Aframax	15	9	20	27	5	14	16	3	11	11
Suezmax	14.5	9	19	25	5	13	14	3	10	10
VLCC										
container-1000TEU	15	9	20	27	5	14	16	3	11	11
--1500TEU	15									
--2000TEU	24	9	24	48	5	18	36	3	15	32
--3000TEU	24	9	24	48	5	18	36	3	15	32
--4000TEU	24									
LNG	20									
Car Carrier	16	9	22	31	5	16	20	3	13	15
Cruise ship	25	9	24	49	5	18	38	3	15	33
tug/barge--freigh	12	9	12	14	0	0	0	0	0	0
--tank	12	9	12	14	0	0	0	0	0	0

Table 3h shows the additional time required with proposed speed restrictions of 10, 12 and 13 knots and proposed geographic extent of the seasonal management areas (SMA) of 20, 25 and 30 nautical miles for vessels calling in Charleston, SC.

2. Retrospective Modeling of Dynamic Management Areas

Analytical Approach

A retrospective review of right whale sightings collected since 1979 was carried out to assess the timeframes and duration of right whale distributions that overlapped with areas of known vessel traffic, i.e., shipping lanes and shipping routes, and for which a Dynamic Management Area (DMA) would be imposed. Because the distribution of right whales can vary from year to year, the potential impacts to vessel traffic could vary significantly on an annual basis. This project was carried out to gain a better understanding of the extent of potential DMAs, how different shipping lanes and routes would be affected, and what level of annual variability exists.

To determine the most adequately surveyed years, annual plots of right whale sightings data found at http://marinegis.org/rwhale_gis.html were reviewed to assess the level of survey coverage. Twelve years for which survey coverage was considered adequate to be useful for this project were utilized for the Great South Channel critical habitat area in the vicinity of the Boston shipping lanes since effort was primarily limited to that area but was sporadic over that time period. The 12 years are: 1979-1981, 1987-1989, 1991, 1998-2002. Only the latter five years of survey effort, 1999-2002 were adequate for the Gulf of Maine, Cape Cod Bay and Block Island Sound. No data was determined to be adequate for the NY/NJ area, though there are opportunistic sighting reports of right whales feeding in the southern approaches.

Right whale sightings data for these years were acquired from the Right Whale Consortium database curated at the University of Rhode Island. The sightings data utilized include both opportunistic sightings and those collected during surveys.

The area covered for this project includes the Gulf of Maine west of the Hague Line (i.e., U.S. / Canadian boundary of the U.S. Exclusive Economic Zone) and the coasts of Maine to New York. The latitude/longitude range from 38.0° to 45.5°N and 65.0° to 75.0°W.

The sightings data were queried using a GIS program, ARCVIEW, to determine when a Dynamic Management Area (DMA) could have been enacted based on trigger events. For the purposes of this project and as recommended in our report, *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales,* a trigger event, which could initiate a DMA, is defined as, for a given day:

- a single sighting/detection of 3 or more animals;
- two or more sightings/detection within one day totaling three or more animals with the sightings within 10 miles of each other;
- a sighting/detection of a mother/calf pair within 15 nm of a shipping lane;
- a sighting/detection of 2 or more animals closer than 10 miles to each other within a designated shipping lane if those animals are thought to be resident or feeding (note: this trigger was not used in this report since the historical data were not clear about feeding or resident behavior); and
- a sighting/detection of one or more animals in the Cape Cod Canal or any harbor area.

Potential DMAs were determined for all areas and times except when an SMA would otherwise be in force. If the SMA was NOT in force, and a DMA was triggered, we imposed the DMA. The areas and the associated time frames of SMAs include:

- Great South Channel east of the shipping lanes leading to Boston – year round. This area is proposed as an Area to be Avoided (ATBA). (An ATBA already exists to the west of the lanes in the Nantucket Shoals for commercial shipping.)
- Cape Cod Bay critical habitat – seasonal ATBA approximately January through May.
- 35 nm portion of Boston shipping lanes near Race Point – 1 April – 15 May.
- The offshore approaches to Block Island Sound.
- The approaches to the ports of NY/NJ.

When a trigger event was identified on a given day, a buffer circle was placed 15 nm around the periphery of sightings to define the extent of a potential DMA. The time duration of the potential DMA was extended for 13 days beyond the initial date of the sightings. If additional sightings were observed within those 13 days that met the trigger criteria, and those sightings were still within the buffer area, the buffer area remained the same but the duration of the area was extended for 13 days beyond the later sighting. If no sightings occurred within the 13-day period, the DMA was suspended at the end of the period. For this project, we did not review the data to determine whether a subsequent survey of a DMA determined that right whales were no longer present within the 13-day timeframe.

For this project, we described all trigger events that occurred outside of the SMA areas and/or timeframes as DMA's. All sightings that fit the trigger criteria were placed into an ARCVIEW table and an ARCVIEW shape file for each potential DMA was created. Each DMA was mapped by year, labeled with start and end date, total number of days, number of animals sighted over the duration of the DMA (note: this included sightings that would have been covered by the DMA but would not necessarily count as a trigger), the diameter of the DMA in nautical miles, and the lateral distance of the DMA along any shipping lanes that were within the DMA.

We reviewed how often these retrospective DMAs overlapped with shipping lanes as well as areas where vessel traffic would likely intersect the right whale areas (e.g., the Gulf of Maine). For each sighting year, a tally of the distance and duration of those DMAs that specifically intersected shipping lanes was compiled. For each shipping lane or shipping area, the total annual duration and the average distance of DMAs imposed were calculated for each year for which that lane or area was reviewed. For each discrete area, the median, mean, maximum[4], minimum, were then calculated using the annual tallies for each lane/area to provide an estimation of best and worst case scenarios and a mean and median annual expected value for each lane/area.

