Compliance with Vessel Speed Restrictions to Protect North Atlantic Right Whales

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ABSTRACT: Environmental regulations can only be effective if they are adhered to, but the motivations for regulatory compliance are not always clear. We assessed vessel operator compliance with a December 2008 regulation aimed at reducing collisions with the endangered North Atlantic right whale that requires vessels 65 feet or greater in length to travel at speeds of 10 knots or less at prescribed times and locations along the U.S. eastern seaboard. Extensive outreach efforts were undertaken to notify affected entities both before and after the regulation went into effect. Vessel speeds of 201,862 trips made between November 2008 and August 2013 by 8,009 individual vessels were quantified remotely, constituting a nearly complete census of transits made by the regulated population. Of these, 437 vessels (or their parent companies), some of whom had been observed exceeding the speed limit, were contacted through one of four non-punitive information programs. A fraction (n=26 vessels/companies) received citations and fines. Despite the efforts to inform mariners, initial compliance was low (<5% of the trips were completely <10 knots) but improved in the latter part of the study. Each notification/enforcement program improved compliance to some degree and some may have influenced compliance across the entire regulated community. Citations/fines appeared to have the greatest influence on improving compliance in notified vessels/companies, followed in order of effectiveness by enforcement-office information letters, monthly summaries of vessel operations, and direct at-sea radio contact. Trips by cargo vessels exhibited the greatest change in behavior followed by tanker and passenger vessels. These results have application to other regulatory systems, especially where remote monitoring is feasible, and any setting where regulatory compliance is sought.

INTRODUCTION

Natural resource conservation and management can take numerous forms, including through environmental regulations. However, environmental regulations are only effective if they are adhered to. A substantial body of socio-legal and economic literature has been devoted to the subject of regulatory compliance, but the factors that motivate individuals and businesses to comply are not always clear (Gunningham & Kagan, 2005; May, 2005). Compliance case studies have involved industrial pollution (Kagan et al., 2011), hazardous waste (Stafford, 2012), agricultural practices (Winter & May, 2001), forestry (Purdy, 2010; Peterson & Diss-Torrance, 2012), fisheries (Honneland, 1999; Ali & Abdullah, 2010), and endangered species conservation (Langpap, 2006; Innes & Frisvold, 2009), among others.

Some studies concluded that regulated communities may lack an understanding of the requirements or may lack the willingness or capacity to comply (Burby & Patterson, 1993; Brehm & Hamilton, 1996); others found that regulated entities may avoid complying because the consequences of noncompliance (i.e., enforcement actions) rarely outweigh the economic benefits of business as usual (Winter & May, 2001; Tyler 2006). However, in many regulatory settings, limited resources may restrict enforcement actions and assessments of compliance to infrequent inspections (e.g., site visits), surveys, interviews, or self-reporting (Winter & May, 2001; Gunningham et al., 2004; Gray & Shimshack, 2011).

With regard to living marine resources, including endangered large whale protective measures, risk assessment estimates have been conducted (van der Hoop et al., 2012; Redfern et al., 2013). But, there is also a need to ensure large whale conservation regulations are meeting their objectives through compliance.

The Problem of Vessel Collisions with Large Whales

Hundreds of fatal vessel collisions (or "strikes") with large whales have been reported, worldwide (Laist et al., 2001; Van Waerebeek et al., 2007). In fact, the actual number of strikes is likely far greater than the reported number because many go undetected or unreported. Collisions

66 with ships are a serious threat to the recovery of the highly depleted North Atlantic right whale

67 (*Eubalaena glacialis*) (Kraus et al., 2005) and collisions along with incidental entanglement in

68 commercial fishing gear, have retarded the recovery of this species (NMFS, 2005). A link has

69 been established between vessel speed and the likelihood of death of a vessel-struck whale

70 whereby the probability of death of a whale involved in a collision increases as vessel speed

71 increases (Vanderlaan & Taggart, 2007; Conn & Silber, 2013).

72   To address the threat to the recovery of the North Atlantic right whale, the National

73 Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS)

74 issued regulations in November 2008 requiring all vessels 65 feet (19.8m) and greater in length

75 to travel at 10 knots or less in areas where North Atlantic right whales and high vessel density

76 co-occur (NMFS, 2008). These areas, called seasonal management areas (SMA), are located

77 along the east coast of the U.S. Atlantic seaboard and are active for fixed periods of the year that

78 correspond with seasonal North Atlantic right whale migration, feeding, calving and nursery

79 activities (Fig. 1). The regulations are broad in geographic scope and affect a substantial number

80 of entities, including nearly all tanker, cargo (e.g., container ships, vehicle transport vessels),

81 passenger vessels, and ferries engaged in international and domestic transport of goods and

82 people entering major U.S. ports.

83 ***Notifying the Affected Community***

84   Extensive efforts by a number of agencies were made – both prior to the regulations

85 going into effect and on an ongoing basis while they were in effect -- to notify the affected

86 community about the speed regulations that included an array of broadcast, print, and electronic

87 media outlets (Appendix 1; Silber & Bettridge, 2012). Knowledge of, and adherence to, the

88 requirements, precautions, and safety-at-sea provisions contained in a number of the print and

89 broadcast notification outlets (e.g., U.S. Coast Pilot publications, Broadcast Notice to Mariners)

90 is mandatory for any vessel sailing in U.S. waters. Most vessels studied here are engaged in

regular and periodic domestic and international routes that would have resulted in repeated

exposure to notification about the speed regulations. Given the breadth of the notification

efforts, we believe vessel operators should have had ample knowledge of the requirements.

