Economic Aspects of Right Whale Ship Strike Management Measures

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Executive Summary

The National Marine Fisheries Service (NMFS) is considering ship traffic management measures to reduce the accidental take of northern right whales due to collisions with ships. This report estimates the cost of such management measures to the shipping industry.

We estimate economic effects for shipping along the US east coast from the Penobscot River, Maine to Port Canaveral, Florida. The ship traffic management measures modeled for this purpose are based in part on recommendations made to NMFS by Russell (2001) and in part on conservative assumptions about how these recommendations might be implemented and how vessel operators might respond. Our base case assumes a 10 knot speed limit imposed on vessel traffic into and out of most ports over a distance of 25 nm during a predictable annual "season" lasting 60 days. Some ports face additional constraints: for example, Boston traffic faces additional speed restrictions in the Great South Channel, and ports within the Southeast Critical Habitat and in southern New England face restrictions over 120 days/year.

The average estimated cost of the base case management measures for larger ports is $1.3 million/year, and ranges from $4.8 million for the Port of New York and New Jersey to about $300,000 for Portland, ME and Wilmington, NC. The average cost per ship call (including those not affected by these measures) is $500, and ranges from $1,170 for the Port of Fernandina Beach to $210 for the Port of Philadelphia. The average cost per affected ship call is $2,350, and ranges from $3,550 in Fernandina to about $1,100 in the Ports of Brunswick and Canaveral. The cost increase due to base case management measures amounts to less than 0.5 percent of total annual operating cost for all vessel types.

We consider these estimates to be conservative (i.e., high) for several reasons, including: (1) in most cases, we assume a larger geographic extent for the speed restrictions than that suggested by Russell (2001); (2) our per-hour operating cost estimates and delay penalties are conservative (high); (3) our assumed normal operating speeds are high; (4) we generally assume larger, more expensive vessels than those actually trading along the US east coast; and (5) operator responses are likely to be more sophisticated than those we have assumed. We suggest, therefore, that our estimates (total cost of about $16 million) are likely to overstate the true cost of these measures. Based on these considerations, it is likely that the true cost of these ship strike management measures to operators along the US east coast would be on the order of $10 million per year.

Introduction

Small numbers of takes of the northern right whale (*Eubalaena glacialis*) have been known to result from collisions with large ships ("ship strikes") along the US eastern seaboard. Although the number of ship strikes is small, the right whale is a highly endangered species, and losses of any individuals from the population are taken seriously (Fujiwara and Caswell 2001). The National Marine Fisheries Service (NMFS) has implemented a "mandatory ship reporting system" for two locations off the east coast of the United States to increase the shipping industry's awareness of this problem and encourage the industry to take actions to reduce the incidence of ship strikes. The Ship Strike Committee of the Northeast and Southeast Implementation Teams for the Recovery of the North Atlantic Right Whale is considering additional regulations designed to reduce the incidence of ship strikes further.

The primary form of regulation presently under consideration is the establishment of traffic management areas where ship traffic overlaps with whale habitat or migration routes. Ships would be required either to reduce speed when transiting these areas, or reroute around the area. Options under consideration (see Russell 2001) include:

- management measures that give ships the option of either slowing or routing around an area;
- shipping lanes or port access routes permanently or seasonally designated as "mandatory" or "recommended" to reduce the risk of ship/whale encounters;
- measures that are permanent, seasonal, or dynamic (triggered by detection of whales or environmental parameters).

This report describes a procedure to estimate the cost to vessel operators of complying with such traffic management regulations.

No final decision has been reached to date on specific vessel traffic management measures to address ship strikes, and there is uncertainty in much of the data on port calls and vessel movements. Our approach is to adopt base case assumptions that will tend to overstate actual costs, and to present cost estimates for a range of traffic management parameters (maximum speed, geographic extent of restriction, etc.). This report covers the northern right whale range along the east coast of the United States, including the ports of Portland ME, Portsmouth NH, Boston MA, Providence RI, New York and New Jersey, Philadelphia PA, Baltimore MD, Hampton Roads VA, Wilmington NC, Charleston SC, Savannah GA, Brunswick GA, Fernandina Beach FL, Jacksonville FL, and Cape Canaveral FL. Some smaller ports have been omitted from this analysis due to resource constraints; but we are confident that in aggregate, our analysis captures more than 95 percent of ship traffic along the US east coast.

Framework

The management measures considered include routing vessels around areas where whales are present and/or imposing speed restrictions on vessels in certain areas. Both types of measures have the effect of increasing the time required for vessels to reach their destination. This increase in the duration of the transit gives rise to additional cost.

We estimate these costs at the port level, since vessel traffic statistics are generally collected at this point. Vessel transits are grouped by vessel type and size, and the nature of cargo; each of these vessel classes is then characterized by a representative normal operating speed, a daily vessel cost, and other constraints such as tide windows.

The transit time delay due to rerouting or speed restrictions is a function of the distance involved and the normal operating speed of the vessel. We distinguish two types of cost: (1) anticipated costs arising from added transit time ("expected" delays) and (2) additional, unexpected costs that arise because a vessel misses its tide or daylight window for entering the port. Unexpected costs (2) arise only where the management regime is dynamic and operators take a high risk response strategy (see discussion of *Scenarios* below). Both transit time delays and unexpected port entry delays are valued according to the vessel's daily cost. In some cases, additional costs are incurred when certain vessels (container ships and cruise vessels) miss their scheduled port call time window.

We assume that vessel operators will adjust to traffic management regulations (usually by altering their schedules) and maintain the prior number of port calls. We do not attempt here to model possible changes in port call plans or the economic effects of such changes.

We distinguish two types of traffic management: static measures, which are imposed for a fixed period of time that is usually known in advance, and dynamic measures, which are imposed "as needed" during an active period as whales are detected in the vicinity. We assume that vessel operators respond to static measures by taking the resulting delay into account when they plan their voyages or schedules. Vessel operators will respond to dynamic management measures in one of two ways: using a "low risk" strategy of incorporating allowances for delays into each transit, or using a "high risk" strategy of assuming no delays and incurring "unexpected" costs when a delay is imposed. Which strategy an operator follows depends on the expected value of additional costs under each strategy, and the operator's risk preferences.

The annual cost C_i of ship strike management measure *m* for port *i* is modeled as the sum of annual costs for each of the approaches to port *i*:

$$C_{m,i} = \sum_j C_{m,i,j}$$

The cost associated with approach *j* is the sum of the costs incurred by vessels using approach *j*:

$$C_{m,i,j} = \sum_{v} (AI_{m,i,j,v} TI_{i,j,v} + AO_{m,i,j,v} TO_{i,j.v})$$

where *AI* is the additional cost incurred on one inbound transit of vessel category *v* and *TI* is the number of inbound transits affected by management measures on this approach in one year. *AO* and *TO* are the outbound equivalents.

The additional cost per transit (*AI* and *AO*) is estimated as discussed above. For a static speed restriction, if the normal operating speed of vessel category *v* is greater than the imposed speed limit, both *AI* and *AO* are equal to the product of the time delay resulting from slowing the vessel over the restricted distance and the unit time cost for vessel category *v*. Unit time cost is estimated as the sum of time charter and operating expenses for transit time, and as time charter only for delays in port, where the vessel is not moving.

For a dynamic speed restriction, vessels may adopt a low risk or high risk response, as described above. Two numbers characterize the temporal extent of a dynamic management regime: the effective days (number of days during the year on which the restriction **is** in force) and the length of the season (the number of days during the year on which the restriction **may be** enforced). The cost of the low risk response is estimated by treating the dynamic scheme as a static speed restriction in effect for the entire season of dynamic management; and *AI* and *AO* are calculated as in the static case above. The cost of the high risk response is the sum of the standard low risk cost estimated only for the number of effective days plus the cost of any additional "unexpected" delays due to missed tide windows, berth assignments, or scheduled arrivals. These latter costs apply only to inbound transits.

We assume that operators are risk neutral and that they will choose a low risk response to dynamic management when the expected cost of the low risk response is less than that of the high risk response.

The cost estimation model is implemented in a spreadsheet (Microsoft Excel). This spreadsheet is available via email on request from hauke@whoi.edu.

Data

To estimate the cost of traffic management alternatives, we require data on vessel traffic, vessel operating speed and cost, and port access constraints and costs that may arise when a vessel incurs an expected delay.

Vessel Traffic

The vessel traffic management measures under consideration directly affect ships headed to or leaving from ports along the US east coast. Therefore, we use traffic data at the port level. Our primary source of vessel traffic data is the US Army Corps of Engineers' *Waterborne Commerce of the United States* for 1999. These data are not as specific as we would like, but they are adequate for our purposes. For some ports (Boston, New York/New Jersey, Charleston, and Jacksonville in particular), we received more specific port call information from the port authorities. See Appendix A for additional information on all ports.

Dry bulk ships carry cargos such as iron ore, coal, or grains. Common size categories include handy (27,000 dwt), handymax (43,000 dwt), Panamax (69,000 dwt), and Cape (150,000 dwt). Tankers carry bulk liquid cargos such as crude and refined petroleum products. Common tanker sizes include product (45,000 dwt), Aframax (90,000 dwt), Suezmax (140,000 dwt), and very large crude carriers (VLCC; 280,000 dwt).

We use estimates of annual port calls in 1999/2000 as the basis for our cost estimates, and do not attempt to forecast future port calls.

		Penobscot R.	*Searsport*	*Portland*	*Portsmouth*	*Salem*	*Boston*
dry bulk	*handy*						
	handymax						150
	Panamax		100		80	30	
	Cape						
tanker	*product*						350
	Aframax						
	Suezmax	20	40	350	100	10	
	VLCC						
container	*1000 TEU*						
	1500 TEU						
	2000 TEU						
	3000 TEU						180
	4000 TEU						
LNG							75
car carrier/RoRo							125
cruise				170			200
tug/barge	*dry*			20	10		50
	tank	70	30	120	70	40	200
total	***ships only***	**20**	**140**	**520**	**180**	**40**	**1080**
	ship&barges	**90**	**170**	**660**	**260**	**80**	**1330**

Table 1a: Port calls by port and vessel type, estimated from USACE (1999).
Additional information provided by the Port of Boston (MassPort).

		Fall River	Providence	New London	New Haven	Bridgeport
dry bulk	*handy*					
	handymax					
	Panamax	100	60	10	110	70
	Cape					
tanker	*product*					
	Aframax					
	Suezmax	10	110	25	110	30
	VLCC					
container	*1000 TEU*					
	1500 TEU					
	2000 TEU					
	3000 TEU					
	4000 TEU					
LNG						
car carrier/RoRo						
cruise						
tug/barge	*dry*	20	60*	60*	150*	500*
	tank	20	370*	100*	560*	300*
total	***ships only***	**110**	**170**	**35**	**220**	**100**
	ship&barges	**150**	*****	*****	*****	*****

Table 1b: Port calls by port and vessel type, estimated from USACE (1999).
*Barge traffic in these ports is assumed to run mainly via Long Island Sound and thus is not subject to the right whale ship strike management measures considered in this report.