The discrete areas that were reviewed are: Portland, ME approach-lanes, Boston approach sea-lanes, Providence/Buzzards Bay traffic lanes, and the New York/Ambrose approach sea- lanes. The Gulf of Maine, where there are no designated lanes, was also reviewed. For Cape Cod Bay,

[4] The maximum figures for annual duration and the average distance may not occur in the same year, therefore worst case scenarios may not be as severe as the maximum figures might suggest.

we examined two areas, an area west of the critical habitat and an area within the critical habitat but outside the historic timeframe of the proposed SMA for the critical habitat.

The distance of the designated shipping lane covered by the DMA was determined by measuring the maximum extent of the arc of the circle if the circle crossed any portion of the lanes. This may result in an over estimation of the number of DMAs imposed that would impact designated shipping lanes since some DMAs would only cover a portion of one lane. However, for the Boston approach sea-lane south of the Race Point SMA, within which right whales may be more consistently present on an annual basis, we developed and used a second method for determining the lateral distance along the axis of the sea lane to impose the DMA. For this alternate method, the Boston approach sea-lanes were segmented into 5 nm increments (23 sections) beginning in the turn in the lane near Race Point to the southern extent of the lanes in the precautionary area. The lateral distance along the sea within the DMA was dependent on how the arc of the buffer crossed the sea-lanes: a line was drawn from the top and bottom of the arc perpendicular to the lanes. The distance was determined to be the number of segments included by the drawn lines, rounding to whichever segment the arc was closest to and multiplying the number of segments by 5 nm for the total distance. This results in a smaller estimation of the geographic extent of DMAs imposed that would impact designated shipping lanes. Figure 1 describes the shipping lane segments and the process used to calculate segments covered by the buffer.

Figures 2 and 3 are examples of the DMA's determined for 1998 and 2000. The plots of all years are found in Appendix II.

Figure 1

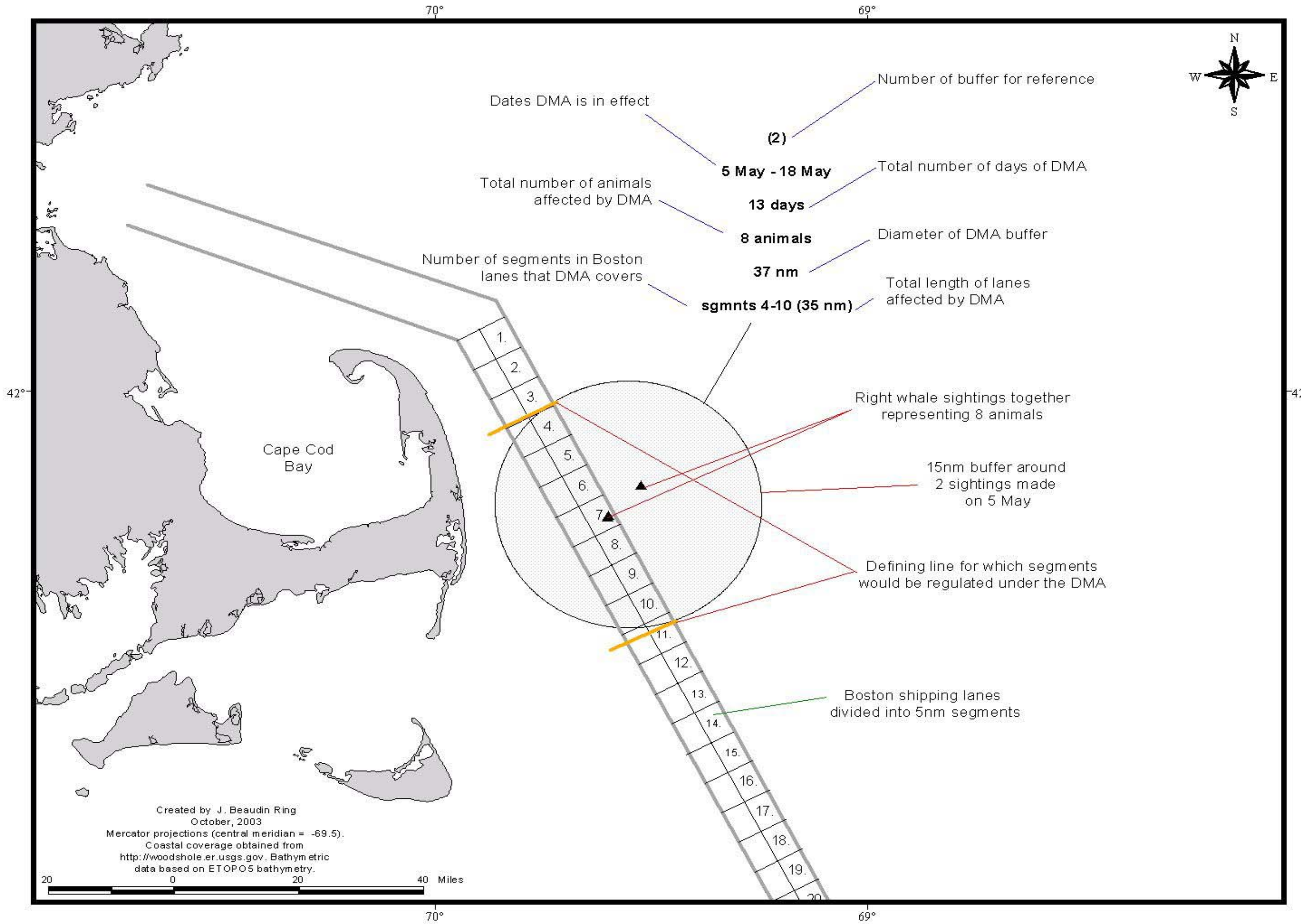

Figure 1 illustrates how the Boston approach shipping lanes in the Great South Channel were segmented into 5 nm increments in order to determine the longitudinal extent of a DMA encompassing part of the lanes.