Compliance Information and Enforcement Programs

After the restrictions went into effect, a subset of the regulated vessel operators or their

companies received notifications and/or citations/fines under one of the information and/or

enforcement programs described below when violations of the rule were detected. The programs

were independently developed and carried out by four federal entities: two by NOAA's Offices

of General Counsel and Law Enforcement, and one each by the United States Coast Guard

(USCG) and NMFS's Office of Protected Resources (OPR). There was no standardization or

coordination between programs regarding protocols for notifying particular vessels/companies or

the identity of operators being contacted. Each of these programs/activities is described

immediately below in the chronological order in which they were first implemented.

Hailing At-Sea: In four periods during the first five years of the regulations (February-May 2009,

January-July 2010, November 2010-July 2011, and January-March 2012), USCG personnel

radioed vessels that were observed (detected via radar, AIS, and/or visually) violating the speed

restrictions and requested that the vessels slow to appropriate speeds. It was the only program

involving real-time, verbal notification. It was also somewhat limited in scope, having been

conducted in only six of 10 SMAs (the Great South Channel, Race Point, Cape Cod Bay,

Philadelphia, Norfolk, and North Carolina to Georgia) and only when USCG cutters were on

routine patrols or engaged in other missions.

Community Oriented Policing and Problem Solving (COPPS) Letters: As part of its Community

Oriented Policing and Problem Solving (COPPS) Program, NOAA's Office of Law Enforcement

(OLE) sent a total of 85 letters between September 2009 and January 2010 to companies whose

vessel operators were determined by OLE agents (based on AIS data analysis) to have made at

least one trip in an SMA that far exceeded the 10-knot limit. The letters were informative rather

than punitive, and included detailed information regarding the observed violation(s) and a

reminder about the speed restrictions.

Notice of Violation and Assessment of Civil Penalties (NOVA): To prosecute violations of the

Endangered Species Act, NOAA's Office of General Counsel Enforcement Section can issue a

Notice of Violation and Assessment of civil penalties (NOVA). A NOVA charges the respondent

with a violation of laws and regulations, and assesses a civil monetary penalty in accordance

with the agency's penalty policy for that violation

(http://www.gc.noaa.gov/documents/031611_penalty_policy.pdf). Limited staff time required

that attention be focused on a small number of vessels that exhibited numerous and flagrant

breaches of the speed restrictions (as indicated by AIS), even though hundreds of violations were

observed. Multiple offending trips were often cited in the NOVAs and fines were cumulative.

Depending on the number of violations, penalties ranged from $5,750 to $92,000 (mean =

$21,845) (www.gc.noaa.gov/enforce-office3.html). A total of 28 NOVAs were issued between

November 2010 and September 2012 (and used to examine recipients' operations described

below): seven in November 2010; two in December 2010 (those issued in November and

December 2010 were defined as "season 3" for our purposes); eight in November 2011 (season

4); one in July 2012; three in August 2012; and seven in September 2012 (these latter three

collectively were considered season 5). NOVAs issued in 2013 were not included in this

analysis.

Monthly Summaries of Vessel Operations: In collaboration with the World Shipping Council

(WSC) and Chamber of Shipping of America (CSA), two industry trade associations that

represent more than 90% of the world's international commercial shipping fleet, NMFS's OPR

developed a program to disseminate AIS-based vessel operations information to WSC and CSA

140 member companies. A total of 17 shipping companies (13 WSC and 4 CSA members; ca. 400

141 vessels) participated in the program. Starting in December 2010, and monthly for the duration of

142 the study, OPR sent reports directly to company officials containing spreadsheet summaries of

143 every vessel transit within active SMAs (regardless of whether the trip was compliant with the

144 regulation) during the previous month which included: vessel name; date/time of entry into the

145 SMA; distance traveled within the SMA; speeds when entering and exiting the SMA; and the

146 mean and maximum speeds within the SMA.

Study Objectives

148   We sought to assess compliance by the regulated community by examining the response

149 to the vessel speed restrictions. Using a remote monitoring program that provided a near-

150 complete census of vessel operations, we quantified vessel operations in SMAs during the first

151 five years of the regulations. In addition to quantifying overall compliance with the regulations,

152 we assessed whether compliance to the regulations changed over time and whether attempts to

153 improve compliance through the targeted notification and enforcement programs produced a

154 change in behavior.

MATERIALS AND METHODS

Monitoring Vessel Operations

157   We examined vessel behavior using Automatic Identification System (AIS) data. AIS is a

158 navigational safety system that transmits very high frequency (VHF) radio signals several times

159 each minute. Each transmission contains static information specific to a given vessel which

160 allowed us to assess compliance by individual vessels and more generally by principal vessel

161 types. The signal also includes dynamic Global Positioning System-linked data unique to a

162 particular voyage including location, heading, and speed (Aarsæther & Moan 2009). Functioning

163 AIS capabilities are required by the International Maritime Organization on all vessels ≥ 300

164 gross tons, and the USCG requires AIS on nearly all vessels sailing in U.S. waters. The USCG

165 has established a national network of AIS receivers that provides coverage of nearly all U.S.