		NY/NJ	Philadelphia	Baltimore	Hampton Roads	Wilmington
dry bulk	*handy*	570				
	handymax	270				
	Panamax	50	1,900	1,100	2,500	250
	Cape	20				
tanker	*product*	1,710				
	Aframax	650				
	Suezmax	70	1,100	160	430	270
	VLCC					
container	*1000 TEU*	1,400				
	1500 TEU	1,000				
	2000 TEU	1,000				
	3000 TEU	1,000	100	500	1,200	110
	4000 TEU	1,200				
LNG				100		
car carrier/RoRo		1,500				
cruise		550				
tug/barge	*dry*	600	2,200	1,700	4,000	1,000
	tank	1,000	5,000	1,800	860	600
total	***ships only***	**10,990**	**3,100**	**1,860**	**4,130**	**630**
	ships&barges	**12,590**	**10,300**	**5,360**	**8,990**	**2,230**

Table 1c: Port calls by port and vessel type, estimated from USACE (1999).
Additional information provided by the Port of New York and New Jersey.

		Charleston	Savannah	Brunswick	Fernandina	Jacksonville	Canaveral
dry bulk	*handy*						
	handymax	70					
	Panamax	90	2,050	770	100	540	790
	Cape						
tanker	*product*	150					
	Aframax	40		590			
	Suezmax		320			240	60
	VLCC						
container	*1000 TEU*	280					
	1500 TEU						
	2000 TEU	1,250					
	3000 TEU	460	650		200	600	
	4000 TEU						
LNG			100				
car carrier/RoRo		70				360	
cruise		20				200	1,900
tug/barge	*dry*	320	120	10	10	700	50
	tank	310	500	160	100	1,400	300
total	***ships only***	**2,430**	**3,120**	**1,360**	**300**	**1,940**	**2,750**
	ships&barges	**3,060**	**3,740**	**1,530**	**410**	**4,040**	**3,100**

Table 1d: Port calls by port and vessel type, estimated from USACE (1999).
Additional information provided by the Ports of Charleston, Jacksonville, and Canaveral.

Although there is more than one approach to some of these ports, we do not have good information about which vessels use each approach, and we assume that all vessels entering and leaving each port are subject to the same management regime. The one exception is the Port of Boston, where we distinguish three approaches: from the south via the Cape Cod Canal and Cape Cod Bay, through Massachusetts Bay and around Cape Cod via the Great South Channel, and from the north via the Gulf of Maine. Each approach faces a distinct management regime. Table 2 describes the number of inbound and outbound transits assumed for each approach.

	inbound			*outbound*		
	CC Canal	*GSC*	*Gulf of ME*	*CC Canal*	*GSC*	*Gulf of ME*
dry bulk	10	80	60	10	80	60
tanker	--	120	230	--	120	230
container	--	120	60	--	90	90
LNG	--	75	--	--	75	--
car carrier	25	100	--	25	100	--
cruise	20	30	150	20	55	125
dry barge	40	5	5	40	5	5
tank barge	180	10	10	180	10	10

Table 2: Transits by approach and vessel type for the Port of Boston.
Based on estimates provided by MassPort and the US Army Corps of Engineers.

Vessel Operating Parameters

We estimate a typical daily cost and normal operating speed for each vessel type and size, as shown in Table 3. Costs are divided into operating cost (fuel, etc.) and time charter cost (the daily cost of the vessel itself). At-sea delays are evaluated as incurring both time charter and operating cost, while in-port delays are evaluated on the basis of time charter cost only. All cost estimates are in 2001 dollars. We make no attempt here to incorporate possible future changes in time charter or operating costs.

vessel category		*operating cost, $/24 hours*	*time charter cost, $/24 hours*	*operating speed, knots*
dry bulk	*handy*	3,000	6,000	14.0
	handymax	4,000	8,000	14.0
	Panamax	5,000	9,500	14.5
	Cape	7,000	14,000	14.5
tanker	*product*	6,000	12,000	14.0
	Aframax	7,000	13,000	15.0
	Suezmax	8,000	16,500	14.5
	VLCC	10,000	22,000	13.0
container	*1000 TEU*	5,000	9,000	15.0
	1500 TEU	7,000	13,500	15.0
	2000 TEU	10,000	18,000	24.0
	3000 TEU	13,000	27,000	24.0
	4000 TEU	16,000	35,000	24.0
LNG		15,000	50,000	20.0
car carrier/RoRo		8,000	16,000	16.0
cruise		20,000	40,000	25.0
tug/barge	*dry*	4,000	8,000	12.0
	tank	4,000	8,000	12.0

Table 3: Vessel cost and operating speed parameters.

Treatment of Unexpected Delays

When vessel operators pursue a high-risk strategy in response to dynamic management measures, their vessels may at times be subject to "unexpected" delays. When this happens, it is possible that vessels may incur additional penalties beyond the transit delay. For example, the vessel may miss its tide window for port entry or miss its scheduled terminal slot.

In our analysis, we apply the following constraints and penalties on unexpected delays, in addition to the additional transit time cost:

- **Container ships:** We assume that container ships are tide constrained and that an unexpected delay exceeding one hour results in an additional delay of one tidal cycle (12 hours). In addition, we assume a $20,000 penalty for missing the scheduled terminal slot.
- **Cruise ships:** We assume that cruise ships are schedule constrained because of passengers' travel connections and the ships' forward schedules. We apply a

$100,000 penalty when cruise ships miss their scheduled arrival time by more than three hours.

- **Tankers:** We assume that tankers are tide constrained and, in some ports, limited to daylight operations, so that an unexpected delay of more than one hour results in an additional delay of two tidal cycles (24 hours).
- **LNG ships:** We assume that LNG ships are tide constrained and that an unexpected delay of more than one hour results in an additional delay of one tidal cycle (12 hours).

These assumptions are based on discussions with port representatives and are not intended to reflect accurately the specific constraints facing particular vessels in a particular port. We believe that these assumptions are conservative and overstate the true constraints and costs in most instances.

The cost associated with additional delay time is estimated using the time charter cost in Table 3.

Traffic Management Scenarios

Final vessel traffic management measures to address right whale ship strikes have not yet been determined. For our analysis, we use a set of traffic management scenarios suggested in Russell's (23 Aug. 2001) report to the National Marine Fisheries Service on *Recommended Measures to Reduce Ship Strikes of North Atlantic Right Whales* and in 2001 meetings of the Southeast and Northeast Implementation Teams for the Recovery of the North Atlantic Right Whale.

The base case speed restriction we use is a limit of 10 knots (the recommended speed restriction from Russell (2001)). We also examine the cost associated with other speed limits ranging from 6 to 14 knots.

Northeast (Gulf of Maine)

Many right whales migrate to the Gulf of Maine and surrounding waters in early spring and stay in the area through the summer and into fall before returning south for the winter. We use the following traffic management scenarios for ports in the northeast:

- Penobscot River, Searsport, and **Portland, ME**: dynamic speed restriction over a maximum of 30 nm for 90 days/year
- Portsmouth, NH and Salem, MA: dynamic speed restriction over a maximum of 30 nm for 90 days/year
- **Boston, MA:**
  - *northern approach (to/from Gulf of Maine)*: dynamic speed restriction over a maximum of 30 nm for 90 days/year
  - *Great South Channel/Massachusetts Bay approach*: static speed restriction over 30 nm (Race Point and parts of Massachusetts Bay) for 30 days/year, plus dynamic speed restriction applied to a maximum of 30 nm of the Great South Channel for 90 days/year
  - *southern approach (to/from Cape Cod Canal)*: dynamic speed restriction over a maximum of 30 nm for 90 days/year
- Fall River, MA, Providence, RI, New London, CT, New Haven, CT, and Bridgeport, CT: static speed restriction over 25 nm for 60 days/year, plus dynamic speed restriction over a maximum of 30 nm for an additional 60 days/year

Mid-Atlantic

The mid-Atlantic region, from New York to Savannah, is primarily a migration zone for right whales moving between their northern and southern habitats. Russell (2001) recommends a speed restriction over 20 nm in the port approaches in this region. We assume a static speed restriction over 25 nm for 60 days/year (30 days each for the northward and southward migration periods) for each of the following ports:

- **New York and New Jersey**
- **Philadelphia, PA**
- **Baltimore, MD**

- **Hampton Roads, VA**
- **Wilmington, NC**
- **Charleston, SC**
- **Savannah, GA**

The 25 nm extent of the speed restriction is designed to cover the region adjacent to the coast, in which most right whales migrate.

Southeast

Ports between Brunswick and Port Canaveral lie along the right whales' southern critical habitat, where many of the whales (especially females) spend the winter. We assume the following traffic management measures for these ports:

- **Brunswick, GA:** static speed restriction over 25 nm for 120 days/year
- **Fernandina Beach, FL:** static speed restriction over 25 nm for 120 days/year
- **Jacksonville, FL:** static speed restriction over 25 nm for 120 days/year
- **Port Canaveral, FL:** static speed restriction over 5 nm for 120 days/year

The 25 nm extent of the speed restrictions covers the width of the southern critical habitat. Port Canaveral lies at the southern end of the habitat, where the habitat extends only about 5 nm offshore. We note that Russell (2001) proposes no restrictions at all for Port Canaveral.

Vessel Operating Response

Vessel operators can adopt either a "low risk" or a "high risk" strategy in response to traffic management measures. Under a low risk approach, operators include time in vessel schedules for the maximum possible delay for each transit. Under a high risk strategy, operators do not budget explicitly for dynamic traffic management delays. On most transits, they will encounter no delays at all; but when dynamic restrictions are imposed, vessels may encounter "unexpected" delays.

The high risk strategy makes sense only for dynamic management measures. Under static management scenarios, the resulting delays are certain and predictable. We assume, therefore, that operators will adopt low risk strategies in all cases expect possibly the approaches to/from Boston and Portland.

Results

Figure 1 shows the total annual cost estimated for the base case traffic management measures at the larger ports (we make an arbitrary distinction between ports with more than 250 ship calls per year and those with fewer). Annual costs at the larger ports range from about $4.8 million/year for New York/New Jersey to about $300,000/year for Portland and Wilmington. Figure 2 shows the same numbers for smaller ports, all of which have total annual costs below $60,000. The average is about $1.3 million/year for ports with more than 250 ship calls/year and $20,000 for ports with smaller volume. Among the larger ports, container ships (average $770,000/port/year) and cruise ships (average $440,000/port/year) account for the most significant costs. Dry bulk ships, tankers, LNG ships, and car carriers/RoRo ships each account for an average of $100,000 to $160,000/port/year.

