Conservation in Practice

Efficacy of a Voluntary Area to Be Avoided to Reduce Risk of Lethal Vessel Strikes to Endangered Whales

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Abstract: *Ocean-going vessels pose a threat to large whales worldwide and are responsible for the majority of reported deaths diagnosed among endangered North Atlantic right whales* (Eubalaena glacialis). *Various conservation policies have been implemented to reduce vessel-strike mortality in this species. The International Maritime Organization adopted the Roseway Basin Area to be avoided on the Scotian Shelf as a voluntary conservation initiative to reduce the risk of lethal vessel strikes to right whales. We initiated the Vessel Avoidance & Conservation Area Transit Experiment to evaluate the efficacy of this initiative because the effectiveness of the avoidance scheme in reducing risk without the imposition of vessel-speed restrictions depends entirely on vessel-operator compliance. Using a network of automatic identification system receivers, we collected static, dynamic, and voyage-related vessel data in near real time from the Roseway Basin region for 12 months before and 6 months after the implementation of the area to be avoided. Using pre- and post-implementation vessel navigation and speed data, along with right whale sightings per unit effort data, all resolved at 3′N latitude by 3′W longitude, we estimated the post-implementation change in risk of lethal vessel strikes. Estimates of vessel-operator voluntary compliance ranged from 57% to 87% and stabilized at 71% within the first 5 months of implementation. Our estimates showed an 82% reduction in the risk of lethal vessel strikes to right whales due to vessel-operator compliance. We conclude that the high level of compliance achieved with this voluntary conservation initiative occurred because the area to be avoided was adopted by the International Maritime Organization. Our results demonstrate that international shipping interests are able and willing to voluntarily alter course to protect endangered whales.*

Keywords: endangered whales, marine area closure, Roseway Basin, voluntary conservation practices, vessels, voluntary compliance, ship strikes

Eficacia de un Área de Exclusión Voluntaria para Reducir el Riesgo de Golpes Letales de Barcos a Ballenas en Peligro

Resumen: *Las embarcaciones oceánicas son una amenaza para las ballenas en todo el mundo y son responsables de la mayoría de las muertes de Eubalaena glacialis reportadas. Se han implementado varias políticas de conservación para reducir la mortalidad por golpes de barco en esta especie. La Organización Marítima Internacional adoptó el Área a Evitar Roseway Basin para reducir el riesgo de golpes letales de barcos a las ballenas. El cierre es voluntario y estacional, y el área está en la Scotian Shelf. Iniciamos el Experimento de Elusión de Barcos y Tránsito por el Área de Conservación para evaluar la eficiencia de esta iniciativa porque la efectividad del plan de elusión en la reducción del riesgo sin la imposición de restricciones a la velocidad de los barcos depende completamente del cumplimiento por parte de los operadores de los barcos. Mediante una red de sistemas de receptores de identificación automática, recolectamos datos estáticos, dinámicos y relacionados con viajes de barcos casi en tiempo real en la región de la Roseway Basin durante 12 meses antes y 6 meses después de la implementación del área de elusión. Utilizando datos de navegación y velocidad pre y post implementación, además datos de avistamientos de ballenas por unidad de esfuerzo, con una resolución de 3′N latitud por 3′W longitud, estimamos el cambio postimplementación*

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Paper submitted March 2, 2009; revised manuscript accepted May 20, 2009.

Conservation Biology, Volume 23, No. 6, 1467–1474

DOI: 10.1111/j.1523-1739.2009.01329.x

del riesgo de colisiones letales con barcos. Las estimaciones del cumplimiento voluntario de los operadores de barcos variaron entre 57% y 87% y se estabilizaron en 71% en los primeros cinco meses de la implementación. Nuestras estimaciones mostraron una reducción de 82% en el riesgo de colisiones letales de barcos con ballenas debido al cumplimiento de los operadores de barcos. Concluimos que el alto nivel de cumplimiento alcanzado con esta iniciativa de conservación voluntaria ocurrió porque el área de elusión fue adoptada por la Organización Marítima Internacional. Nuestros resultados demuestran que los intereses de navegación internacionales están capacitados y dispuestos a alterar voluntariamente su curso para proteger ballenas en peligro.