166 coastal waters, a continuously sampled record of operations, and, for us, a nearly complete

167 census of the community subject to the speed limits. The AIS's reporting rates provided

168 hundreds of records per trip and resulted in a large and rather precise record of vessel speed and

169 operations.

Assessing Compliance

171   Using AIS data collected between November 1, 2008 and August 1, 2013, we analyzed

172 all trips by vessels ≥65 feet in length that were located within the geographic boundaries of the

173 SMAs (our analytical approach is described further in Silber & Bettridge 2010). A trip located in

174 an active SMA was considered compliant if all speeds were ≤10 knots. Because binning trips as

175 compliant/noncompliant in this way may not fully capture more subtle responses to the

176 regulations (e.g., vessel operators who were not fully compliant but may have modified their

177 behavior when travelling through active SMAs), we also calculated the percent of total transit

178 distance traveled within SMAs at speeds >10 knots (PDGT10), and average speeds when all or a

179 portion of the trip exceeded 10 knots. With the exception of the average speeds >10 knots metric,

180 we did not calculate mean trip speeds because AIS signals are transmitted at regular and frequent

181 time intervals and, as such, slower speeds are more heavily represented than higher speeds.

182 PDGT10 is not influenced by the distributions of speed values, provides a standard measure that

183 is independent of trip length or duration, and, along with average noncompliant speeds, allowed

184 us to quantify degrees of compliance (or noncompliance).

185   The above-mentioned metrics (compliance, PDGT10, and average noncompliant speed)

186 were quantified for vessels by type (vessel type analyses were limited to those principally

187 impacted by the regulations, which included cargo, tanker, and passenger), by association with

188 the different notification/enforcement programs (USCG Hailing At-Sea, COPPs Letters, NOVA,

189 WSC and CSA Monthly Summaries), before and after they had received these

notification/enforcement actions and for periods when the restrictions were not in effect.

Summary statistics were generated for each SMA active season, which we define as beginning

on the first day of November (coinciding with the opening of the migratory and calving grounds

SMAs) and ending on July 31 of the following year (closing of the Great South Channel SMA)

(Fig. 1).

Statistical Modeling

The observational design of the study made it difficult to directly associate changes in

vessel behavior with any particular notification/enforcement program. The implementation of the

suite of notification programs overlapped, confounding attempts to directly implicate any one

action in the reduction of vessel speed. As such, we were limited to presenting summary

statistics for the vessels associated with each notification/enforcement program.

We were, however, able to estimate the change in PDGT10 over time by examining the

differences in its mean value across the sequence of the SMA active seasons during the first five

$$f(x \mid \alpha, \beta) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} \, x^{\alpha-1}(1-x)^{\beta-1}$$

years of the speed restrictions. A natural statistical model to describe the distribution of these

values in a given season is the beta distribution, which is typically modeled as a function of scale

(α) and shape (β) parameters:

We were interested in modeling the mean of this distribution (rather than the scale and shape

specified above), so we reparameterized the beta distribution in terms of a mean μ and parameter

v, which we interpret informally as a "sample size". Here we used the scaled distance of each

segment as this sample size parameter, so that segments are weighted according to their length;

we included the scale parameter as an unknown in the model, by giving it a diffuse prior

210 we included the scale parameter as an unknown in the model, by giving it a diffuse prior

$$\alpha = \mu\nu$$
$$\beta = (1-\mu)\nu$$
$$\mu_{ijk} = \theta_i + \psi_j + \phi_{ik}$$

211 distribution. This reparameterization is:

212   We expected the mean PDGT10 to vary with several factors, including three variables of

213 interest: SMA, vessel type, and season. Thus, we modeled μ using a mixed effects model:

214 where θ_i is the mean for vessel type i, ψ_j is a random effect corresponding to SMA j, and φ_{ik} is

215 the fixed effect of season k on vessel type i. The first season in any SMA (either 2008 or 2009,

216 depending on the SMA's location) is treated as the baseline; hence θ can be interpreted as the

217 mean in the first season, and φ the effect of a subsequent season, relative to the first. It is these

218 seasonal difference effects that are of primary interest. The random effect ψ_j where $j=1...,S$ is

219 modeled as:

220   To account for individual variation not attributable to vessel type, season or SMA, we

$$\psi_j \sim N(0, \tau_\psi)$$

221 also employed a random effect, which draws a θ value from a normal distribution for each

222 unique vessel.

$$f(\sigma \mid \beta) = \frac{2}{\pi\beta[1 + (\frac{\sigma}{\beta})^2]}$$

223   For each scale parameter in the model $(\tau_\psi, \tau_\theta, \tau_\upsilon)$, we specified a half-Cauchy distribution

224 in the inverse square-root of the parameter:

225 This results in a relatively diffuse, weakly-informative prior (after transforming by $\tau = \sigma^{-2}$) that is

226 easily overwhelmed by the data (Gelman, 2006).