The total estimated annual cost of the base case management measures along the US east coast is about $16 million. Because our assumptions have been chosen purposely to overstate likely true costs, and because ship operators will almost certainly develop more sophisticated response strategies than we have done here, these numbers overstate the true cost of the management measures. It is likely that true costs along the US east coast ultimately would be on the order of $10 million per year.

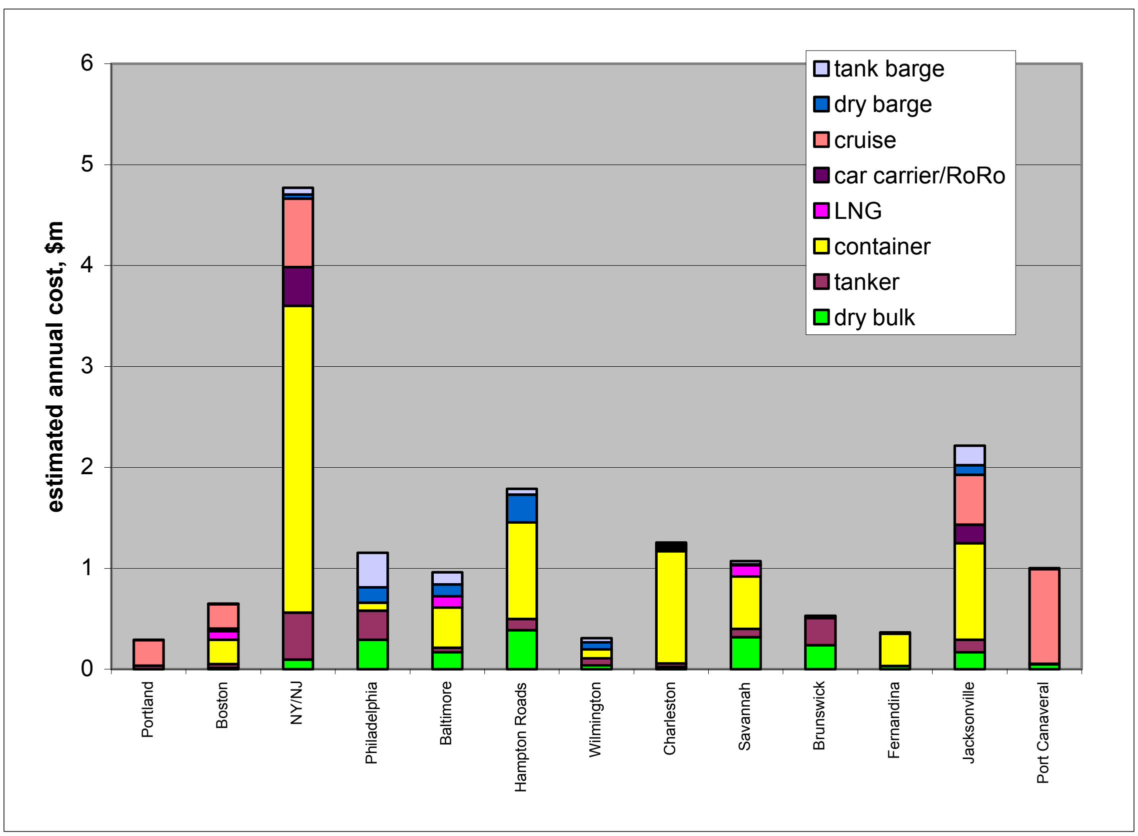

Figure 1: Annual estimated cost by port for base case traffic management measures for ports with more than 250 ship calls/year ("ship calls" does not include barge traffic).

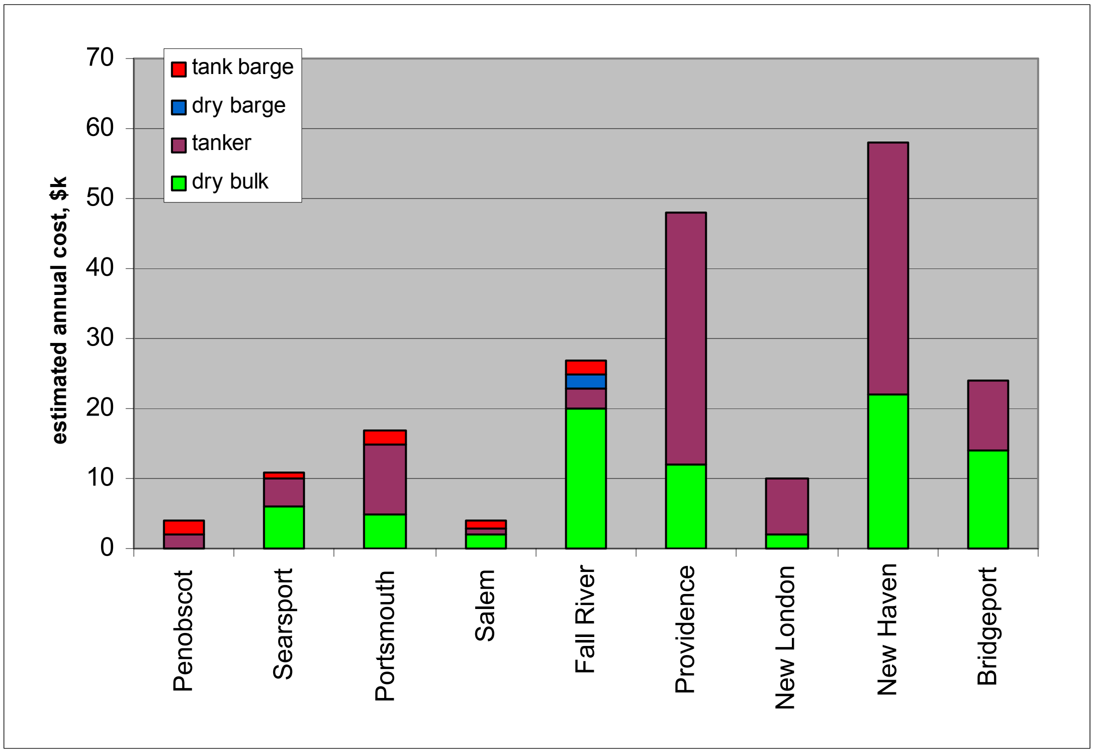

Figure 2: Annual estimated cost of base case traffic management measures for ports with fewer than 250 ship calls/year ("ship calls" does not include barge traffic).

Base case costs for smaller ports with dynamic management are based on a 10 knot speed restriction imposed over an average distance of 20 nm on one third of the days of the dynamic management season (that is, on 30 days in the Gulf of Maine ports and 20 days in the southern New England ports). The southern New England ports also face the additional base case static 10 knot speed restriction for 60 days/year.

Because traffic volume varies greatly among ports, it is useful to consider per-port call costs (Figure 3 for large ports, Figure 4 for small ports). The average cost per ship port call (not including barge traffic) for the larger ports is about $500. For most large ports, the cost is between $300 and $500 per ship call. It is significantly higher for Fernandina Beach and Jacksonville because of the length of the southeastern management season and the relative importance of faster ships (container and cruise vessels) in their traffic profiles. Philadelphia and Brunswick, by contrast, have low per ship call costs relative to their neighbors because their traffic profile is dominated by slower (bulk cargo) ships. The per ship call costs for smaller ports (Figure 4) is about $80 in the Gulf of Maine and $260 in southern New England. The difference here is due to the longer management season and the 60-day static management component in the southern New England ports.

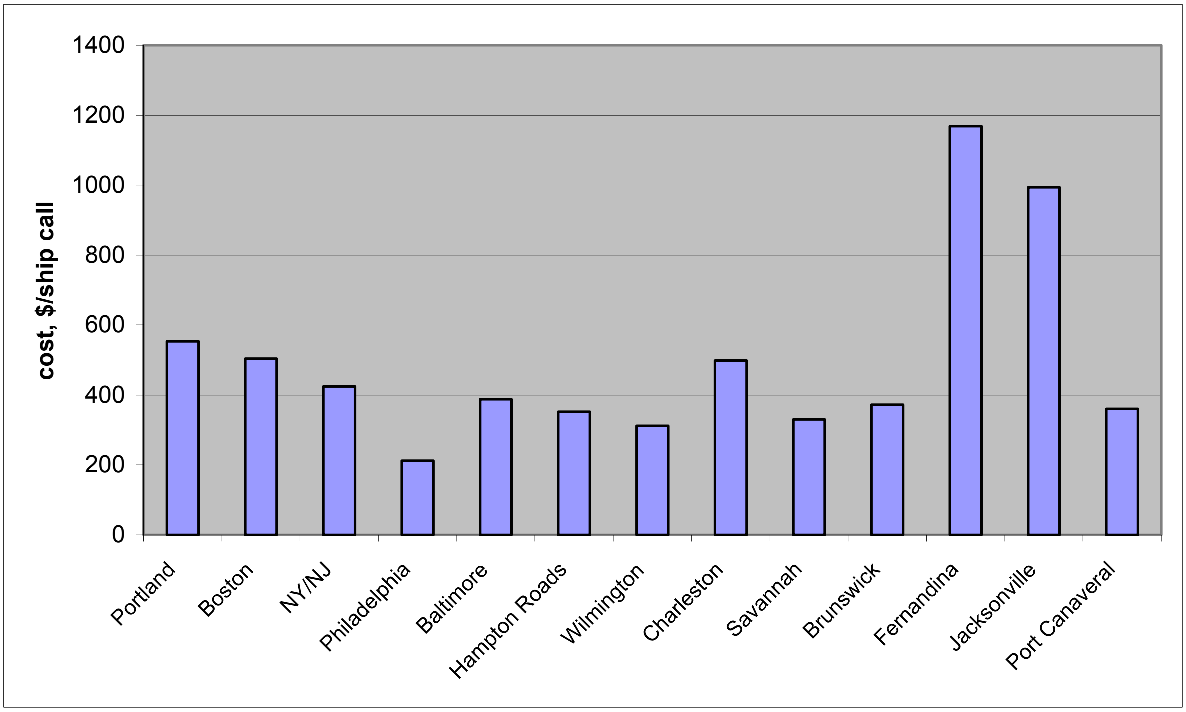

Figure 3: Estimated cost of base case traffic management measures per ship call (excluding barges, but including ship calls not affected by management measures) for ports with more than 250 ship calls/year.