Palabras Clave: área marina cerrada, ballenas en peligro, barcos, cumplimiento voluntario, golpes de barcos, prácticas de conservación voluntarias, Roseway Basin

Introduction

Ocean-going vessels pose a threat to all large whales worldwide and constitute pressing conservation issues for some species (Laist et al. 2001). Historical worldwide records (1885–2002; $n = 294$; Laist et al. 2001; Jensen & Silber 2003) of vessels striking large whales reveal that the most frequently reported victims of vessel strikes are fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), right (*Eubalaena* sp.), and gray (*Eschrichtius robustus*) whales. On a per capita basis and relative to all other large whales reported struck, however, the North Atlantic right whale (*Eubalaena glacialis*, Rosenbaum et al. 2000; hereafter referred to as right whale) is two orders of magnitude more prevalent as a victim (Vanderlaan & Taggart 2007), likely because the species inhabits one of the most urbanized coastal regions in the world (Kraus & Rolland 2007).

Vessel strikes are responsible for 53% of all deaths diagnosed among right-whale necropsies (Campbell-Malone et al. 2008). If this endangered species (IUCN 2008), represented by approximately 350 individuals, is to avoid extinction (Caswell et al. 1999), then all human-induced mortalities must decrease (Kraus et al. 2005). Preventing as few as two female deaths per year would increase the population growth rate to replacement levels that would initiate recovery (Fujiwara & Caswell 2001). Such prevention is particularly relevant given that contemporary probability estimates of deaths from vessel strikes could be as high as 10 individuals in any given year (Vanderlaan et al. 2009).

Various conservation policies designed to reduce the probability of a vessel striking a right whale or the lethality of a strike (where risk is the probabilistic intersection of the two) have been implemented along the East Coast of North America. Such policies include the designation of right whale conservation areas (DFO 2000); mandatory ship-position reporting (Ward-Geiger et al. 2005); mandatory vessel-routing amendments to International Maritime Organization (IMO) traffic separation schemes (TSS) (IMO 2003, 2006*a*); mandatory vessel-speed restrictions (NOAA 2008); and recommended (i.e., voluntary) areas to be avoided (ATBA) (IMO 2007, 2008).

These policies may prove successful as practical conservation tools for reducing the risk of vessel strikes. The amendment to the TSS in the Bay of Fundy was designed to reduce the risk of lethal vessel strikes to right whales by as much as 90% in the region where the original outbound lane of the TSS intersected the Grand Manan Basin Right Whale Conservation Area (Vanderlaan et al. 2008). The amendment of the Boston TSS is expected to reduce co-occurrence of vessels and right whales by 58% and to all baleen whales by 81% (IMO 2006*b*). Recent recommendations for an ATBA in the Great South Channel region (IMO 2008) are predicted to result in a 39% reduction in vessel and right whale encounters if vessels comply with voluntary rerouting that may be reinforced (Vanderlaan et al. 2009) through mandatory but seasonal speed restrictions in the region (NOAA 2008).

The ATBA adopted by the IMO (2007) for the Roseway Basin region on the Scotian Shelf of the Northwest Atlantic was implemented by Canada on 1 May 2008, and it is seasonally effective each year from 1 June through 31 December. The Roseway Basin ATBA is precedent setting because it is the first ATBA designed and implemented specifically to reduce risk to an endangered species. Nevertheless, the effectiveness of this ATBA in protecting right whales from vessel strikes cannot be evaluated until a measure of voluntary compliance is determined (Vanderlaan et al. 2008). Wiley et al. (2008) argue the necessity of evaluating voluntary conservation programs after demonstrating marginal (12–26%) voluntary vessel compliance with a conservation program initiated to protect endangered whales from whale-watching vessels. We initiated the Vessel Avoidance & Conservation Area Transit Experiment (VACATE) to monitor vessels navigating the Roseway Basin region and to measure their compliance with the ATBA recommendation. Monitoring allowed us to evaluate the efficacy of this voluntary policy in reducing the risk of lethal vessel strikes. Risk reduction is a function of vessel-operator compliance and vessel speed (Vanderlaan et al. 2008); the lethality of a strike is a function of vessel speed (Vanderlaan & Taggart 2007).