Figure 2

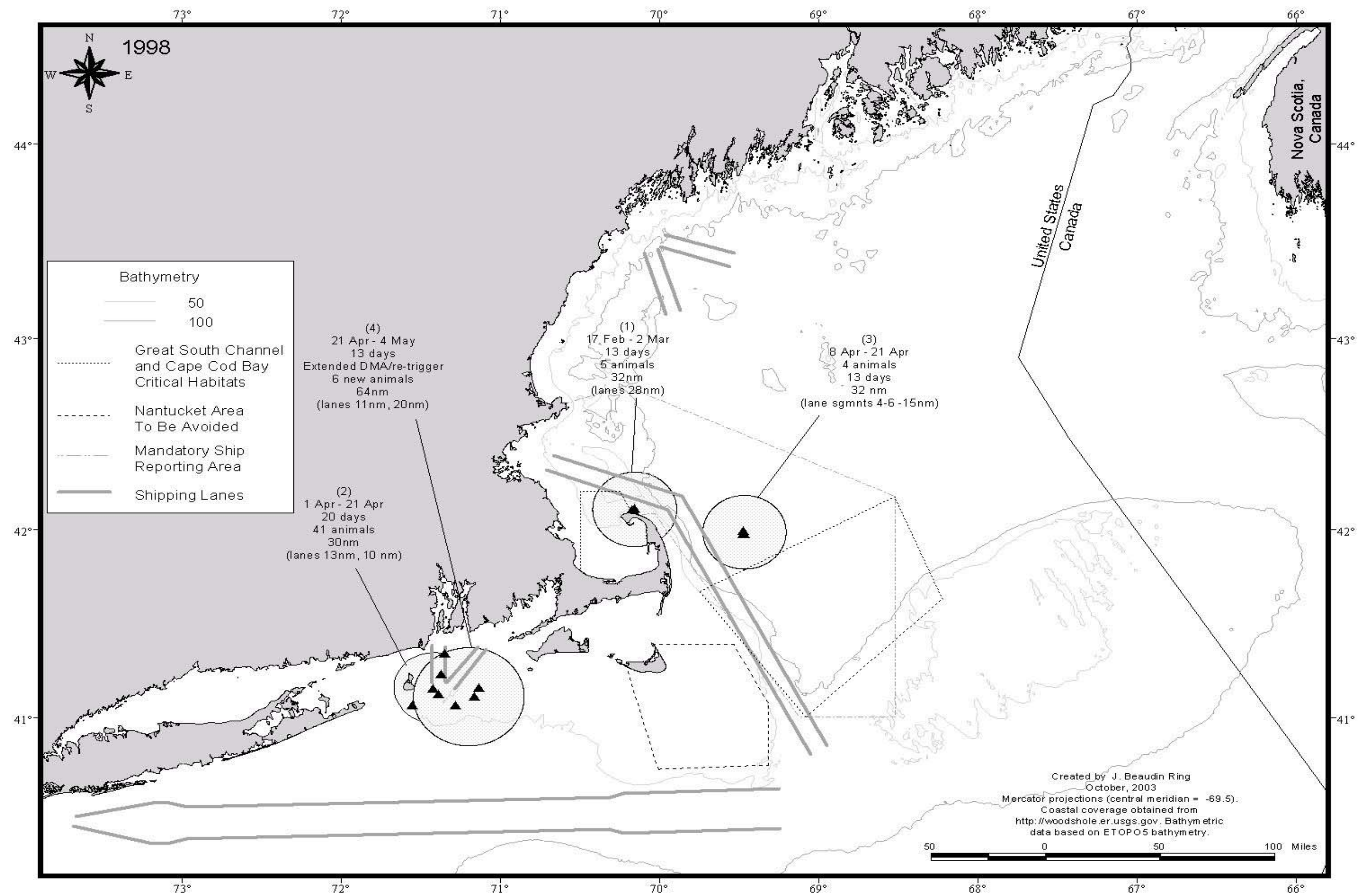

Figure 2 is an example of the DMA's determined for 1998. The plots of all years are found in Appendix II.