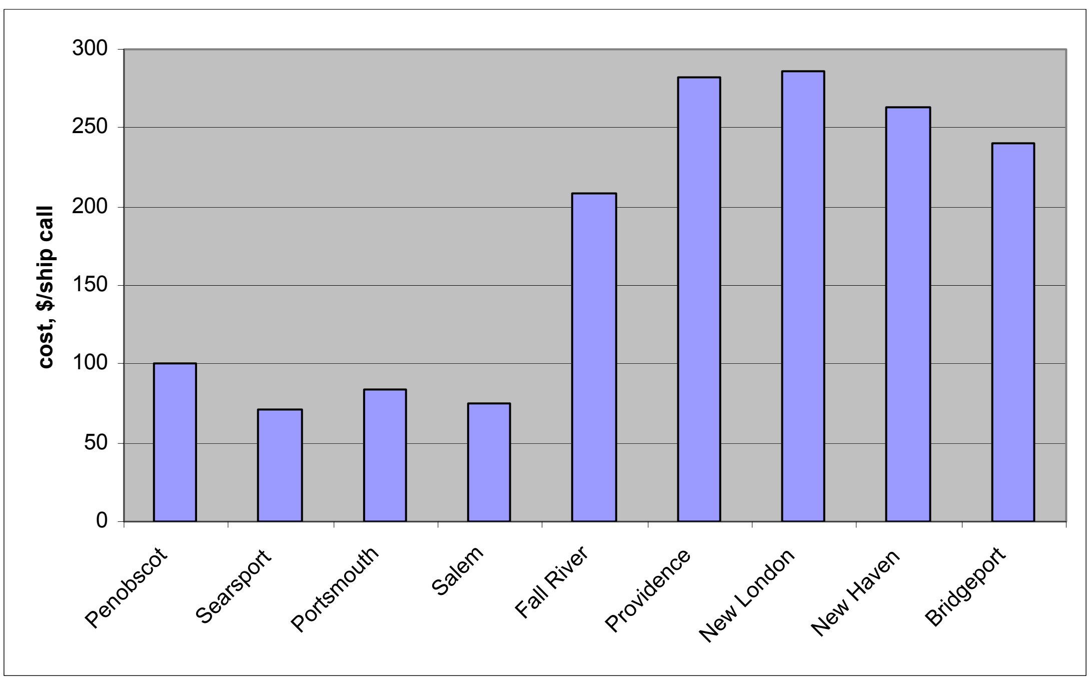

Figure 4: Estimated cost of base case traffic management measures per ship call (excluding barges, but including ship calls not affected by management measures) for ports with fewer than 250 ship calls/year.

The values shown in Figures 3 and 4 are total ship-call related delay costs divided by total ship calls for each port. The cost per **affected** port call is greater, since only a fraction of all ship calls are affected by the management measures. About 25 percent of all ship transits are potentially affected in Gulf of Maine, 16 percent in the mid-Atlantic region, and 33 percent in the Southeast. If we consider only the affected ship calls, the average cost per port call for the larger ports is $2,350, and ranges from about $3,600 in Fernandina to $1,100 in Port Canaveral. Figure 5 shows these values for the larger ports.

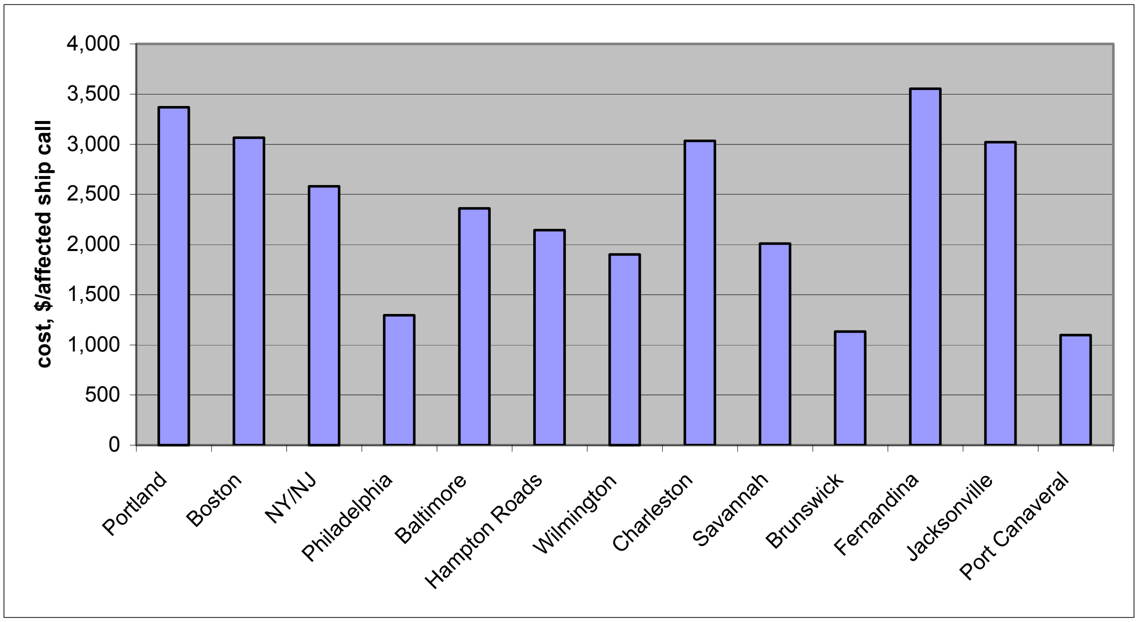

Figure 5: Estimated cost of base case traffic management measures per affected ship call for ports with more than 250 ship calls/year.

The total annual cost increase due to base case traffic management measures is less than 0.5 percent of the estimated total annual operating cost for all affected vessels. Table 4 shows estimates of this percentage for the vessel classes used in this analysis. We assume here that underway (incurring operating as well as time charter expenses) 75 percent of the time, and that bulk carriers and RoRo ships are affected on two port calls per year, container ships and tug/barges on 10 port calls, and cruise ships on 5 port calls per year.

Table 5 shows the maximum expected delays for inbound transits under the base case management regime. Faster ships suffer more significant delays when they are forced to reduce their speed. Thus, container ships, cruise ships, and LNG carriers incur the most significant time penalties, while barges, bulk carriers, and Ro/Ro ships are affected less. The approach affected most significantly is the Boston Great South Channel route, since vessels may encounter speed restrictions over a total of 60 nm (30 nm in the Race Point/Massachusetts Bay static segment and 30 nm in the Great South Channel dynamic segment).

vessel category		*delay cost per port call, $*	*number of affected port calls per year*	*total annual operating expense, $m*	*operating cost increase due to management measures, %*
dry bulk	*handy*	600	2	3.0	0.04
	handymax	800	2	4.0	0.04
	Panamax	970	2	4.8	0.04
	Cape	1,400	2	7.0	0.04
tanker	*product*	1,200	2	6.0	0.04
	Aframax	1,330	2	6.7	0.04
	Suezmax	1,630	2	8.2	0.04
	VLCC	2,130	2	10.8	0.04
container	*1000 TEU*	1,750	10	4.7	0.38
	1500 TEU	2,560	10	6.8	0.38
	2000 TEU	3,500	10	9.3	0.38
	3000 TEU	5,000	10	13.4	0.38
	4000 TEU	6,380	10	17.2	0.38
LNG		7,040	2	22.4	0.06
car carrier/RoRo		1,600	2	8.0	0.04
cruise		7,500	5	20.1	0.19
tug/barge	*dry*	400	10	4.0	0.10
	tank	400	10	4.0	0.10

Table 4: Cost increase for vessels affected by base case ship traffic management measures.

Table 5 also illustrates which vessels may incur unexpected port-related delays or penalties as a result of dynamic speed restrictions in the approaches to Portland and Boston. In most cases, these vessels will likely elect to avoid these penalties through a low-risk response strategy.

Delays encountered at the smaller ports not listed in Table 5 are 0.8 hours for dry bulk ships and tankers, and 0.4 hours for barges.

	Port	*Bos N/S*	*Bos GSC*	*NY*	*Phil*	*Bal*	*HR*	*Wil*	*Char*	*Sav*	*Brun*	*Fern*	*Jacks*	*PC*
dry bulk		0.9	1.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2
tanker	0.9	0.9	**1.7**	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8		0.8	0.2
container		**1.8**	**3.5**	1.5	1.5	1.5	1.5	1.5	1.5	1.5		1.5	1.5	
LNG			**3.0**			1.3				1.3				
Ro/Ro			1.9	0.8					0.8					
cruise	**1.8**	1.8	**3.6**	1.5					1.5				1.5	0.3
barge	0.5	0.5	1.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1

Table 5: Maximum inbound per-transit time delay, in hours, under the base case management regime. "Box N/S" refers to the northern and southern approaches, and "Bos GSC" to the Great South Channel approach, to the Port of Boston. Delays in **red/bold** indicate "unexpected" port-related delays or penalties resulting from high-risk strategies in response to dynamic management.

The following sections provide a more detailed analysis of costs for the larger ports.

Portland

The base case traffic management measure for Portland is a dynamic 10 knot speed restriction over a maximum distance of 30 nm. This restriction is triggered by detection of whales at any time during a continuous season lasting 90 days. If a 20 nm restriction is imposed on 30 of those 90 days, the estimated cost is about $290,000/year, or $554 per ship call. Cruise ships ($252,000) and tankers ($36,000) make up almost all of the traffic and the cost. All vessels except cruise ships will likely choose a high risk response strategy. With about 25 percent of Portland traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $3,370.

Because much of the Portland cruise ship traffic is a Nova Scotia ferry on stringent schedule constraints, we assume that a one hour delay (rather than the normal 3 hours) will result in a port penalty for these ships. Figure 6 illustrates how the estimated cost changes with different speed limits and effective distance of speed restriction, and under which combinations the cruise vessels might choose a low risk response.