227   Because typical at-sea speeds vary widely for the different vessel types, models were fit

228 for each of the three most common vessel types in the dataset: cargo, tanker and passenger

229 vessels. Model parameters were estimated using Markov chain Monte Carlo (MCMC) methods

230 as provided by the PyMC (version 2.3, Patil et al., 2010) software package. Each model was run

231 for 20,000 iterations, with the first 10,000 conservatively discarded as burn-in, leaving 10,000

232 samples for inference. Models were checked for lack of convergence using the Gelman-Rubin

233 statistic (Gelman & Rubin, 1992) and for lack of fit using posterior predictive checks (Gelman et

234 al., 2003).

235   Our Bayesian logistic mixed-effects model generated estimates of the differences among

236 seasons for different vessel types across all SMAs, along with corresponding measures of

237 uncertainty, 95% posterior credible intervals. Intervals that include zero may be interpreted as

238 not statistically different from zero. Interpreting coefficients on the inverse-logit scale is

239 challenging, since the underlying function is non-linear. For a given parameter value, the effect

240 will be larger near the middle of the logistic curve (0.5), where it is steepest, and smaller near the

241 boundaries (0 and 1), where it is flat. Thus, it is conventional to consider the upper bound on the

242 parameter's effect by estimating its maximum influence. A useful rule of thumb is to divide the

243 parameter value by four to get an approximate upper bound on the effect. For example, the

244 estimated median of the difference between active periods 2 and 1 for cargo ships is -0.02, which

245 corresponds to a maximum drop of 0.09 in PDGT10 (from 0.50 to 0.41); by comparison, the

246 median value of -1.07 for the difference between active periods 5 and 1 would take an expected

247 PDGT10 value of 0.50 down to 0.16.

248 **RESULTS**

249   A total of 201,862 trips made by 8,009 individual vessels were analyzed. In the first two

250 active seasons of the speed restrictions (i.e., the regulated community's initial response to the

251 novel regulation), 4.0% and 4.2% of the trips were fully compliant and PDGT10 values averaged

252 57.3% and 55.5%, respectively (Table 1; Fig.2). In comparison, when speed restrictions were not

253 in effect during the first two years of the regulations, 1.7% and 2.3% of the trips within the

254 geographic boundaries of the SMAs were conducted entirely with speeds ≤10 knots and

255 PDGT10 values were 83.4% and 83.2%, respectively (Table 1).

256   The largest response in PDGT10 values over time among the three vessel types analyzed

257 was for cargo ships (Table 2). The temporal effect of the second active season relative to the first

258 for this vessel class was significantly negative, with a median value of -0.02 (95% BCI = -0.06,

259 0.01). This effect increased 35-fold for the third active season to -0.70 (-0.72, -0.66), dropped

260 further in the fourth active season to -1.20 (-1.24, -1.17), and then to -1.07 (-1.11, -1.03) in the

261 fifth active season. For tankers, there was a notable drop in expected PDGT10 beginning in the

262 third active season, with the median seasonal difference dropping to -0.25 (-0.31, -0.18), and

263 further to -0.48 (-0.54, -0.41) and -0.62 (-0.69, 0.56) in seasons four and five, respectively (Table

264 2; Fig. 3). The change in vessel speed for passenger vessels was less consistent, showing little

265 change in the first three active seasons (nominally higher in the third season) before becoming

266 significantly negative in the fourth and fifth active season (Table 2; Fig. 3). None of the three

267 models showed obvious lack of convergence, nor was there indication of lack of fit, based on the

268 results of posterior predictive checks.

269   Of the notification programs studied, vessels hailed by the USCG seemingly exhibited

270 the smallest relative change in compliance following their notification (Table 3); and, transits by

271 this group subsequent to their notification were consistently higher than the population as a

272 whole (Fig. 2). The average PDGT10 values of COPPS letter recipients decreased from 66.3% to

273 33.3% after being notified (Table 3), representing a clear but modest response to the program.

274   Vessels/companies that received NOVAs seemed to exhibit the greatest relative change in

275 fully compliant trips and average PDGT10 after being cited. Average PDGT10 values went from

276 62.0% for trips prior to notification to 14.5% after fines were issued (Table 3). Average PDGT10

values for NOVA and monthly summary (both WSC and CSA) recipients declined in each
successive active period following receipt of their respective enforcement/notification actions
(Fig. 2). WSC monthly summary recipients made some of the largest relative adjustments in
behavior (second only to NOVA recipients) with respect to full compliance (Table 3). Among the
non-punitive programs, CSA monthly summary recipients had the greatest number of fully
compliant trips (55.6%) and lowest average PDGT10 (12.3%) after being notified (Table 3).

DISCUSSION

The U.S. Endangered Species Act (ESA) and related environmental legislation provide
rather broad agency discretion for developing and implementing conservation regulations.
However, without compliance, such regulations will be largely ineffective no matter how well
they are designed or how important their mandates are perceived. In our study, substantial
modifications to normal practices were expected of a large, multi-national community to a novel
ESA-promulgated regulation.

We found that, while much of the regulated community responded when vessel speed
restrictions were instituted, a substantial number of trips were not in total compliance and the
10-knot limit was routinely exceeded. This suggests that extensive initial and ongoing efforts to
inform the regulated community about the speed restrictions provided no assurances that
widespread compliance would necessarily follow, even though this information was provided
using virtually every available conventional maritime communications system and requirements
that mariners fully understand applicable regulations while sailing in U.S. waters. In addition,
non-punitive notifications to violators (i.e., radio contact at sea, COPPS letters) by recognized
enforcement authorities resulted in only modest changes in compliance rates.