Methods

Overview

We delineated our study area on the basis of aggregated right whale sightings per unit effort (SPUE) survey data (North Atlantic Right Whale Consortium [NARWC] 2005). The data were resolved as cell-specific SPUE estimates across the 25 × 20 cell survey-grid in which each cell had dimensions of 3′N and 3′W that delineated an area of ~23 km^2 (details provided in Vanderlaan et al. 2008). This is the limiting resolution used in the risk analyses below. To measure vessel-operator compliance among individual vessel-navigation tracks, the eastern and western boundaries of the survey grid were each extended by approximately 20 km to create the vessel domain (Figs. 1 & 2).

The IMO requires Automatic Identification System (AIS) transponders on all international vessels ≥300 gross tonnage and on all passenger vessels. To determine vessel compliance and vessel speed, we used a network of dual-channel AIS receiver stations to collect vessel data. The receivers were connected to expandable-cavity multicouplers used to bandpass the two AIS transmissions (channels 161.9765 and 162.025 MHz) received via VHF cell-tower antennas. The AIS data were captured by the AIS receivers, logged onto RAID-drive computers, and decoded. Dynamic data, including vessel identity, speed, and location, were logged at 1-min intervals, and static data, including vessel identity and type, were logged at 6-min intervals. The data were compiled by the computer daily (24-h periods) prior to and following implementation of the ATBA and then automatically downloaded daily from the remote AIS stations to the laboratory via digital subscriber line (DSL) modems.

Determining Vessel Navigation Tracks

We examined the navigation tracks for each uniquely identified vessel navigating the vessel domain over the periods 15 June through 31 October 2007 (before implementation) and 1 June through 31 October 2008 (after implementation) (Figs. 2a & 2b). We selected these nearly equivalent periods to evaluate vessel navigation before and after implementation, although the vessel monitoring system was not in place until 15 June 2007. We did not include vessel data after October because the reception range of AIS data decreases with changes in atmospheric refraction. When location information for a given vessel was interrupted (i.e., no AIS reception) for a period of 20 min or more (equivalent to approximately 9 km for a vessel steaming at 26 km/h), the vessel track was linearly interpolated when possible.