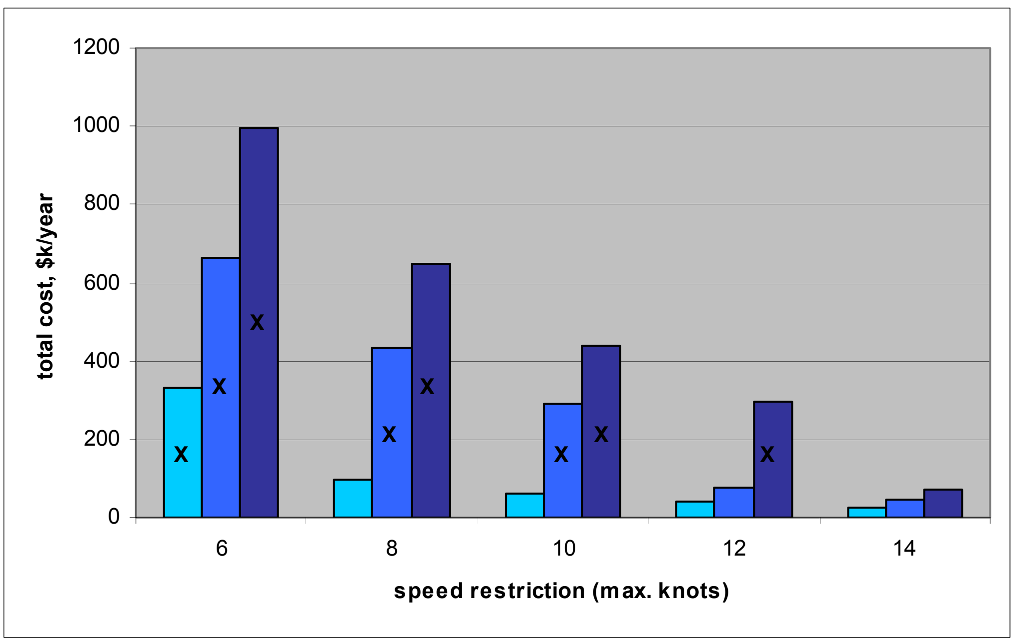

Figure 6: Annual operating cost increase due to speed restrictions for Portland traffic.
Base case: dynamic 10 knots limit over 20 nm for 30 out of 90 days/year: $292,000.
Bars marked with an "X" indicate "low risk" strategy adopted by cruise vessels.
Sensitivity analysis on effective distance of speed restriction:

speed restriction effective over:	10 nm	20 nm	30 nm

All the results in Figure 6 assume 30 days of effective limits. Variations in the number of effective days will scale the total cost linearly for the "high risk" scenarios but will have little effect on the "cruise ship low risk" scenarios (X-marked bars in Figure 6) because these cases are dominated by the low risk response of the cruise ships.

Our estimates do not include costs associated with delays of Portland-bound vessels due to traffic management measures in the Great South Channel. We were able to obtain no data on the number of Portland-bound vessels making use of the Great South Channel.

Boston

The base case traffic management measures for Boston include a dynamic 10 knot speed restriction over a maximum of 30 nm for up to 90 days/year on the northern (Gulf of Maine) and southern (Cape Cod Bay/Canal) approaches. The Great South Channel approach is managed with a static speed restriction over 30 nm (Race Point across Massachusetts Bay) for 30 days/year and a dynamic restriction on an additional (max.) 30 nm for up to 90 days/year in the Great South Channel itself. The estimated total cost of these measures, assuming a typical dynamic restriction over 20 nm on 30 days, is about $640,000/year, or $504 per ship call. Cruise ships ($242,000) and container ships ($231,000) account for most of the cost, followed by LNG ships ($84,000). With about 25 percent of Boston traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $3,070. Table 6 illustrates the contribution to total cost of each vessel type in each approach.

	northern approach (Gulf of Maine)	*southern approach (Cape Cod Canal)*	*Great South Channel approach*		**total**
			Race Point (static)	*GSC (dynamic)*	
dry bulk	3	1	6	4	**14**
tanker	16	--	13	8	**37**
container	72	--	58	101	**231**
LNG	--	--	50	34	**84**
car carrier/RoRo	--	2	15	10	**27**
cruise	136	20	44	42	**242**
dry barge	--	2	--	--	**2**
tank barge	--	4	--	--	**4**
total	**227**	**29**	**186**	**199**	**641**

Table 6: Contribution to total annual cost ($1000) of Port of Boston base case management measures by vessel type and approach.

The southern (Cape Cod Bay/Canal) approach contributes little to overall cost because it is used primarily by barge traffic. Traffic in the southern approach will respond with a high risk strategy, which results in a base case cost of $29,000/year. Even at a 6 knot speed restriction, this cost rises only to $81,000/year. The southern approach cost becomes significant ($246,000/year) only in the extreme case of a 6 knot restriction over 30 nm, in which case cruise ships will adopt a low risk strategy.

Figure 7 illustrates how the cost of dynamic speed restriction on the northern approach changes with different speed limits and effective distance of the restriction. The base case – a 10 knot dynamic limit imposed over 20 nm on 30 days out of a 90 day season – results in an estimated cost of $227,000/year. Container vessels are likely to adopt a low risk strategy in all scenarios marked with “X” in Figure 7. Tankers are likely to do the same at the 8 knot limit over 20 and 30 nm, and possibly at the 6 knot limit over 20 nm. Cruise ships will adopt a low risk strategy only for the 30 nm, 6 knot limit scenario.

The Great South Channel approach includes a static and a dynamic segment. Figure 8 shows the annual cost of the static segment from Race Point across Massachusetts Bay for a variety of scenarios. The base case, a 10 knot restriction imposed for 30 days/year over 30 nm, results in a total cost of $186,000/year.

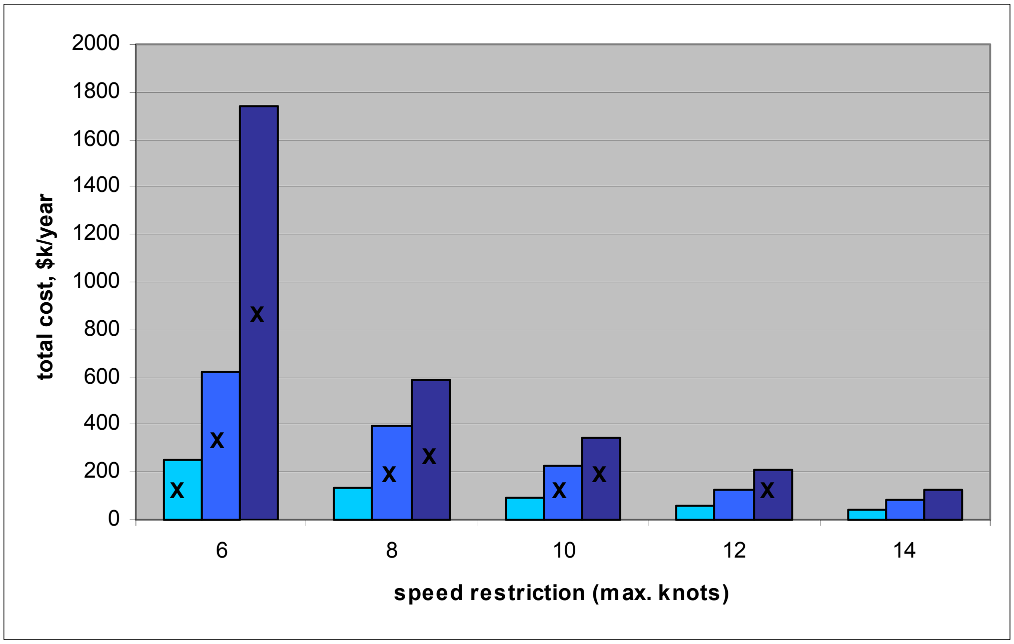

Figure 7: Annual operating cost increase due to dynamic speed restrictions for Boston northern approach (to/from Gulf of Maine). Base case: 10 knots limit over 20 nm for 30 out of 90 days/year: $227,000. Low risk strategy is pursued by various vessels in scenario marked with "X" (see text for details). Sensitivity analysis on effective distance of speed restriction:

speed restriction effective over:	10 nm	20 nm	30 nm

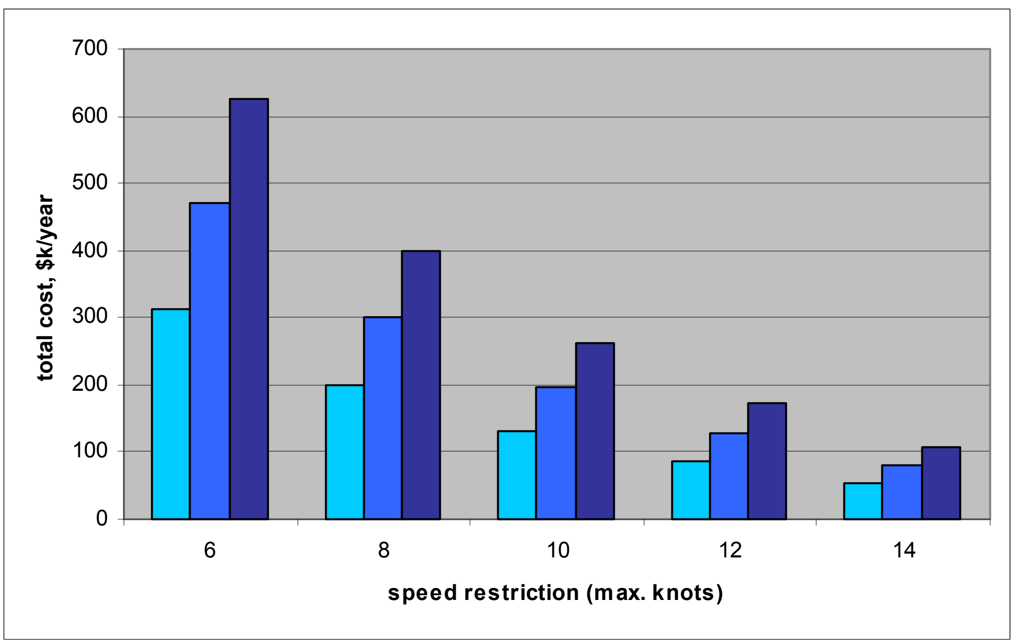

Figure 8: Cost of static speed restriction around Race Point and across Massachusetts Bay in the Great South Channel approach to Boston. Base case: 10 knot limit imposed over 30 nm for 30 days/year: $186,000. Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 30 days/year, and	20 nm	30 nm	40 nm
speed restriction over 30 nm, and	20 days/year	30 days/year	40 days/year

Figure 9 illustrates the cost associated with dynamic management in the Great South Channel itself. The base case – a 10 knot restriction imposed over 20 nm on 30 days out of a 90 day season – results in an estimated cost of $199,000/year. Container ships are expected to adopt low risk strategies under all scenarios marked with an "X" in Figure 9. LNG ships will do the same, except under a 12 knot restriction or if a 10 knot restriction extends only for 20 nm. Product tankers adopt a low risk strategy at 6 and 8 knots over 20 or 30 nm, and cruise ships may do so in the extreme case of a 6 knot restriction over 30 nm.