Due to the number and diversity of entities affected by this rule, it is possible that several
years were needed for the community to incorporate speed limits into their operating
procedures. It is worth noting, for example, that some printed and broadcast information about
the restrictions may have become available to "foreign-flagged" vessels (a large portion of ships

303 entering U.S. ports) primarily after entering U.S. waters. However, most commercial vessels

304 studied here, including foreign-flagged vessels, are engaged in repeated, scheduled routes and

305 likely were exposed multiple times each year to broadcast and broadly-disseminated

306 information about the restrictions.

307   Our results indicate that in response to the restrictions vessel operators tended to use

308 speeds that while not always less than 10 knots for the duration of a transit were nonetheless

309 slower than they might otherwise use. At-sea speeds typically range from 10-15, 15-25, and 20-

310 25 knots for tanker, cargo, and passenger vessels, respectively. Accordingly, cargo vessels, the

311 most numerous vessel type in our study and the type most named in enforcement actions, were

312 required to make significant shifts in operations to comply with the speed regulation. Relative to

313 cargo and passenger vessels, tankers needed to make the smallest changes in speeds to comply

314 with the regulation, and it appears the approach taken by this vessel class was to reduce speeds

315 when traveling through active SMAs (as reflected in their PDGT10 values), but, not to a point of

316 full compliance.

317   The highest compliance rates were observed in the latter active periods, with notable

318 changes occurring in the third season. Given the timing of the first set of NOVAs, these results

319 suggest, but do not confirm, that the issuing of citations strongly influenced the behavior of

320 notified vessels/companies. In addition, although they were issued to a fraction of the regulated

321 community, citations appear to have improved compliance in the regulated population as a

322 whole. This is consistent with findings by others whereby environmental monitoring and

323 enforcement activities had a strong impact not only in reducing future violations (Gray &

324 Shimshack, 2011), but also that deterrence resulting from these activities was almost as strong

325 in affecting the compliance of others in the regulated community as it was on the sanctioned

326 entity (Shimshack &Ward, 2005). Assessing internal business actions is beyond the scope of

327 this study, but anecdotal reports to us indicate that there was broad knowledge among maritime

328 industries that citations/fines were being issued. In addition, OLE press releases and industry

trade publications notified readers about the issuing of fines and named the violator's company. Societal expectations, perceived social costs, and the importance of reputation have been identified as motivators in corporate compliance behavior (May, 2005; Gunningham et al., 2005), and these factors may have been at play in our study.

Each of the targeted notification programs appeared to have at least some effect on improved compliance in individual vessels. There are important distinctions between these programs that may be reflected in their relative effectiveness. An at-sea hailing incident may have been known only to the vessel operator and this program was limited geographically and temporally. Its modest influence on compliance suggests that when the perceived likelihood of detection is low (no visible enforcement entity present on the majority of trips) the threat of adverse consequences is also low. Receipt of NOVAs or monthly summaries of operations to association members (and perhaps COPPS letters) was almost certainly known throughout a given company (in most cases, company officials were the entities being notified) which may have led to company-wide directives regarding compliance. CSA members comprise a diverse set of vessel types, tankers being strongly represented; likely, minimal alteration of operations was needed for many of these vessels to comply. In addition, many CSA-member vessels are engaged largely in domestic trade and in making repeated U.S. port entries may have been exposed to a greater degree than other vessels to awareness-raising about the restrictions.

Multiple notification/enforcement programs can have an additive value in influencing compliance rates (Gray & Shimshack, 2011) and the threat of punitive actions may bolster the effectiveness of non-punitive measures (Abbot, 2009; Scholz & Gray, 1990). We note that shortly after NOVAs were issued the industry associations sought to develop regular non-compliance notification programs for their members. Therefore, these follow-up programs likely complimented enforcement actions and provided periodic reminders that operations were being routinely monitored.

354   Enforcement activities can be labor- and resource-intensive and may be difficult if the

355 regulated population is large or widely dispersed (Abbott, 2009; Ali & Abdullah, 2010). Where

356 feasible, remote-monitoring can be a cost-effective means to improve compliance (Purdy, 2009).

357 Whereas we did not attempt to quantify agency costs involved in the monitoring/enforcement

358 activities described here, by utilizing an existing infrastructure for remote monitoring and relying

359 on electronic means or surface mail for nearly all enforcement and notification activities, costs

360 were almost certainly considerably less than those involved in conventional inspection or law

361 enforcement activities.

362   The vessel speed restrictions appear to be working as intended: no fatal vessel strike-

363 related right whale deaths were reported in or near active SMAs since the rule went into effect, a

364 period that is nearly twice the longest interval between subsequent known vessel collision

365 fatalities in these same areas in an 18-year study period prior to adoption of the rule (Laist, et al.,

366 2014). Modeling studies have indicated that the risk of fatal vessel collisions of right whales has

367 been reduced by the vessel speed restriction (Lagueux, et al., 2011; Wiley et al., 2011). The

368 probability (a 80-90% reduction in risk) of fatal vessel collisions was lowest in the latter part of

369 the period in which the rule was in effect (Conn & Silber, 2013), during which improved

370 compliance rates were observed.