Figure 3

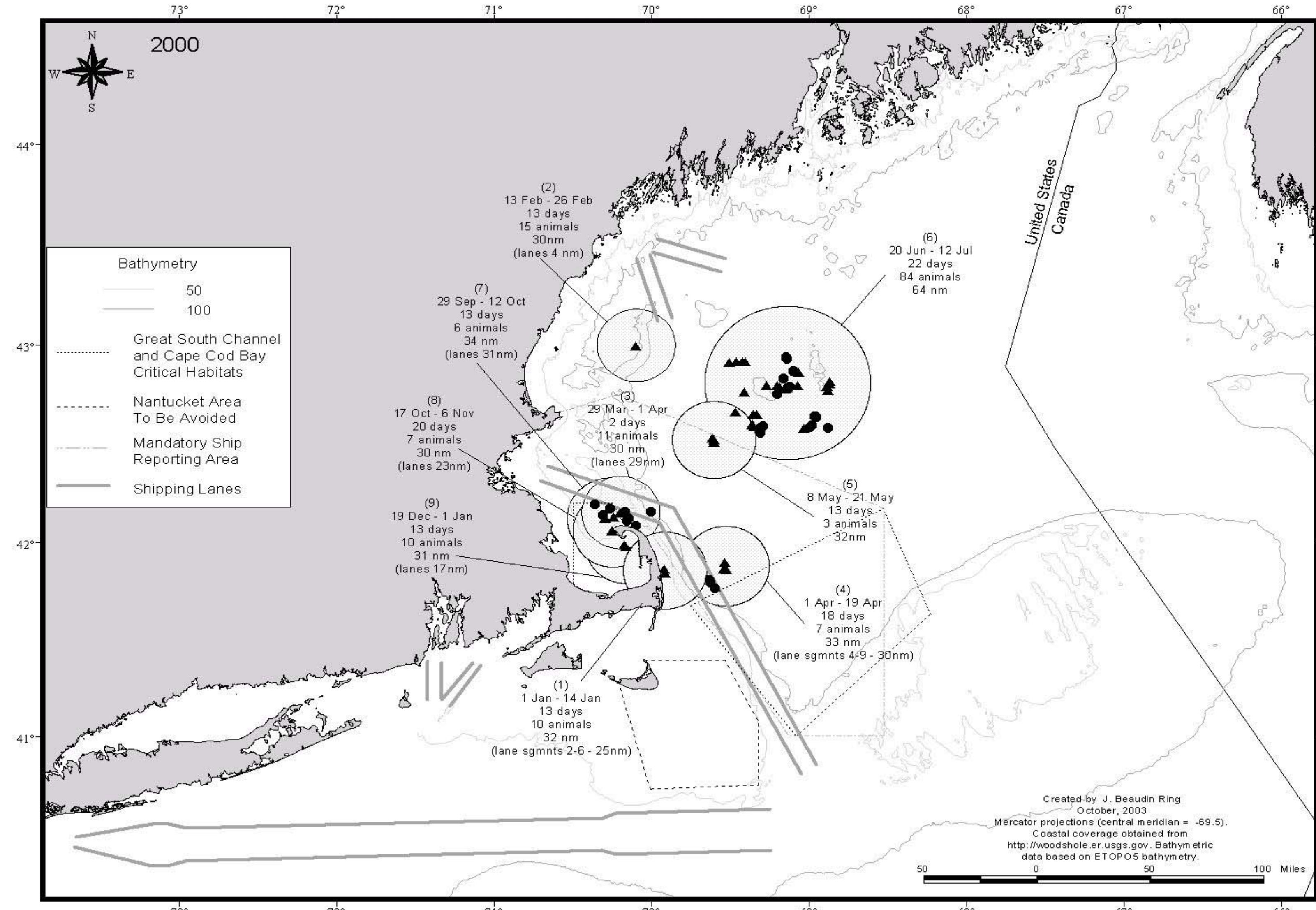

Figure 3 is an example of the DMA's determined for 2000. The plots of all years are found in Appendix II.

Tables 5a-c are the compilations and calculations for each geographic area of the:

- mean, median, maximum, and minimum annual duration in days per year of potential DMAs;
- mean, median, maximum, and minimum average-annual geographic distance of DMAs in the identified areas,
- total number of DMAs over the study period; and
- average number of DMAs per year during the study period.

A median of zero (O) implies irregular frequency of occurrence of a DMA in the geographic area. A mean number of DMAs per year greater than or equal to 1 implies a 100% probability of occurrence of a DMA in the geographic area. A mean number of DMAs per year less than 1 implies a probability less than 100% of occurrence of a DMA in the geographic area. In Notes 1A&B and Notes 2A&B we further refine the compilation and calculations in the Gulf of Maine area and for the Boston Approach sea-lanes. For example, masters regularly traveling from Canada, south to Boston would plan a voyage to encounter a DMA at the frequency provided for the entire Gulf of Maine, Table 5A. Similarly, masters operating solely in the Southern Gulf of Maine would base voyage planning on the smaller figure in Table 5B, Note 1B. Another example: a master regularly calling Portland, ME routing through the Great South Channel would base voyage planning on potential DMAs in three areas: Great South Channel, Gulf of Maine and Portland Approaches. Information on the seasonal occurrence of right whales can be found in the U.S. Coast Pilots 1-4. Appendix II, the plots of DMAs by year, are useful in understanding historical temporal and geographic occurrence of DMAs.

Table 5a

Area/Port	Portland, ME (*Note: only 4 years of data were used, 1999-2002)		Gulf of Maine (Note 1A&B)		Cape Cod Bay, western side		Cape Cod Bay ATBA		Boston Sea Lanes (Note 2A&B)		Block Island Sound	
	Duration, days	Distance, nm	Duration, days	Distance, nm	Duration, days	Distance, nm	Duration, days	Distance, nm	Duration, days	Distance, nm	Duration, days	Distance, nm
Median	7	2	0	0	0	0	0	0	27	29	0	0
Mean	10	3	16	16	0	0	3	6	39	27	9	13
Minimum	0	0	0	0	0	0	0	0	13	30	0	0
Maximum	13	10	44	48	0	0	13	31	66	40	20	30

Number of Potential Dynamic Management Areas

	Portland, ME	Gulf of Maine	Cape Cod Bay, western side	Cape Cod Bay ATBA	Boston Sea Lanes	Block Island Sound
5 year total	3*	4	0	1	See Notes 2A&B	2
mean number per year	.75*	0.8	0	0.2		.4

Table 5b

Note 1	Note 1A		Note 1B	
	Northern Gulf of Maine		Southern GOM	
	Duration, days	Distance, nm	Duration, days	Distance, nm
Median	0	0	0	0
Mean	9	6	7	10
Minimum	0	0	0	0
Maximum	41	41	35	48
Number of Potential Dynamic Management Areas				
5 year total	2		2	
Mean number per year	0.4		0.4	

Table 5c

Note 2	Note 2A		Note 2B	
	Great South Channel		Northern approaches	
	Duration, days	Distance, nm	Duration, days	Distance, nm
Median	14	28	13	31
Mean	25	27	14	26
Minimum	0	0	0	0
Maximum	63	50	35	55
Number of Potential Dynamic Management Areas				
12 year total for GSC / 5-year total for northern approaches	24		9	
Mean number per year	2		1.8	

Tables 5a-c are the compilations and calculations for each geographic area of the mean, median, maximum, and minimum annual duration in days per year of potential DMAs; mean, median, maximum, and minimum average-annual geographic distance of DMAs in the identified areas, total number of DMAs over the study period; and average number of DMAs per year during the study period.