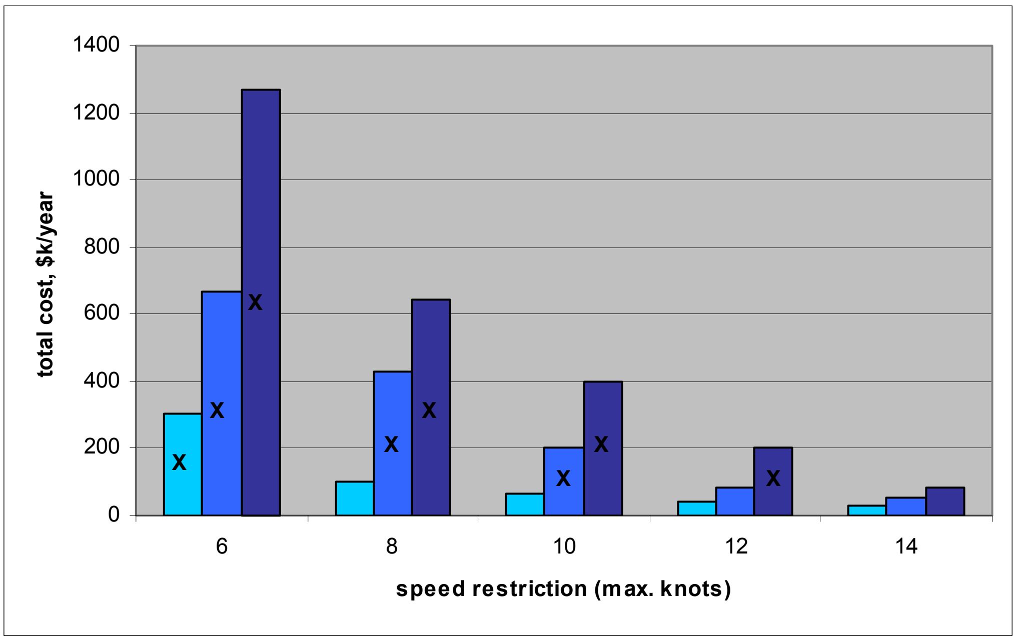

Figure 9: Cost of dynamic speed restriction in Great South Channel imposed for 30 days/year out of a 90 day season. Base case cost (10 knots, 20 nm): $199,000/year.
Bars marked with an "X" represent "low risk" response by operators (see text for details).
Sensitivity analysis on effective distance of speed restriction:

speed restriction effective over:	10 nm	20 nm	30 nm

Great South Channel traffic has, in theory, the option of avoiding the Race Point and GSC management measures by diverting around Georges Bank. This traffic would then face the dynamic management imposed on traffic bound for Boston via the northern approach. The cost of this diversion is estimated to be in excess of $4 million/year, and this option is therefore not likely to be considered seriously by operators.

New York/New Jersey

The base case traffic management measure for the Port of New York and New Jersey is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of approximately $4.8 million/year, or $424 per ship call. Container ships ($3.0 million) account for most of the cost, followed by cruise ships ($680,000), tankers ($470,000), and car carriers/RoRo ships ($380,000). With about 16 percent of New York traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $2,580. Figure 10 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

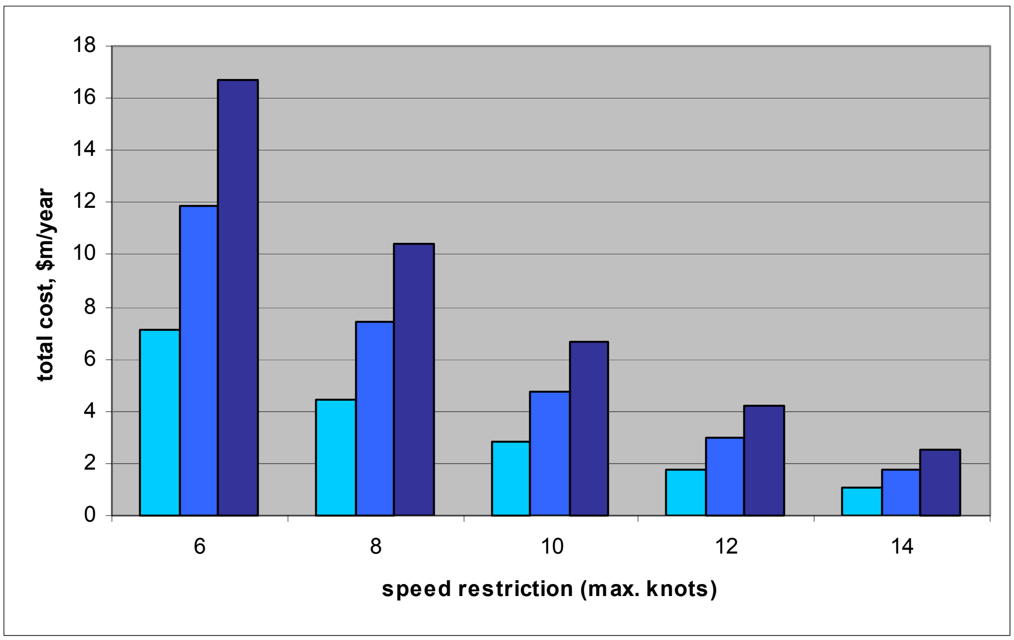

Figure 10: Annual operating cost increase due to speed restrictions for New York/New Jersey traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $4,771,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Our estimates do not include costs associated with delays of New York-bound vessels due to traffic management measures in the Great South Channel. We were able to obtain no data on the number of New York-bound vessels making use of the Great South Channel.

Philadelphia

The base case traffic management measure for Philadelphia is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of approximately $1.2 million/year, or $213 per ship call. Tank barges ($342,000), dry bulk ships ($293,000), and tankers ($286,000) account for most of the cost. With about 16 percent of Philadelphia traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $1,290. Figure 11 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

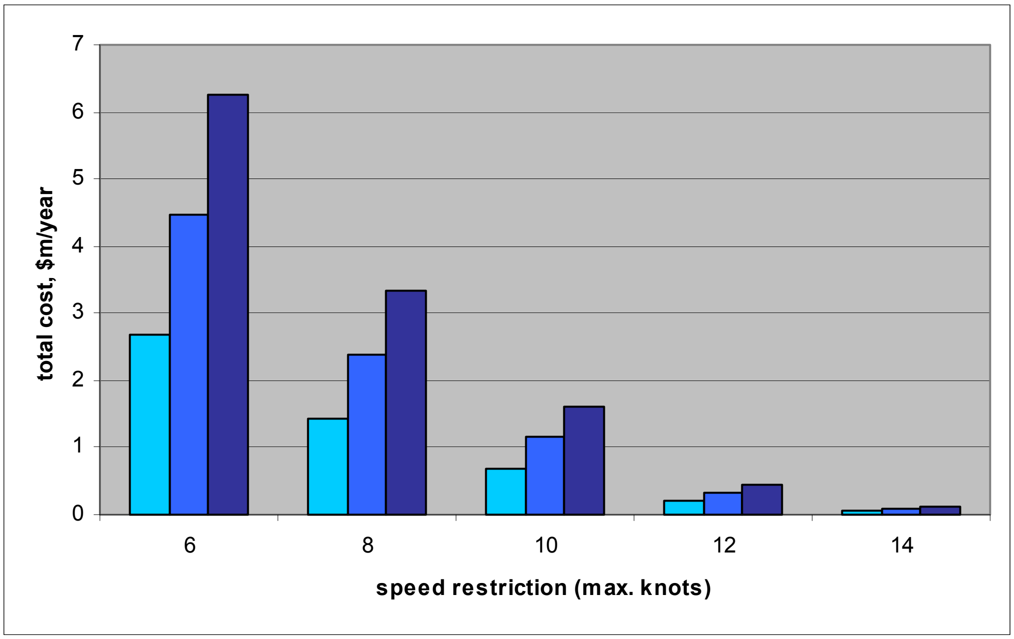

Figure 11: Annual operating cost increase due to speed restrictions for Philadelphia traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $1,152,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Baltimore

The base case traffic management measure for Baltimore is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of about $960,000/year, or $388 per ship call. Container ($400,000) and dry bulk ships ($170,000) account for most of the cost, followed by tank barges ($123,000), dry barges ($116,000), and LNG ships ($111,000). With about 16 percent of Baltimore traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $2,360. Figure 12 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

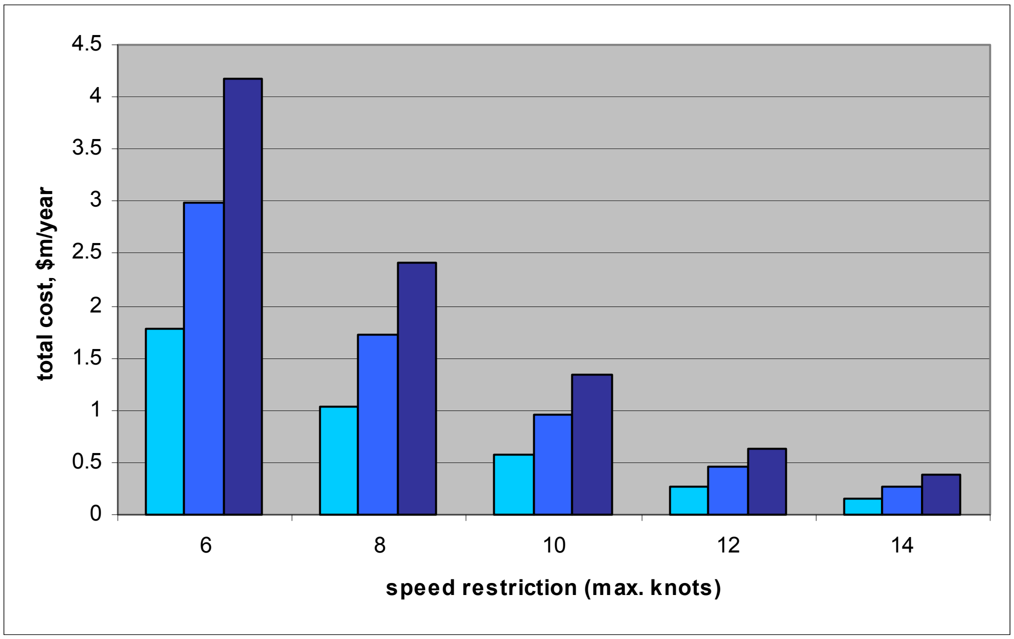

Figure 12: Annual operating cost increase due to speed restrictions for Baltimore traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $962,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Hampton Roads

The base case traffic management measure for Hampton Roads is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of approximately $1.8 million/year, or $353 per ship call. Container ($959,000) and dry bulk ships ($385,000) and dry barges ($274,000) account for most of the cost. With about 16 percent of Hampton Roads traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $2,150. Figure 13 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