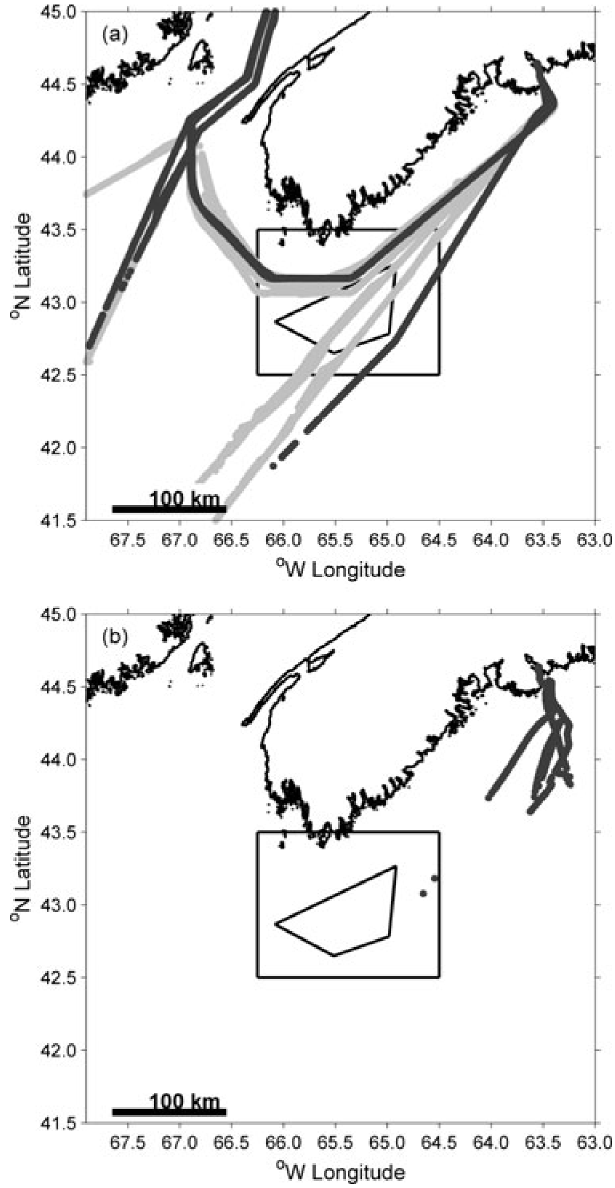

Figure 1. The Roseway Basin region on the Southwest Scotian Shelf showing the vessel domain (black rectangle) and the area to be avoided (ATBA) (black polygon). (a) An example of a unique vessel transiting the ATBA (gray tracks) before implementation and navigating around the ATBA (dark gray tracks) after implementation, and (b) an example of vessel track data (dark gray tracks) in the vessel domain where data are insufficient to determine compliance with the ATBA.

Determining Voluntary Vessel Compliance

We measured vessel compliance (C) with the Roseway Basin ATBA over semimonthly intervals after implementation. Uniquely identified vessel-navigation tracks, or trips, through the vessel domain were examined for each