371   Voluntary actions and incentives are approaches that have been widely used and can be

372 effective in reducing environmental impacts (Dietz & Stern, 2002; Gunningham et al., 2004;

373 Stafford, 2012). However, in regard to the conservation issue of vessel strikes of large whales,

374 mandatory and enforced changes in vessel operations appear to have considerable conservation

375 value while adherence to -- and therefore effectiveness of – previously implemented voluntary

376 measures to reduce whale disturbance (Wiley, et al., 2008) and vessel/whale collisions (Silber et

377 al., 2012) was low.

378 Costs incurred in issuing and enforcing living resource conservation regulations and costs
379 to regulated entities might be assessed relative to societal benefits (Gren & Li, 2011). Economic
380 impacts to the regulated community arising from vessel speed restrictions (including the effect of
381 lost time, indirect impacts to intermodal transport systems etc.) are a fraction of the value of the
382 goods and services provided by the affected maritime and associated industries (Nathan
383 Associates, 2012), and these might be weighed in the context of societal valuation studies of the
384 virtues of preserving endangered and threatened species (e.g., Wallmo & Lew, 2011).

385 **SUMMARY AND CONCLUSIONS**

386 This study provides information about the relative roles of punitive and non-punitive
387 targeted actions designed to enhance compliance. Our findings, like those of others, appear to
388 strongly suggest that citations/fines were motivators in improving compliant behavior and these
389 may have been backed by targeted notifications of violation. Progressively improving
390 compliance rates appeared to have been influenced, to varying degrees, by broad-scale
391 notification programs and the threat (or reality) of enforcement activities. These results may help
392 in formulating management strategies for this particular conservation concern and in improving
393 compliance in virtually any setting in which regulatory compliance is sought.

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401 lifetime of innovation and compassion in service to others have provided constant inspiration.

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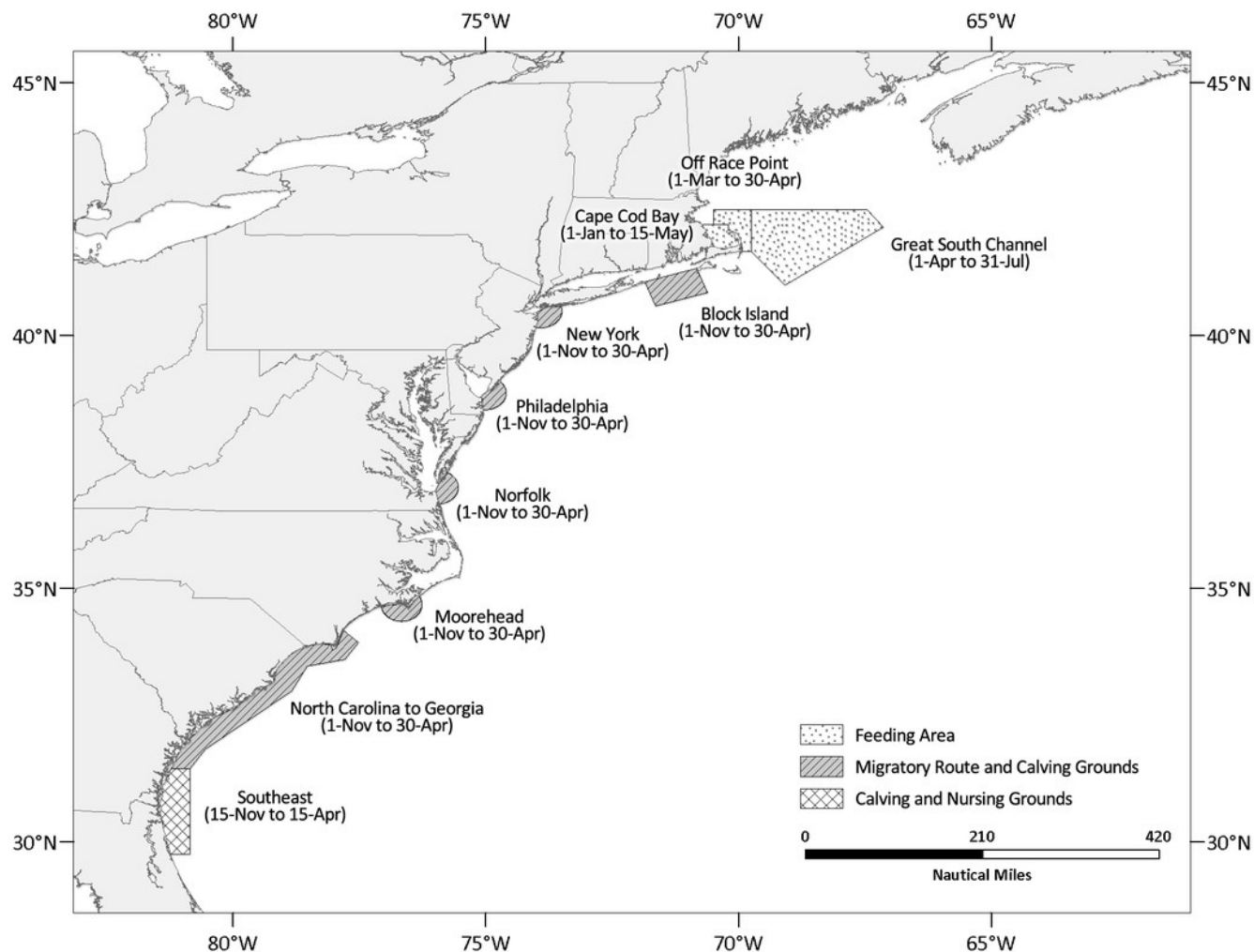
Figure 1