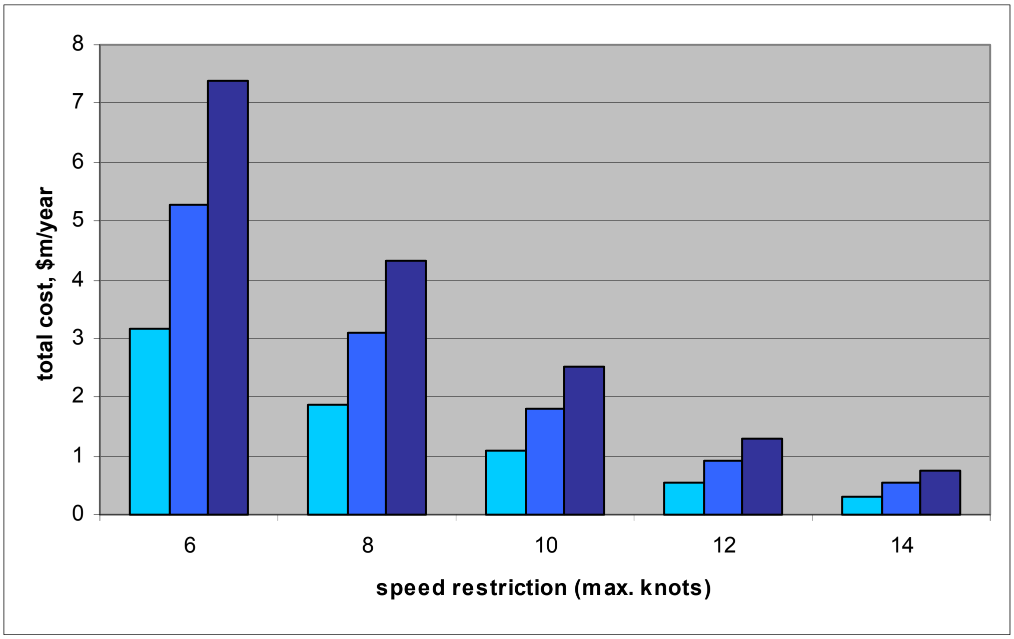

Figure 13: Annual operating cost increase due to speed restrictions for Hampton Roads traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $1,789,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Wilmington, North Carolina

The base case traffic management measure for Wilmington is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of about $310,000/year, or $312 per ship call. Container ships ($88,000), tankers ($70,000), and dry barges ($68,000) account for most of the cost. With about 16 percent of Wilmington traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $1,900. Figure 14 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

Figure 14: Annual operating cost increase due to speed restrictions for Wilmington traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $306,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Charleston

The base case traffic management measure for Charleston is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of approximately $1.3 million/year, or $499 per ship call. Container ships ($1,112,000) account for most of the cost. With about 16 percent of Charleston traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $3,030. Figure 15 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

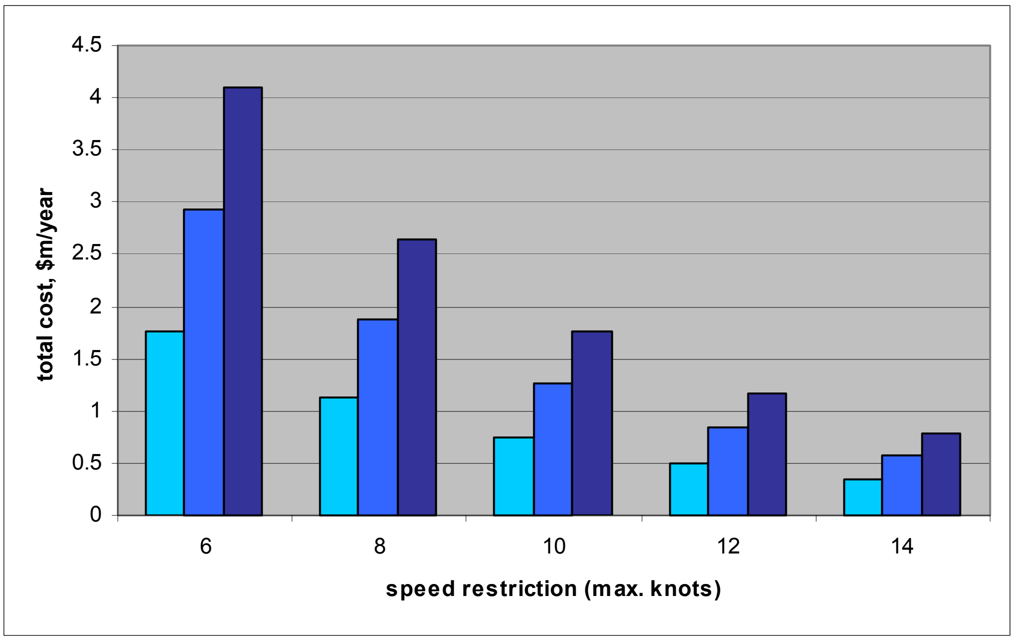

Figure 15: Annual operating cost increase due to speed restrictions for Charleston traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $1,255,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Savannah

The base case traffic management measure for Savannah is a static 10 knot speed restriction over 25 nm for 60 days/year, with an estimated cost of approximately $1.1 million/year, or $330 per ship call. Container ($519,000) and dry bulk ships ($316,000) account for most of the cost. With about 16 percent of Savannah traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $2,010. Figure 16 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

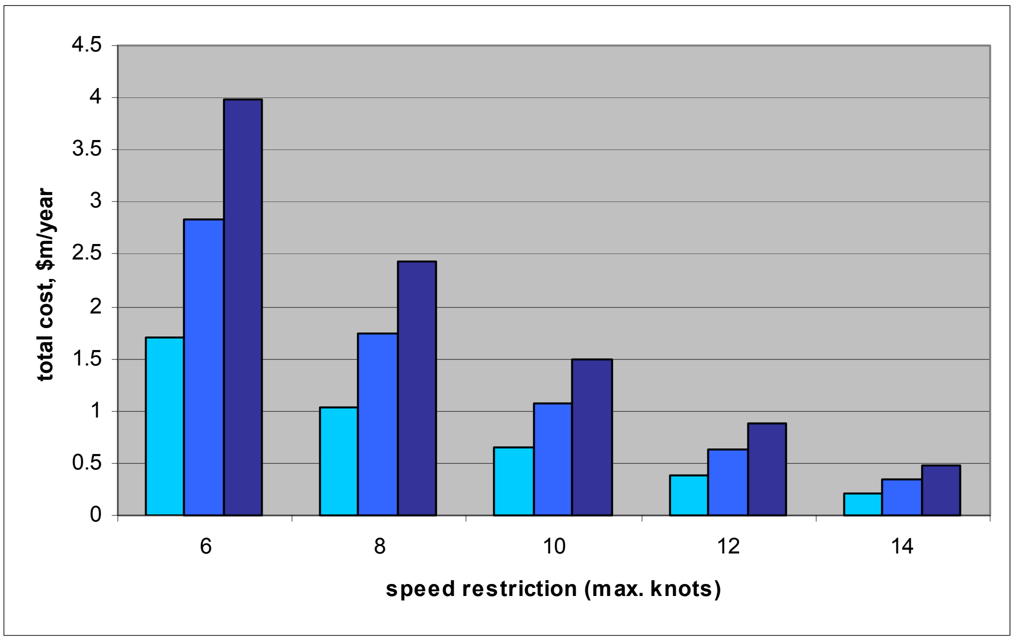

Figure 16: Annual operating cost increase due to speed restrictions for Savannah traffic.
Base case: 10 knots limit over 25 nm for 60 days/year: $1,072,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 60 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	36 days/year	60 days/year	84 days/year

Brunswick

The base case traffic management measure for Brunswick is a static 10 knot speed restriction over 25 nm for 120 days/year, with an estimated cost of about $500,000/year, or $373 per ship call. Tankers ($269,000) and dry bulk ships ($237,000) account for most of the cost. With about 33 percent of Brunswick traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $1,130. Figure 17 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

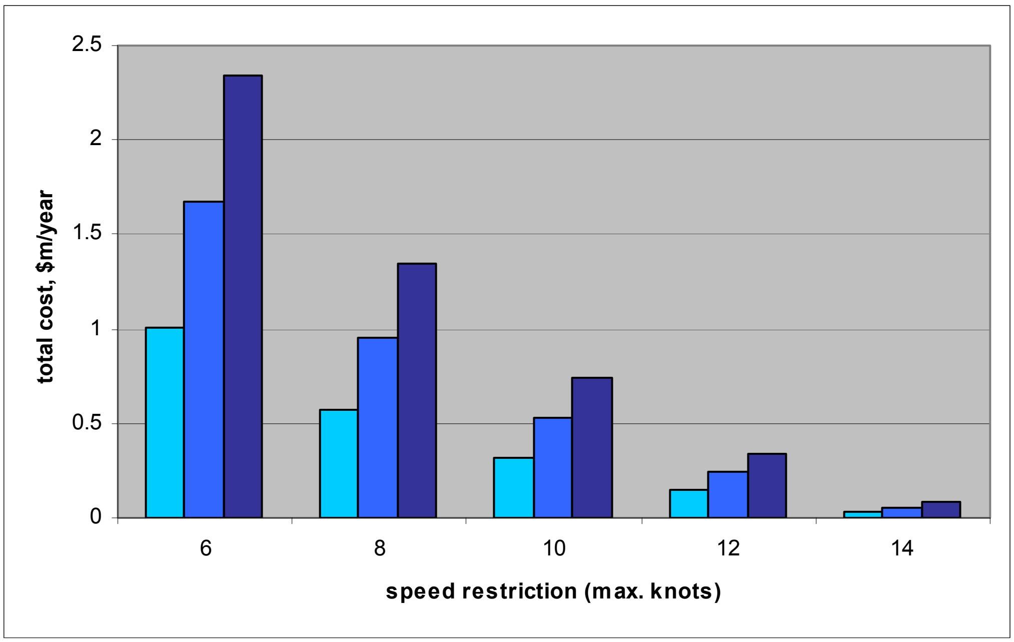

Figure 17: Annual operating cost increase due to speed restrictions for Brunswick traffic.
Base case: 10 knots limit over 25 nm for 120 days/year: $503,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 120 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	72 days/year	120 days/year	168 days/year

Fernandina Beach

The base case traffic management measure for Fernandina Beach is a static 10 knot speed restriction over 25 nm for 120 days/year, with an estimated cost of about $370,000/year, or $1,168 per ship call. Container ships ($320,000) account for most of the cost. With about 33 percent of Fernandina traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $3,550. Figure 18 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

Figure 18: Annual operating cost increase due to speed restrictions for Fernandina Beach traffic.
Base case: 10 knots limit over 25 nm for 120 days/year: $366,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 120 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	72 days/year	120 days/year	168 days/year

Jacksonville

The base case traffic management measure for Jacksonville is a static 10 knot speed restriction over 25 nm for 120 days/year, with an estimated cost of approximately $2.2 million/year, or $993 per ship call. Container ships ($959,000) and cruise ships ($493,000) account for most of the cost, followed by tank barges ($192,000), car carriers ($184,000), and dry bulk ships ($166,000). With about 33 percent of Jacksonville traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $3,020. Figure 19 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