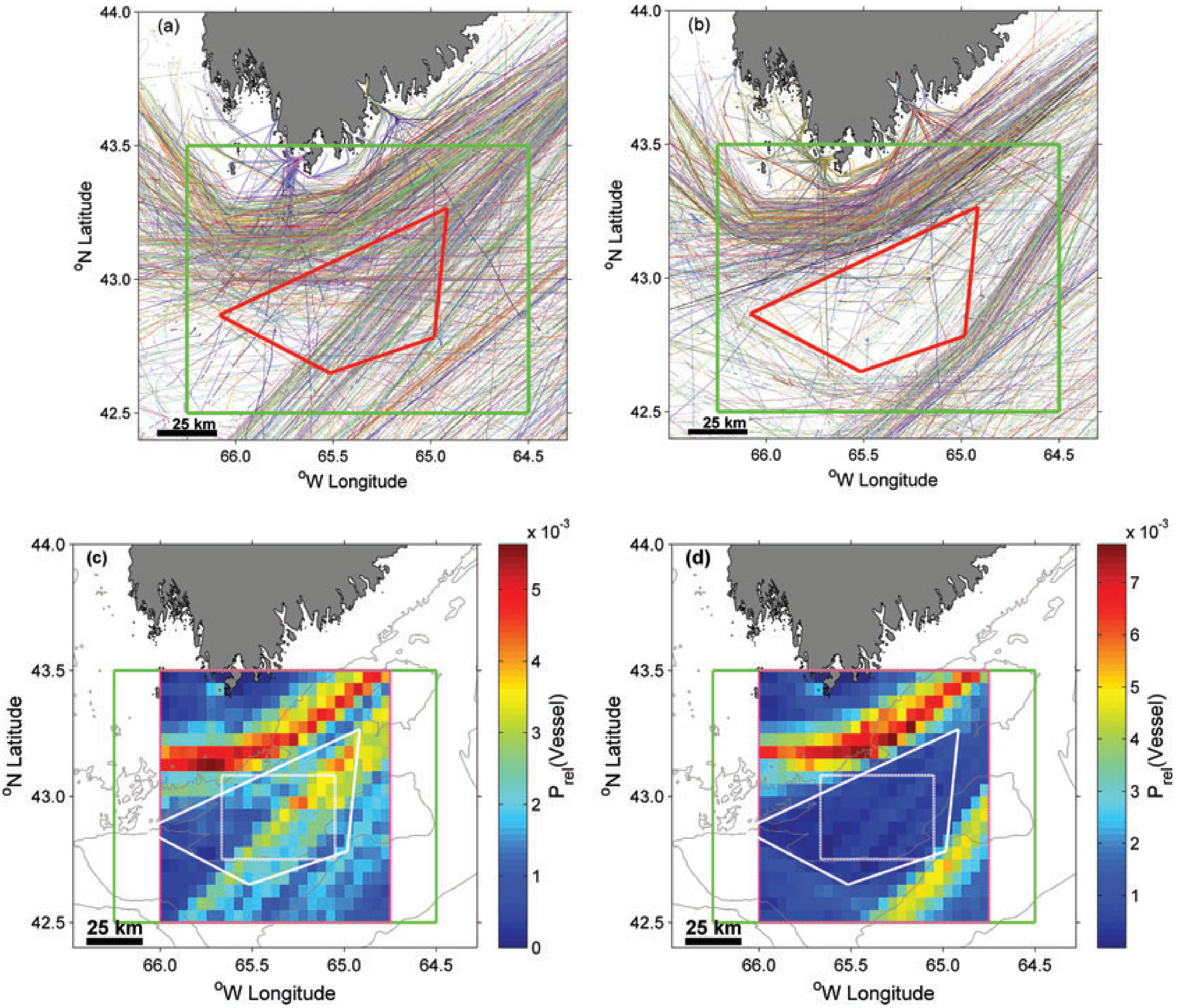

Figure 2. Bathymetric (100-m resolution) charts of the Roseway Basin region on the Southwest Scotian Shelf illustrating the vessel domain (green rectangle); North Atlantic Right Whale Consortium survey grid (pink dashed rectangle in [c] [d]); Right Whale Conservation Area (white dashed rectangle); and area to be avoided (ATBA) (red polygon in [a] and [b] or white in [c] and [d]). Navigation tracks for each vessel and trip through the region from (a) 15 June through 31 October 2007 and from (b) 1 June through 31 October 2008 prior to and following the implementation of the ATBA, respectively, and the relative probability of observing a vessel, P_{rel}(Vessel), prior to (c) and following (d) the implementation of the ATBA are also shown.

semimonthly period to determine whether a given vessel was actively avoiding the area. A vessel was classified as not avoiding (*N*) if the post-implementation track occupied the ATBA. A vessel was classified as "avoiding" (*A*), if the post-implementation track showed clear evidence of navigating around the ATBA, which was determined by the fact that the observed route would have been shorter if the vessel did not avoid the area. We were able to frequently substantiate the latter by comparing the pre-ATBA routing of a given vessel to its post-ATBA routing (Fig. 1a). If a vessel track was incomplete, such that it could not be used to determine whether the vessel navigated through or around the ATBA (Fig. 1b), then the vessel was classified as indeterminate (*I*) with respect to compliance and was used to contribute to the uncertainty estimate around the compliance estimate. Voluntary vessel compliance and the associated uncertainty (expressed as percentage) were estimated as follows:

$$C = \frac{\sum A}{\sum N + \sum A + \sum I} \pm \frac{\sum I}{\sum N + \sum A + \sum I}. \qquad (1)$$

Vessels in the vessel domain with a navigation track that indicated no need to avoid the area were not included in calculation of compliance and consequently ($\Sigma N + \Sigma A + \Sigma I$) does not equal the total number of vessels observed within the vessel domain. Coast guard vessel operators may not be able to navigate around the ATBA, so their vessels were excluded from our compliance-related analyses.

Determining Relative Risk

To determine efficacy of the ATBA in reducing risk of lethal vessel strikes to right whales, we used methods similar to those detailed in Vanderlaan et al. (2008) to estimate relative risk. Our estimates were derived from the grid-cell spatial measures of right whale SPUE, and the pre- and post-implementation cell-specific estimates of AIS vessel density and average vessel speed within the survey grid. One coast-bound grid cell along the northern boundary of the vessel domain and survey grid was omitted from estimates due to the virtually continuous and mostly stationary presence of one particular coast guard vessel fitted with an AIS transponder.

Results

During the period extending from 15 June through 31 October 2007, before implementation of the ATBA, 478 uniquely identified vessels, including 12 coast guard vessels, navigated the vessel domain that encompasses the ATBA (Figs. 2a & 2c). As defined in Vanderlaan et al. (2009), a habitual traffic pattern (HTP) is a self-determined principle path, route, or lane in the ocean traveled by vessels that connect one or more geographic locations. Two primary HTPs became evident when the relative probability of observing an AIS vessel in the survey grid was examined (Fig. 2c). The first HTP was composed of vessels navigating to the north of the ABTA, and the second was composed of vessels diagonally transiting the Right Whale Conservation Area that is mostly (96%) encompassed by the ATBA. On the basis of the mean relative probability of observing an AIS vessel, vessels were 1.5 times more likely to transit the northern HTP than the diagonal HTP, and they did so at an average speed of 27.7 km/h (SD 7.4). Although fewer vessels transited the diagonal HTP, they did so at a greater (Student's t test, $p < 0.0001$) average speed of 30.5 km/h (SD 7.1).