The following is a comparison of our preliminary DMA vessel traffic management scenarios and the mean values from our revised estimates.

- Boston, MA:
  - *Northern approach (to/from Gulf of Maine): DMA* of 30nm for 90 days/year. Revised results: **16nm for 16 days/year.**
  - *Great South Channel/Massachusetts Bay approach: DMA* of 30nm for 90 days/year. Revised results: **27nm for 39 days/year.**
  - *Southern approach (to/from Cape Cod Canal):* Dynamic speed restriction of 30nm for 90 days/year. **Revised results: No DMA.**
  - Block Island Sound (Fall River, MA, Providence, RI, New London, CT, New Haven, CT, and Bridgeport, CT) DMA of 30nm for an additional 60 days/year. **Revised results: 13nm for 9 days/year.**

The preliminary vessel-traffic management scenarios were a gross estimate of the potential worst case scenarios that clearly exceed the maximum DMAs we identified. However, our preliminary estimates did not account for vessels having to slow from sea speed to maneuvering speed and then back to sea speed. We understood this, which contributed to our deliberate over-estimation. It is somewhat difficult to assess how these combined factors will impact the economic assessment without several modifications to the economic assessment model. This is best left to Drs. Kite-Powell and Hoagland.

However, a quick comparison can provide some insights. For example, a vessel traveling in the GSC at 20 knots entering a DMA of 27nm at 12 knots, considering the need for a vessel to slow prior to entering the DMA (and then returning top sea speed), would take an additional 1.5 hours, vs. 1.1 hours based on our earlier scenario. This equates to a DMA equivalent of 39nm - a 44% increase from the initial estimate of 30nm. The reduction in annual duration from 90 days to 39 days per year results in a 57% decrease. Net change is an 18% decrease in estimated annual impact measured in days-miles. This has a one-to-one correlation to costs.

3. Review of Sightings Data in the Mid Atlantic

Analytical Approach

A project to analyze all existing right whale sighting and survey effort data in the mid Atlantic region was completed in 2002. This report titled *Right Whale Sightings and Survey Effort in the Mid Atlantic Regions: Migratory Corridor, Time Frame, and Proximity to Port Entrances* by A. Knowlton, J. Beaudin Ring, and B. A. Russell is available from Amy Knowlton. The goal of this effort was to better understand right whale movements through this high-use shipping region. Detailed analyses of time frame, distance from shore and water depth of all right whale sightings were conducted. Buffers ranging from 10-40 nm were placed around each port entrance to determine which buffer distance would capture the majority of sightings near the given port entrance.

Results

The data indicate that buffers ranging from 20-30 nm, depending on the port entrance would capture the majority of animals migrating past the given port entrances. As discussed earlier a range of buffer distances, 20, 25 and 30nm were used when calculating the amount of time needed to transit SMAs at each port entrance.

Based on our revised analyses, which now capture all of the sightings found at each port entrance, the timeframes vary from 84-210 days per year, depending on the port. We note however, as complete and comprehensive as these analyses are, these results are based on a paucity of information of right whale occurrence in this area, and should only be considered as a starting point for further research. Our original estimates were predicated on managing the pulse of migrating whales with those time frames capturing over 95% of the migrating animals. These durations below address most of the migration and mother calf pair residence from Savannah, GA north to and including Georgetown, SC. These results are presented in Table 6.

Table 6

Port	Miles Offshore	Annual Duration
Block Island Sound Approaches	20-30nm	84-112 days
NY/NJ	30nm	98-140
Ports of Philadelphia	20-30nm	120-180
Norfolk / Hampton Roads	30nm	98-140
Baltimore, MD	30nm	98-140
Morehead City, NC	20-25nm	150
Wilmington, NC	20nm	150
Georgetown, SC	20-30nm	180-210
Charleston, SC	20-25nm	180-210
Savannah, GA	25nm	180

Table 6 shows the seaward limit of the area and annual duration of proposed seasonal management areas for mid Atlantic ports.

As our original estimates were duration of 60 days per year the revised findings are 40%-250% larger, depending on the port. Promising modeling research by Russell Leaper and Lex Hiby, *Preliminary Analysis of the Use of Photographic Capture Histories of Individually Identified North Atlantic Right Whales in the Southeast United States to Make Inferences about Whale Occurrence in the Mid-Atlantic Region,* may provide better insights on how whales migrate through the mid Atlantic.

The net difference between our revised calculations and our original estimates is determined by multiplying the percentage difference in speed restrictions (see p. 15) and the percentage change in duration. For example:

- For a large container ship calling at Hampton Roads, Virginia under a proposed 10 knot speed restriction and a proposed SMA of 30 nautical miles from the baseline or closing line, with a duration of 140 days per year (the most extreme restrictions), the annual impact of the measures would be (1-0.23) x 2.33, or 180% of our preliminary estimates[5].

- For a large container ship calling at Charleston, South Carolina under a proposed 10 knot speed restriction and a proposed SMA of 30 nautical miles from the baseline or closing line, with a duration of 210 days per year (the most extreme restrictions), the annual impact of the measures would be (1-0.93) x 3.5, or 24.5% of our preliminary estimate.

Finally, we note that many vessels transit coastwise along the eastern seaboard. Generally, northbound deep draft vessel traffic is well offshore using the Gulf Stream to add several knots to the speed over ground. South bound traffic runs near shore, as close as 7-10 nm off the coast, depending on the water depth and vessel draft. Masters of southbound vessels would likely route to the east of the proposed SMAs (depending on the weather and other conditions), thus adding some additional mileage to their voyages. The shipping data is not available to document the cumulative impact on shipping.