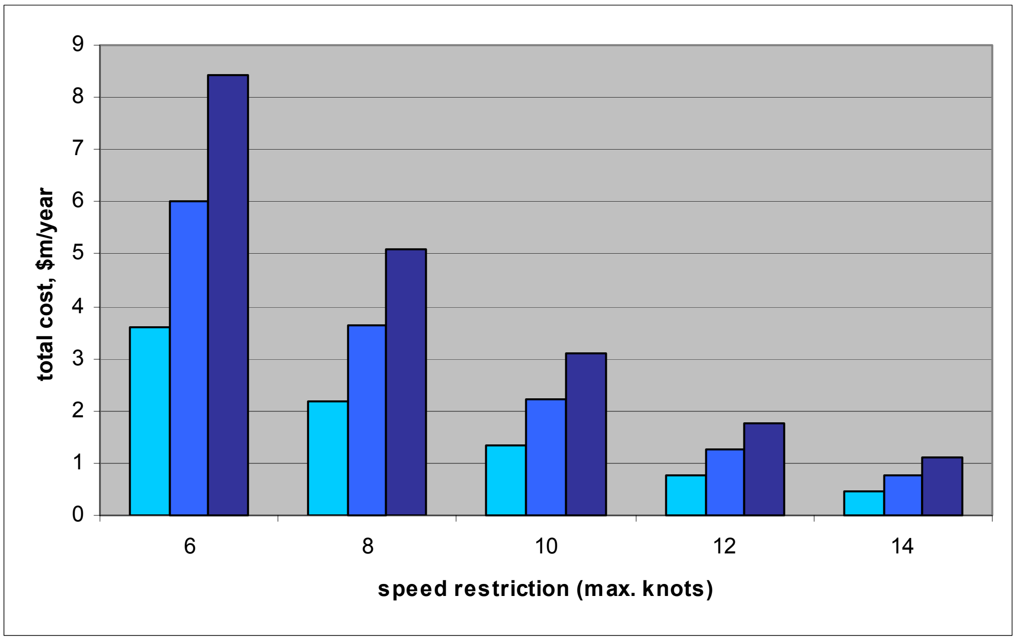

Figure 19: Annual operating cost increase due to speed restrictions for Jacksonville traffic.
Base case: 10 knots limit over 25 nm for 120 days/year: $2,215,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 120 days/year, and	15 nm	25 nm	35 nm
speed restriction over 25 nm, and	72 days/year	120 days/year	168 days/year

Port Canaveral

The base case traffic management measure for Port Canaveral is a static 10 knot speed restriction over 5 nm for 120 days/year, with an estimated cost of approximately $1.0 million/year, or $361 per ship call. Cruise ships ($937,000) account for most of the cost. With about 33 percent of Canaveral traffic potentially affected by the base case management measures, the estimated average cost per affected ship call is $1,100. Figure 20 illustrates how the estimated cost changes with different speed limits, effective distance of speed restriction, and time duration of the restriction.

We note that Russell (2001) recommends no traffic management measures of any kind for Port Canaveral because the port's sea buoy, at which ships slow to take on a pilot, is near the outer edge of the right whale critical habitat.

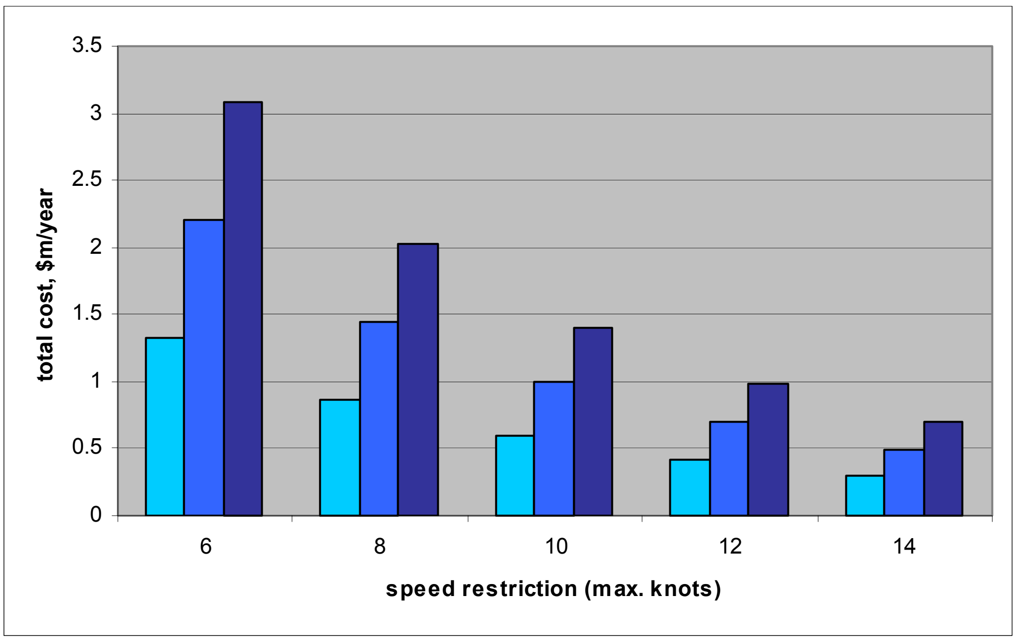

Figure 20: Annual operating cost increase due to speed restrictions for Port Canaveral traffic.
Base case: 10 knots limit over 5 nm for 120 days/year: $1,002,000.
Sensitivity analysis on effective distance and duration of speed restriction:

restriction in place 120 days/year, and	3 nm	5 nm	7 nm
speed restriction over 5 nm, and	72 days/year	120 days/year	168 days/year

References

Fujiwara, M. and H. Caswell. 2001. Demography of the endangered North Atlantic right whale. *Nature* 414:537-41.

Russell, Bruce A. 2001. Recommended measures to reduce ship strikes of North Atlantic Right Whales. Submitted to the National Marine Fisheries Service via the Northeast and Southeast Implementation Teams for the Recovery of the North Atlantic Right Whale. 23 August 2001.

Appendix A: Port Data

Sources: Cargo movements: US Army Corps of Engineers *Waterborne Commerce of the United States*; container cargo movements: *Containerization International Yearbook* 1998; facilities: US Army Corps of Engineers & Containerization International.

	Penobscot River, ME	*Searsport Harbor, ME*	*Portland, ME*	*Portsmouth, NH*
cargo moved, 1999, 1000s short tons	**1,102**	**1,302**	**20,347**	**4,656**
petroleum and petroleum products	989	1,006	19,658	2,608
coal				
chemicals & related products				
crude materials, inedible except fuels		176		1,330
primary manufactured goods				
food and farm products				
manufactured equipment & products				
container cargo, 1997				
TEU moved				
tonnage moved				
facilities				
controlling channel depth, ft, 1999	18	34	45	33
official project depth, ft, 1999	22	35	45	35
total container berth length				
container cranes				
terminal facility area, $m^2 * 10^6$				

	Salem, MA	*Boston, MA*	*Fall River, MA*	*Providence, RI*
cargo moved, 1999, 1000s short tons	**1,423**	**20,716**	**3,384**	**8,584**
petroleum and petroleum products	552	16,606	280	7,206
coal	864		3,055	
chemicals & related products				
crude materials, inedible except fuels		1,303		683
primary manufactured goods		1,220		638
food and farm products				
manufactured equipment & products				
container cargo, 1997				
TEU moved		136,722		
tonnage moved, 1000s short tons		997		
facilities				
controlling channel depth, ft, 1999	30	36	25	30
official project depth, ft, 1999	32	40	35	40
total container berth length, m		821		
container cranes		5		
terminal facility area, $m^2 * 10^6$		0.4		

	New London, CT	*New Haven, CT*	*Bridgeport, CT*	*New York and New Jersey*
cargo moved, 1999, 1000s short tons	**1,731**	**8,563**	**4,133**	**101,893**
petroleum and petroleum products	835	6,867	3,256	68,647
coal	612			
chemicals & related products				
crude materials, inedible except fuels	126	523	586	6,285
primary manufactured goods		1,098		5,543
food and farm products				7,395
manufactured equipment & products				6,408
container cargo, 1997				
TEU moved				2,518,750
tonnage moved, 1000s short tons				15,401
facilities				
controlling channel depth, ft, 1999	20	30	30	35
official project depth, ft, 1999	23	35	35	35
total container berth length, m				7,454
container cranes				45
terminal facility area, m^2*10^6				5.1

	Philadelphia, PA	*Wilmington, DE*	*Baltimore, MD*	*Hampton Roads, VA*
cargo moved, 1999, 1000s short tons	**86,639**	**4,323**	**26,824**	**43,646**
petroleum and petroleum products	66,756	924		3,490
coal			7,810	27,293
chemicals & related products				
crude materials, inedible except fuels		791	8,797	2,610
primary manufactured goods	6,832	318	3,383	2,885
food and farm products	2,627	1,911	2,110	2,497
manufactured equipment & products	528	231	1,740	2,805
container cargo, 1997				
TEU moved	95,086	168,000	484,300	1,208,000
tonnage moved, 1000s short tons	855	1,150	4,373	9,400
facilities				
controlling channel depth, ft, 1999	38	33	45	45
official project depth, ft, 1999	40	40	50	45
total container berth length, m	1,373	475	3,977	2,927
container cranes	8	1	25	13
terminal facility area, m^2*10^6	0.7	1.0	4.1	3.7

	Wilmington, NC	*Charleston, SC*	*Savannah, GA*	*Brunswick, GA*
cargo moved, 1999, 1000s short tons	**6,145**	**19,613**	**17,752**	**2,108**
petroleum and petroleum products	2,147	3,307	3,523	
coal				
chemicals & related products	2,083	3,036	1,542	68
crude materials, inedible except fuels	1,275	3,819	5,672	1,321
primary manufactured goods	453	3,764	2,904	201
food and farm products	289	2,209	1,578	184
manufactured equipment & products	249	3,398	1,976	334
container cargo, 1997				
TEU moved	103,588	1,151,401	650,253	
tonnage moved, 1000s short tons	722	9,412	4,965	
facilities				
controlling channel depth, ft, 1999	38	40	38	30
official project depth, ft, 1999	40	40	38	
total container berth length, m		3,102	1,978	
container cranes	8	20	11	
terminal facility area, $m^2 * 10^6$	1.6	2.1	3.4	

	Fernandina Beach, FL	*Jacksonville, FL*	*Port Canaveral, FL*
cargo moved, 1999, 1000s short tons	**502**	**17,096**	**3,344**
petroleum and petroleum products		7,813	1,419
coal		1,361	
chemicals & related products	35	833	
crude materials, inedible except fuels	58	1,982	454
primary manufactured goods	296	1,414	1,236
food and farm products	29	1,289	225
manufactured equipment & products	81	2,390	
container cargo, 1997			
TEU moved	18,661	607,942	
tonnage moved, 1000s short tons	170	3,665	
facilities			
controlling channel depth, ft, 1999	32	34	36
official project depth, ft, 1999	32	34	36
total container berth length, m	400		
container cranes	3	13	
terminal facility area, $m^2 * 10^6$	0.1	0.6	