Evaluation of similar data over a comparable period (1 June through 31 October 2008) following implementation of the ATBA revealed a total of 476 uniquely identified vessels, again including 12 coast guard vessels, that navigated the vessel domain (Figs. 2b & 2d). Although the number of unique vessels transiting the vessel domain was virtually identical before and after implementation, their navigation patterns were markedly different. The diagonal HTP that once intersected the conservation area (Fig. 2c) shifted to the southeast (Fig. 2d). Overall, there was a significant change in the distribution of vessels in the survey grid (generalized two-sample Cramér–von Mises test, $p = 0.0001$; Syrjala 1996). The shift in the diagonal HTP was solely due to AIS vessels navigating around the ATBA rather than through it—a direct result of voluntary compliance with the recommendatory ATBA.

There were 197 uniquely identified vessels that actively avoided the ATBA after implementation. The majority (64%) of these vessels made only one trip for which active avoidance was observed (i.e., sometimes the same vessel on a different trip was navigating in a manner such that active avoidance would not be required). The remainder (36%) made between 2 and 10 trips each, wherein they exhibited active avoidance of the ATBA. Seventy-six unique vessels among 92 different trips did not comply with the ATBA at least once. Of these 76 vessels, there were 22 among 86 different trips that sometimes complied with the ATBA and sometimes did not. Ten of the 22 unique vessels that initially did not comply with the ATBA subsequently complied (later trips). Twelve of the 22 vessels were inconsistent in exhibiting avoidance. On average, 39% (SD 16) of the trips exhibited by the above 22 vessels transited the ATBA.

Vessel-operator compliance with the ATBA reached 57 ± 9% within the first 15 days of implementation; this estimate subsequently increased and ranged between 62 ± 8% and 87 ± 7% (Fig. 3a). The cumulative percent compliance through to the end of October 2008 indicated that compliance was stabilizing at 71 ± 11% (Fig. 3b). The relatively few vessels that continued to navigate the diagonal HTP through the ATBA did so at an average speed of 28.1 km/h (SD 7.5). Vessels navigating around the ATBA within the new HTP to the southeast did so at an average speed of 31.2 km/h (SD 6.2). Thus, voluntary compliance with the ATBA decreased the number of vessels transiting the ATBA and those remaining navigated at a significantly (Student's t test, $p < 0.0001$) lower average vessel speed. These reductions jointly contributed to a decrease in the predicted risk of lethal vessel strikes to right whales.

When standardized, the risk estimates allow for a direct comparison between pre- and post-implementation (Fig. 4), and the comparison revealed an 82% reduction in risk of lethal strikes to right whales within the survey grid. Our analyses further indicated that 76 unique vessels (a subset of the 476 above) did not always comply with the ATBA.

Discussion

Our results demonstrate that the majority of vessels navigating the Roseway Basin region comply with the ATBA and a substantial decrease in the risk of lethal vessel