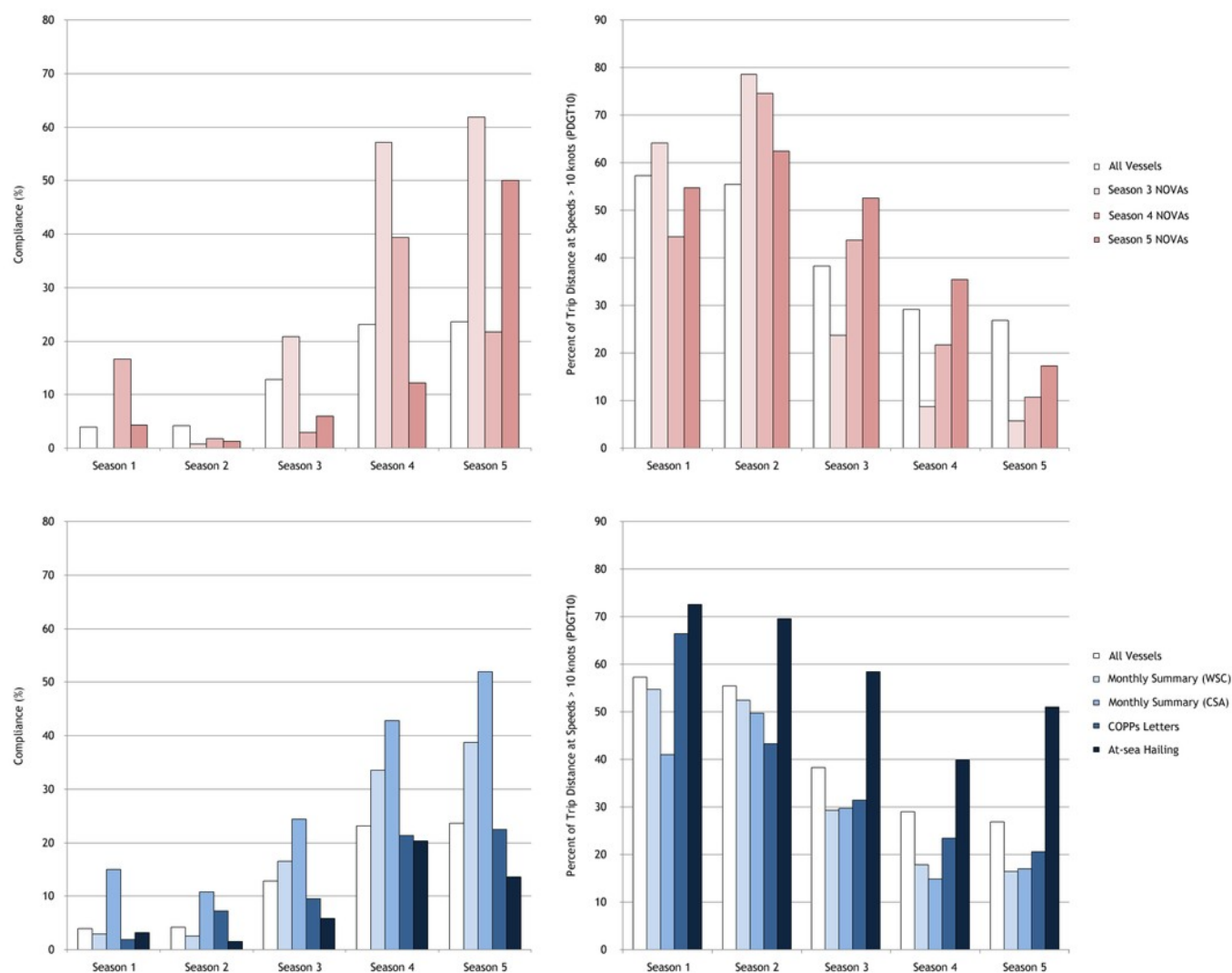
Map depicting the location and active periods of the north Atlantic right whale seasonal management areas (SMAs).

Compliance metric summary statistics for trips through the SMAs during active and inactive periods by all vessels (cargo, tanker, and passenger) for the first five years of the speed restrictions.

Season	SMA Status	Trips	Vessels	Compliance[1]	PDGT10	Mean Noncompliant Speed[1]
1	Active	14907	1776	4.0	57.3	12.0
	Inactive	25974	2401	1.7	83.4	14.3
2	Active	19439	2019	4.2	55.5	12.0
	Inactive	22685	2065	2.3	83.2	14.3
3	Active	20782	2126	12.8	38.3	11.6
	Inactive	21408	2202	2.3	81.8	14.1
4	Active	18339	2097	23.1	29.1	11.7
	Inactive	20075	2092	2.1	80.9	14.1
5	Active	17927	2063	23.7	26.9	11.7
	Inactive	20326	2068	2.9	79.5	14.1

[1] Compliance and Mean Noncompliant Speed for inactive SMA trips refer to trips with all speeds ≤10 knots and mean of all speeds >10 knots, respectively.