4. Review of Vessel Traffic in Cape Cod Bay

Analytical Approach and Results

No data is currently available on the number or type/category of vessels that would be impacted. No data is available on the exact routes vessels are currently taking through the Cape Cod Bay critical habitat (the proposed SMA is contiguous with the critical habitat). We conducted no critical analyses of the geographic coordinates of the critical habitat and the duration of the SMA. However, information received from the Northeast Pilots after we published our report, *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales,* indicated that the proposed SMA (regulated navigation area (area to be avoided)) in Cape Cod Bay and the proposed SMA in the Boston approaches sea lane off Race Point would impact a significant number of vessels using the Cape Cod Canal. Northbound vessels enroute to Canada or Europe presently transit across the proposed Cape Cod Bay SMA and the SMA in the Boston approach sea lanes off Race Point. Southbound vessels are avoiding taking a longer route around Cape Cod.

[5] The impact of speed restrictions is 23% less than our preliminary estimates. The duration is 233% greater than our preliminary estimates.

We estimate that both northbound and southbound vessels that currently transit across the critical habitat and the proposed SMA could add less than 25 nm to their routes.

We also expect that some of these vessels would not cut across the SMA in the Boston approach sea lanes off Race point, as the net transaction costs to slow and then speed up would be higher that steering to the north and west before heading north and east.

Mr. Owen Nichols, Center for Coastal Studies, recently received a grant to conduct an *Analysis of Risk to North Atlantic Right Whales (Eubalaena glacialis) from Shipping Traffic in Cape Cod Bay.*

5. Review of Sightings Data off Boston Approach Sea-lane off Race Point.

<u>Analytical Approach</u>

A project to review right whale sightings in relation to survey effort was completed in 2001, *GIS Presentation of Survey Tracklines, Right Whale Sightings and Right Whale Movements: 1978-2000*, Knowlton, A., Beaudin Ring, J, Kenney, R.D. and Russell, B.A. This report is available at www.marinegis.org under the News section. One aspect of this project was to look at short term individual animal movements to gain a clearer understanding of how and when right whales migrate between feeding areas.

To understand the movement of right whales in the vicinity of the Race Point sea-lane area, individual animal sightings from Cape Cod Bay to points outside of Cape Cod Bay were reviewed. Little data exists documenting where right whales are arriving from when they enter the Bay in the beginning of the season so this was not reviewed. Shortest distance routes of right whales departing Cape Cod Bay were created to determine where along the sea lanes the animals might intercept in transit to offshore areas, especially during the early spring through early summer when their winter food supply in Cape Cod Bay depletes.

We reviewed our original estimates and decided to revisit our approach with the sole objective of determining the duration and longitudinal distance over which the proposed SMA would affect traffic using the Boston approach sea-lane. Thus we focussed only on the examining the eastern and western boundaries of the proposed SMA. We assumed that aggregations of right whales in these sea lanes or several miles to the north of the sea lanes in the Stellwagen Bank Marine Sanctuary that do not occur regularly, could be managed using the proposed DMA measures.

<u>Results</u>

Our original estimates were for 25-35 nautical miles for 30 days. Our analysis found that our high-end estimate, 35 nautical miles, would provide the maximum zone of protection. We also reviewed the duration and concluded that 45 days per year would preclude the need to manage early or late right whale movements dynamically.

Findings: Summary of results by geographic area and recommended vessel traffic-management scenarios for economic analyses

In the following tables, we provide our findings on a port by port basis, and for routes that would be impacted for vessels not necessarily calling at a U.S. port.

In the tables, we provide and note the following.

Second column. For DMAs, mean, median, maximum, and minimum duration and average distance, the number of trigger events for 5 or 12 years, and the average number per year.

Third column. Where masters, voyage planners and analysts should consider the additional time necessary to slow from sea speed to maneuvering speed and then back to sea speed. (See Table 1). Our calculations for this ***are*** included for all mid Atlantic ports.

Fourth column. Where masters, voyage planners and analysts should consider impacts from other operational measures depending on a vessel's exact route. For example, a vessel calling in Portland, ME and transiting through the Great South Channel should consider measures in the Great South Channel, the Gulf of Maine and the approaches to Portland. In doing so, Coast Pilots 1 and 2 should be consulted for the geographic and seasonal distribution of right whales. Also, Appendix II provides historical occurrences of DMAs. In this Portland example, it is important to note that on a single voyage a vessel would likely encounter no more than one DMA due to the widespread seasonal distribution of congregating right whales.

Fifth column. Our earlier preliminary vessel-traffic management scenarios.

Table 7a

Port(s)	Dynamic Management Areas[6]	Seasonal Management Areas[5]	Other factors that may impact vessel traffic	Earlier Scenarios
Penobscot River, Searsport, and Portland, ME Portland, ME	**Gulf of Maine DMAs** Mean 16 days, 16 nm Median 0 days, 0 nm Min 0 days, 0 nm Max 44 days, 48 nm 5 year total: 4 Mean #/year: 0.8 ----------------------------- In addition, Portland approach sea lanes: Mean 10 days, 3 nm Median 7 days, 2 nm Min 0 days, 0 nm Max 13 days, 10 nm 5 year total: 3 Mean #/year: .75	None	For vessels calling via Cape Cod Bay or the Great South Channel, see Boston, MA area - Great South Channel/Massachusetts Bay approach or Cape Cod Bay approach (to/from Cape Cod Canal).	Dynamic speed restriction of 30nm for 90 days/year
Portsmouth, NH and Salem, MA	**Gulf of Maine DMAs** Mean 16 days, 16 nm Median 0 days, 0 nm Min 0 days, 0 nm Max 44 days, 48 nm 5-year total: 4 Mean #/year: 0.8	None	For vessels calling via Cape Cod Bay or the Great South Channel, see Boston, MA area - Great South Channel/Massachusetts Bay approach or Cape Cod Bay approach (to/from Cape Cod Canal).	Dynamic speed restriction of 30nm for 90 days/year.

Table 7a: Columns 2-4, summary of revised vessel traffic scenario results for Gulf of Maine ports. Column 5 shows earlier recommendations.