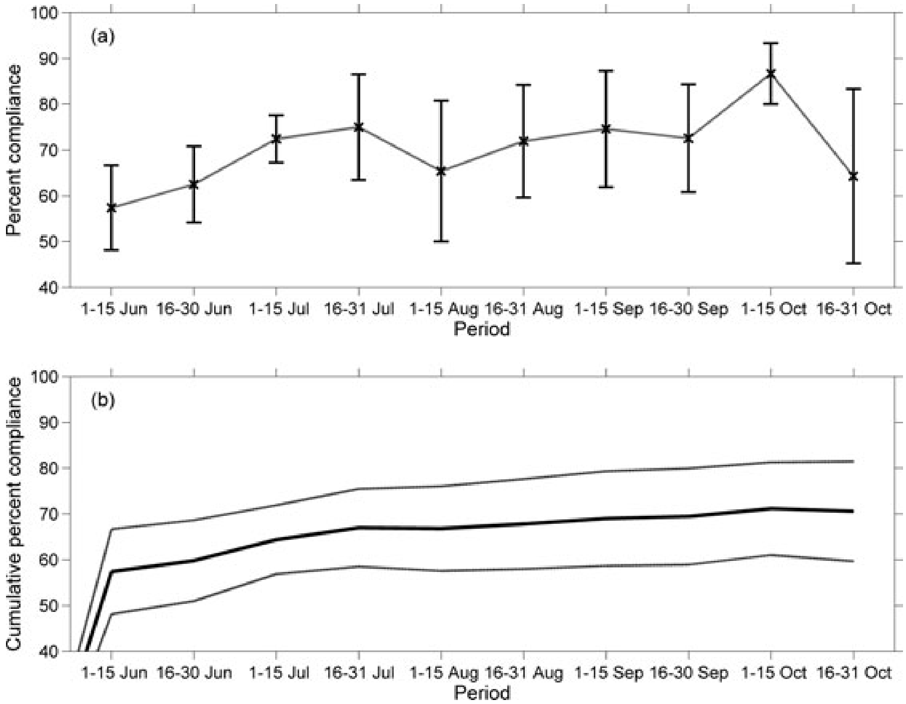

Figure 3. Semimonthly changes in (a) percent compliance (black cross; uncertainty, bars), and (b) cumulative percent compliance (solid line; uncertainty, dashed lines) by vessels navigating around the area to be avoided (ATBA) in the Roseway Basin region from 1 June though 31 October 2008, immediately following the implementation of the ATBA on 1 June 2008.

strikes to right whales has accrued in the survey grid. As in Vanderlaan et al. (2008), we used this risk reduction to coarsely estimate the decrease that might accrue to the actual number of lethal vessel–whale collisions. The risk reduction of 82% in the Roseway Basin predicts a decrease in the number of documented lethal vessel strikes from one every 16 years to one every 89 years due to the voluntary compliance with the ATBA. We emphasize that this estimate is extremely conservative because it relies only on reported and substantiated lethal strikes. Actual lethal vessel strikes could have been as high as one every 2 years prior to implementation of the ATBA (cf. Vanderlaan et al. 2009) and thus could decrease to one every 15 years if vessel operators continue to comply with the ATBA in the same manner as measured here.

Determining conservation-policy impacts on more than one species is appropriately precautionary when a policy is designed to protect one species. The Roseway Basin ATBA was designed and implemented to reduce the risk of lethal vessel strikes to right whales in the basin, where they seasonally aggregate. Sei (*B. borealis*), humpback, blue (*B. musculus*), minke (*B. acutorostrata*), and fin whales are also sighted during the right whale surveys in the basin region (NARWC 2008). Although the surveys are not specifically designed to estimate abundance and distribution of other baleen species, we used SPUE data for the sei, humpback, and fin whales to cautiously approximate changes in risk to these species that arise from vessels complying with the ATBA. Similar calculations are virtually meaningless for blue and minke whales because they are rarely sighted within the survey grid. The change in vessel distribution in the survey grid could lead to a slight increase (7%) in risk to fin whales due to the fin-whale SPUE being near maximum in the vicinity of the newly emergent diagonal HTP where vessels now transit to comply with the ATBA (Fig. 2d). This relatively small increase in risk may not substantially affect this endangered species (IUCN 2008) for three reasons. On a worldwide basis, fin whales are 250-fold more abundant than North Atlantic right whales (Aguilar 2002; Kenney 2002). Fin whales represent the largest standing stock of large whales along the north-eastern coast of the United States (Hain et al. 1992). In our survey grid the SPUE estimates for right whales are 10-fold greater than those for fin whales during September, when estimates for both species are at a maximum. We estimated risk reduction to humpback whales at 11% and to sei whales at 74%. Thus, vessel compliance with the ATBA achieves substantial reductions in the risk of lethal vessel strikes not only for the right whale, but also for the endangered sei whale (IUCN 2008), which demonstrates effectiveness of the ATBA as a conservation initiative applicable to a least two other large-whale species.