Figure 2

Temporal changes in vessel speed restriction compliance metrics during the first five years of the regulations for vessels associated with the different notification/enforcement programs.

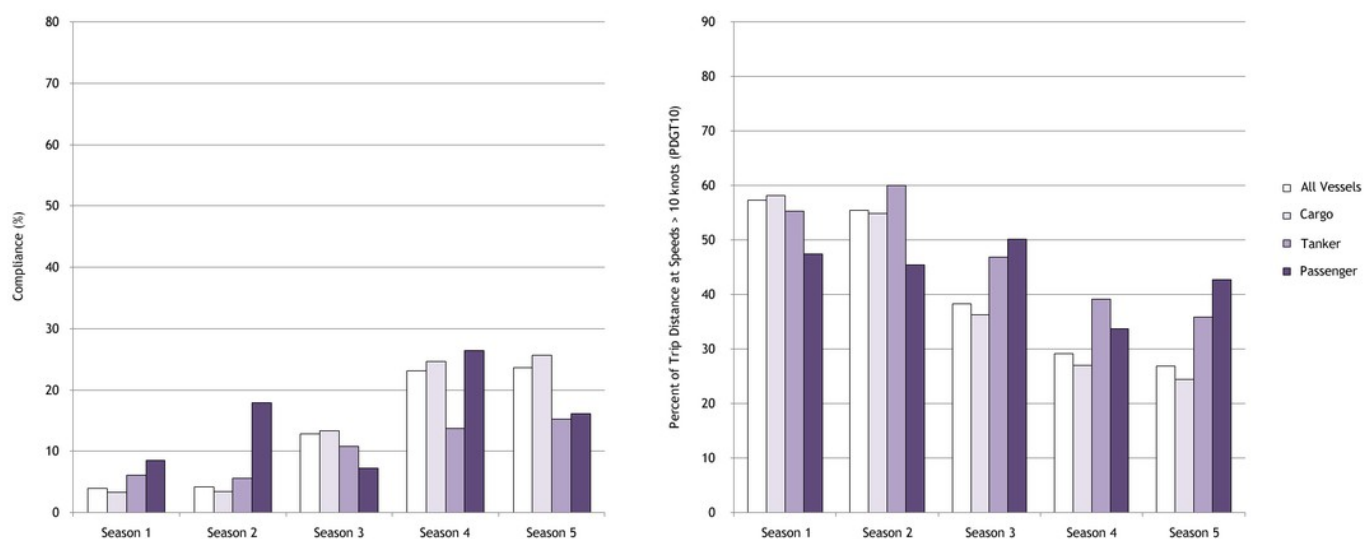
Compliance metrics for all vessels analyzed are also included for comparison and NOVA recipients have been further split based on when they received NOVAs (e.g. Season 3 NOVAs includes vessels that received their notices of violation shortly before or after the onset of Season 3) to better illustrate potential impacts associated with the enforcement action.

Model-based estimates of seasonal differences in PDGT10 for cargo, tanker and passenger vessels, along with posterior 95% credible intervals (highest posterior density intervals).

Each parameter represents the expected difference in PDGT10 in a specified season, relative to the first season, on the inverse-logit scale. Intervals that do not contain positive values are highlighted in bold.

Vessel Type	Season	Median	Standard Deviation	95% HPD Interval
Cargo	2	-0.02	0.001	**(-0.06, 0.01)**
	3	-0.70	0.001	**(-0.74, -0.66)**
	4	-1.20	0.001	**(-1.24, -1.17)**
	5	-1.07	0.001	**(-1.11, -1.03)**
Tanker	2	0.18	0.002	(0.11, 0.25)
	3	-0.25	0.002	**(-0.31, -0.18)**
	4	-0.48	0.002	**(-0.54, -0.41)**
	5	-0.62	0.002	**(-0.69, -0.56)**
Passenger	2	0.12	0.008	(-0.07, 0.32)
	3	0.25	0.006	(0.07, 0.41)
	4	-0.56	0.007	**(-0.74, -0.39)**
	5	-0.48	0.007	**(-0.65, -0.31)**

Figure 3

Temporal changes in vessel speed restriction compliance metrics during the first five years of the regulations for the three principal vessel types analyzed.

Compliance metrics for all vessels analyzed are also included for comparison.

Compliance metric summary statistics for trips through active SMAs by vessels associated with notification/enforcement programs both before and after the notification/enforcement.

Program	Timing	Trips	Vessels[1]	Compliance	PDGT10	Mean Noncompliant Speed
At-sea Hailing	Before	964	46	4.9	70.3	13.2
	After	1260	44	11.8	48.7	12.1
COPPs Letter	Before	1572	85	2.6	66.3	12.8
	After	2743	62	14.3	33.3	11.9
Monthly Summary (CSA)	Before	2197	40	29.5	35.8	10.9
	After	2119	30	55.6	12.3	10.6
Monthly Summary (WSC)	Before	14203	317	3.3	51.7	11.8
	After	19416	303	29.0	20.8	11.7
NOVA	Before	1318	28	3.3	62.0	13.0
	After	562	14	40.4	14.5	11.7

[1] Not all vessels with trips prior to (or associated with) the initiation of their respective notification/enforcement program made subsequent trips through active SMAs.