[6] Speed restrictions must account for additional time to slow from sea speed to maneuvering speed.

Table 7b

Port(s)	**Dynamic Management Areas**[7]	**Seasonal Management Areas**[5]	**Other factors that may impact vessel traffic**	**Earlier Scenarios**
Boston, MA area: ***northern approach (to/from Gulf of Maine)***	**Gulf of Maine DMAs:** **Mean 16 days, 16 nm** **Median 0 days, 0 nm** **Min 0 days, 0 nm** **Max 44 days, 48 nm** **5-year total: 4** **Mean #/year: 0.8**	**None**		**Dynamic speed restriction of 30nm for 90 days/year.**
Boston, MA area: ***Great South Channel / Massachusetts Bay approach***	**Mean 39 days, 27 nm** **Median 27 days, 29nm** **Min 13 days, 30 nm** **Max 66 days, 40 nm** **12/5-year total: 33** **Mean #/year: 3.8**	**SMA off Race Point:** **Speed restriction over 35nm for 45 days/year.**	**Parts of the Great South Channel east of the TSS would be an area to be avoided.**	**Speed restriction over 30nm for 30 days/year**
Boston, MA area: ***Cape Cod Bay approach from Cape Cod Canal (west side)***	**Mean 0 days, 0 nm** **Median 0 days, 0 nm** **Min 0 days, 0 nm** **Max 0 days, 0 nm** **5-year total: 0** **Mean #/year: 0**	**None**	**The eastern side of the Cape Cod Bay would be a seasonal area to be avoided. Occasionally single right whales are found near or in the**	**Dynamic speed restriction of 30nm for 90 days/year.**

Table 7b: Columns 2-4, summary of revised vessel traffic scenario results for the port of Boston and transiting Cape Cod Bay. Column 5 shows earlier recommendations.

[7] Speed restrictions must account for additional time to slow from sea speed to maneuvering speed.

Table 7c

Port(s) / Routes	Dynamic Management Areas[5]	Seasonal Management Areas	Other factors that would impact vessel traffic	Earlier Recommendations
Cape Cod Bay approach (to/from Cape Cod Canal) to points north and east (e.g. Canada and Europe)	**CCB Critical Habitat:** **Mean 3 days, 6 nm** **Median 0 days, 0 nm** **Min 0 days, 0 nm** **Max 13 days, 31 nm** **5-year total: 1** **Mean #/year: 0.2**	**SMA off Race Point:** **Speed restriction from 10-20nm for 45 days/year.** **Additional time to slow from sea speed to maneuvering speed must be considered.** **---------------------------------------** **Cape Cod Bay ATBA: See fourth column.**	**The critical habitat may be designated an Area to Be Avoided. If this were the case, vessels that have historically transited to/from the Cape Cod Canal to/from points north and east of Boston would be prohibited from cutting across the critical habitat. These vessels would then have to route around the ATBA and would add up to ~25nm to their voyages, depending on their speed and destination).**	**None**

Table 7c: Columns 2-4, summary of revised vessel traffic scenario results for transiting Cape Cod Bay to ports north and east of Boston. Column 5 shows earlier recommendations.

Table 7d

Port(s)	Dynamic Management Areas[5]	Seasonal Management Areas	Other factors that may impact vessel traffic	Earlier Recommendations[6]
Block Island Sound and approaches, including New Bedford, Fall River, MA, Providence, RI, New London, CT, New Haven, CT, and Bridgeport, CT	**Within Block Island Sound:** **Mean 9 days, 13 nm** **Median 0 days, 0 nm** **Min 0 days, 0 nm** **Max 20 days, 30 nm** **5-year total: 2** **Mean #/year: 0.4**	**For vessels entering BIS from the Atlantic Ocean:** **Speed restriction over 20-30 nm 84-112 days/year for vessels calling from the Atlantic. Additional time to slow from sea speed to maneuvering speed must be considered.**	**Vessels that approach via the Cape Cod Canal should factor in additional time to transit Cape Cod Bay, depending on their route through Cape Cod Bay. See Table 7b & c.**	**Dynamic speed restriction over a maximum of 30nm for 60 days/year, plus seasonal speed restriction over 25 nm for 60 days/year.**

Table 7d: Columns 2-4, are summaries of revised vessel traffic scenario recommendations for Block Island Sound approaches. Column 5 shows earlier recommendations.

Table 7e

Port(s)	Dynamic Management Areas[5]	Seasonal Management Areas	Other factors that may impact vessel traffic	Earlier Recommendations[6]
New York / New Jersey	Approaches subject to DMA	Speed restriction over 30 nm 98-140 days/year	Two or more feeding/foraging right whales (i.e. resident right whales or a mother calf pair) have been sighted in the southern approaches.	Seasonal speed restriction of 25nm for 60 days/year.
Ports of Philadelphia	Approaches subject to DMA	Speed restriction over 30 nm 120-180 days/year		Seasonal speed restriction of 25nm for 60 days/year
Baltimore, MD	Approaches subject to DMA	Speed restriction over 30 nm 98-140 days/year		Seasonal speed restriction of 25nm for 60 days/year
Hampton Roads area	Approaches subject to DMA	Speed restriction over 30 nm 98-140 days/year		Seasonal speed restriction of 25nm for 60 days/year

Figure 7e: Columns 2-4, are summaries of revised vessel traffic scenario recommendations for mid Atlantic. Column 5 shows earlier recommendations.