Monitoring and evaluating are critical components of voluntary conservation initiatives that aim to protect endangered species (Stem et al. 2005). Recommendations for voluntary avoidance and speed reduction within the Roseway Basin Right Whale Conservation Area (Fig. 2) have been printed on the back of Canadian Hydrographic Service navigation charts since 2000 (DFO 2000). It appears that the above initiative has failed because there has been no indication of compliance with these Canadian recommendations on the basis of historical (Vanderlaan et al. 2008) and contemporary (Figs. 1a & 1c)

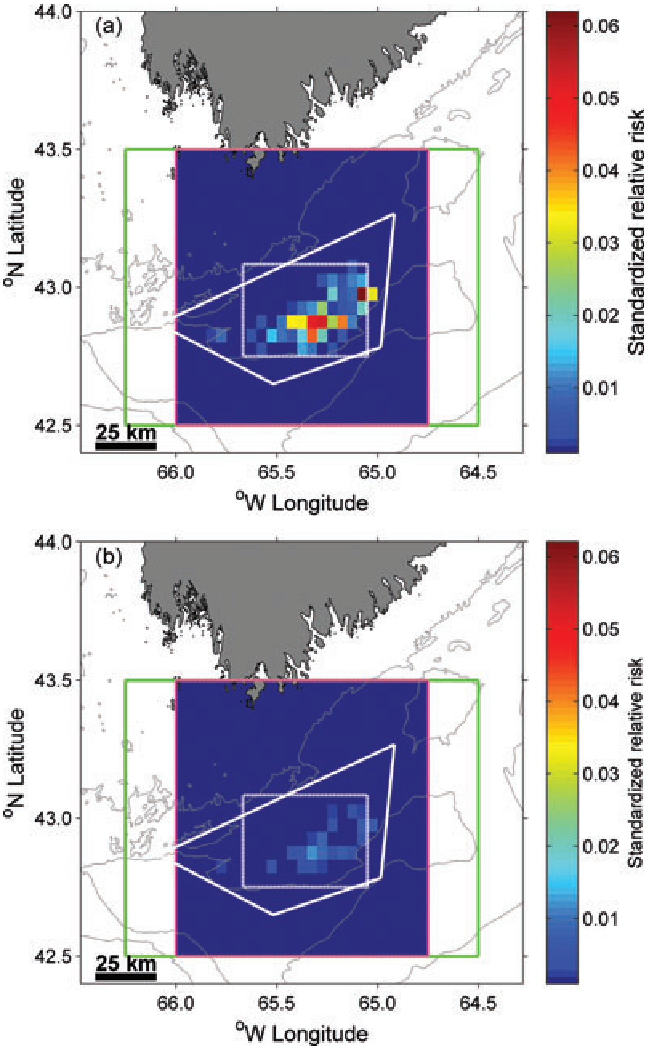

Figure 4. Bathymetric (100-m resolution) chart of the Roseway Basin region on the Southwest Scotian Shelf illustrating vessel domain (green rectangle); North Atlantic Right Whale Consortium survey grid (pink dashed rectangle); Right Whale Conservation Area (white dashed rectangle); the area to be avoided (ATBA) (white polygon); and standardized (comparable scale) relative risk of a lethal vessel strike to a right whale (a) before and (b) after implementation of the ATBA.

vessel-monitoring analyses. In the same region, and unlike the chart-based notices associated with the conservation area, the precedent-setting ATBA appears to have been a successful initiative as monitored through our study. The degree of compliance we observed is likely due to adoption of the ATBA by the IMO (of which Canada is a member state) simply because routing measures internationally sanctioned by the IMO are more likely to be recognized and adhered to by national and international shipping interests (Roberts 2005).

We conclude that IMO-adopted areas to be avoided, as voluntary conservation initiatives, can and will be used by the shipping industry to protect endangered whales. It follows that other internationally sanctioned conservation efforts, such as those adopted by the IMO, deserve greater consideration on a worldwide basis, especially where shipping has been identified as a threat to the ocean environment (e.g., Hooker et al. 1999; Best et al. 2001; Panigada et al. 2006). Our results demonstrate that there are methods to reduce such threats, ocean "users" will voluntarily contribute to threat and risk reduction, and there are methods by which these reductions can be measured and evaluated. Our analyses further indicate that, to date, if 76 different vessels from a total 476 voluntarily complied with the ATBA, a risk reduction approaching 100% in the Roseway Basin survey grid could be achieved.

Acknowledgments

We thank E. Grace, T. Chipman, D. Morrison, D. McGrath, E. Connell, and Bell Aliant for AIS monitoring support. The research was supported by the Environment Canada Habitat Stewardship Programme, the Canadian Whale Institute, and K. Smedbol (Saint Andrews Biological Station). We thank the anonymous referees for advice and critiques.

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