Table 7e (continued)

Port(s)	Dynamic Management Areas[5]	Seasonal Management Areas	Other factors that may impact vessel traffic	Earlier Recommendations
Morehead City, NC	Approaches subject to DMA	Speed restriction over 20-25 nm 150 days/year		Seasonal speed restriction of 25nm for 60 days/year
Wilmington, NC	Approaches subject to DMA	Speed restriction over 20 nm 150 days/year		Seasonal speed restriction of 25nm for 60 days/year
Georgetown, SC	Approaches subject to DMA	Speed restriction over 20-30 nm 180-210 days/year	Two or more feeding/foraging right whales (i.e., mother-calf pairs) have been sighted in the approaches.	Seasonal speed restriction of 25nm for 60 days/year
Charleston, SC	Approaches subject to DMA	Speed restriction over 20-30 nm 180-210 days/year	Two or more right whales (i.e., surface active groups, and mother-calf pairs) have been sighted in the approaches.	Seasonal speed restriction of 25nm for 60 days/year
Savannah, GA	Approaches subject to DMA	Speed restriction over 20-30 nm 180-210 days/year	Two or more right whales (i.e., surface active groups, and mother-calf pairs) have been sighted in the approaches.	Seasonal speed restriction of 25nm for 60 days/year

Figure 7e: Columns 2-4, are summaries of revised vessel traffic scenario recommendations for mid Atlantic. Column 5 shows earlier recommendations.

Table 7f

Port(s)	Dynamic Management Areas	Seasonal Management Areas	Other factors that may impact vessel traffic	Earlier Recommendations[6]
Brunswick, GA	**Approaches subject to DMA**	**Speed restriction over 22 nm 120 days/year**	**Recommendations do not address routing options currently under study.**	**Seasonal speed restriction of 22nm for 120 days/year**
Fernandina Beach, FL	**Approaches subject to DMA**	**Speed restriction over 22 nm 120 days/year**	**Recommendations do not address routing options currently under study.**	**Seasonal speed restriction of 22nm for 120 days/year**
Jacksonville, FL	**Approaches subject to DMA**	**Speed restriction over 22 nm 120 days/year**	**Recommendations do not address routing options currently under study.**	**Seasonal speed restriction of 22nm for 120 days/year**

Figure 7f: Columns 2-4, are summaries of revised vessel traffic scenario recommendations for ports within the Southeast U.S. critical habitat. Column 5 shows earlier recommendations.

[6] Recommendations did not address routing options currently under study. Our original recommendations were for 22 nm. Kite-Powell and Hoagland used 25 nm is their analyses.

Recommended Future Analyses

1. On the basis of these more accurate vessel traffic-management scenarios, revise the *Economic Aspects of Right Whale Ship Management Measures*, by Kite-Powell and Hoagland. The revisions should address the following:

    - Include the ports of Georgetown, SC and Morehead City, NC.
    - When ranges of duration or timeframe are provided, provide economic aspects as a function of duration similar to what has been provided for speed restrictions and distances.
    - In some areas, it will be necessary to examine economic impacts on fishing vessels and large recreational passenger vessels (including whale watch vessels).
    - In addition to presenting the economic costs by port, it would be helpful to also present this information by measure. So for example, for vessels calling on Boston via the Great South Channel, the economic costs would be presented as total costs, as well as the components.

2. Continue ongoing research, including sighting surveys and modeling, into the seasonal occurrence, both geographic and temporal, of right whales in the Mid Atlantic. Promising modeling research by Russell Leaper and Lex Hiby, *Preliminary Analysis of the Use of Photographic Capture Histories of Individually Identified North Atlantic Right Whales in the Southeast United States to Make Inferences about Whale Occurrence in the Mid-Atlantic Region,* may provide better insights on how whales migrate through the mid Atlantic.

3. Research and develop shipping data or estimates for southbound traffic in the Mid Atlantic. In the mid Atlantic, masters of southbound vessels would likely route well to the east, of the proposed SMAs, (depending on the weather and other conditions), thus adding some additional mileage to their voyages. The shipping data is not available to document the cumulative impact on shipping.

4. Research and develop shipping data or estimates of vessels transiting Cape Cod Canal to points north and east of Boston. No data is available on the routes vessels are currently taking through Cape Cod Bay. No data is currently available on the number or type/category of vessels that would be impacted.

5. Research and develop shipping data or estimates for vessels calling at Gulf of Maine ports north of Boston which transit via Cape Cod Bay or the Great South Channel. This information is needed to address potential additional transit time to these ports.

6. Following completion of the analyses of the viability of routing in the Southeast critical habitat by Kite-Powell and Hoagland (WHOI), and Lance Garrison (NMFS SEFSC), develop vessel traffic-management scenarios and assess the economic impacts.

7. Two possible methods for defining the overlap of DMA's within shipping lanes have been described. The first method, determining the overlap of the DMA with the shipping lane using the maximum extent of the arc of the buffer, was carried out for all the lanes except for the Boston lanes, south of the dogleg. For the south Boston lanes, twenty-three 5 nm line segments were mapped along the extent of the lanes and only the segments which overlapped with the DMA were noted along with total miles (in 5 nm increments) that would be covered. The pros and cons of each type of system and how best to relay the information to ship traffic should be explored.

References

Kite-Powell, H. Hoagland, P, *Economic Aspects of Right Whale Ship Management Measures*, Woods Hole Oceanographic Institution, March 2002.

Knowlton, A. Beaudin Ring, J, and Russell, B.A., *Right Whale Sightings and Survey Effort in the Mid Atlantic Region: Migratory Corridor, Time Frame, and Proximity to Port Entrances*, July 2002.

Leaper, R., Hiby, L., *Preliminary Analysis of the Use of Photographic Capture Histories of Individually Identified North Atlantic Right Whales in the Southeast United States to Make Inferences about Whale Occurrence in the Mid-Atlantic Region,* April 2003.

Knowlton, A., Beaudin Ring, J, Kenney, R.D., and Russell, B.A, *GIS Presentation of Survey Tracklines, Right Whale Sightings and Right Whale Movements: 1978-2000.*

Russell, B.A., Knowlton, A., *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales,* Northeast and Southeast Implementation Teams, 23 August 2001.