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Potential vessel collisions with Southern Hemisphere humpback whales wintering off Pacific Panama

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ABSTRACT

Vessel collision is a threat to many whale species, and the risk has increased with expanding maritime traffic. This compromises international conservation efforts and requires urgent attention from the world's maritime industry. Humpback whales (*Megaptera novaeangliae*) are at the top of the death toll, and although Central America is a wintering area for populations from both the Northern and Southern Hemispheres, existing efforts to reduce ship-whale collisions are meager. Herein, we evaluated the potential collisions between vessels and humpback whales wintering off Pacific Panama by following the movements of 15 whales tagged with satellite transmitters and comparing these data with tracks plotted using AIS real-time latitude-longitude points from nearly 1,000 commercial vessels. Movements of whales (adults and calves) in the Gulf of Panama coincide with major commercial maritime routes. AIS vessel data analyzed for individual whale satellite tracks showed that 53% (8 whales) of whales had 98 encounters within 200 m with 81 different vessels in just 11 d. We suggest implementing a 65 nmi Traffic Separation Scheme and a 10 kn maximum speed for vessel routing into the Gulf of Panama during the wintering season. In so doing, the area for potential whale-vessel collisions could be reduced by 93%.

Key words: humpback whale, *Megaptera novaeangliae*, satellite telemetry, nursery area, vessel collision, traffic separation scheme, Gulf of Panama.

Vessel collisions are a threat to endangered whale species and the problem is complex; no easy technological solutions exist to reduce ship strikes (Silber *et al*. 2009, 2010). Collision risk has increased with expanding maritime traffic, vessel tonnage, and speed, and thus may constitute a conservation issue for most species and coastal states (Laist *et al*. 2001, Panigada *et al*. 2006, Vanderlaan and Taggart 2007, Van Waerebeek *et al*. 2007, Douglas *et al*. 2008, Silber *et al*. 2010). Slow movement and time spent at the surface during calving near the coast or even habituation to vessel noise make whales highly vulnerable to lethal or severe injuries due to collision with ships (Watkins 1986, Stevick 1999, Laist

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et al. 2001), and this threat is especially severe across their migration routes and wintering areas.

Vessel-whale collision has been an issue of concern for countries with major port facilities and shipping routes along the North Atlantic and North Pacific Oceans and the Mediterranean Sea, but the issue has received little attention in the southern hemisphere (Van Waerebeek *et al*. 2007). Indeed, little is known about the impact of ship strikes on the southeastern Pacific humpback whale (*Megaptera novaeangliae*) populations near the several well-known breeding grounds in the region (Scheidat *et al*. 2000, Florez-Gonzalez *et al*. 2007), and it is considered that the species "may be struck by ships more frequently than previously thought" (Laist *et al*. 2001). To date, whale mortality in the Southern Hemisphere has been documented for only Ecuador and Colombia (Capella *et al*. 2001, Felix and Van Waerebeek 2005, Van Waerebeek *et al*. 2007). Scarcity of records across the region may be a consequence of lack of monitoring and systematic reporting (Van Waerebeek *et al*. 2007).

Vessel collisions occur along coastal areas where whales concentrate or transit seasonally for feeding or breeding (Laist *et al*. 2001). Humpback whale populations from the Southern and Northern hemispheres migrate annually to wintering areas off Pacific Central America (Rasmussen *et al*. 2007), with suggested population overlap occurring during winter along the coasts of Panama and Costa Rica (Stone *et al*. 1990, Acevedo and Smultea 1995, Florez-Gonzalez *et al*. 1998, Rasmussen *et al*. 2007). However, this important wintering area is not internationally protected, nor is it included in existing or proposed whale sanctuaries (Gerber *et al*. 2005). Therefore, humpback whales are highly vulnerable to vessel collisions during both migratory seasons along the coastal eastern Pacific corridor. One particular area of concern is Panama, which is ranked among the 20 most central ports of the global cargo-shipping network. The waters on the Pacific side of Panama include several routes that are traveled several thousand times per year just by cargo ships larger than 10,000 GT (Kaluza *et al*. 2010).

The objective of this study was to evaluate the potential for collisions between vessels and humpback whales wintering off Pacific Panama by following movement patterns of individual whales tagged with satellite transmitters and comparing these data with real-time commercial vessel track data obtained from the global Automatic Identification System (AIS) network.

Methods

Study Area

Las Perlas Archipelago (8.41ºN, 79.02ºW) is located *ca.* 60 km southeast of Panama City, Republic of Panama. It is composed of 250 basaltic rock islands and islets, which are mostly uninhabited and fall within the Tropical Eastern Pacific (TEP) Panamic biogeographic province (Benfield *et al*. 2007, Robertson and Cramer 2009). The archipelago, which lies in the center of the Gulf of Panama, is the second largest in the TEP and the second largest (1,688 km^2) marine protected area (MPA) in Panama (Guzman *et al*. 2008). The Gulf of Panama experiences an upwelling period during the dry season (January–April) that results in low water temperature, plankton blooms, and high marine productivity (D'Croz and O'Dea 2007).

Las Perlas Archipelago, located within the 50 m isobaths with shallow water averaging 15 m depth, has been a natural wintering area for humpback whales mainly from the Southern Hemisphere for centuries. The breeding season generally lasts from June to December, with peaks in whale abundance in August and September. The preliminary estimate of the size of the visiting population across all seasons is over 900 whales, with estimates of 100–300 animals for a single season with 15–20 calves. The high percentage of calves in the population (nearly 20%) is significant if considering that the behaviors of this age class makes them more vulnerable to vessel collisions (*sensu* Laist *et al.* 2001). This estimate is based on photo-identification of flukes and dorsal fins taken from 2003 to 2009 (Guzman *et al.*, unpublished data), and may represent an underestimation if considering that the average humpback whale population size estimates are 7,000 and 10,000 for northern and southern Pacific populations, respectively (see Florez-Gonzalez *et al.* 2007).

Whale Data Acquisition

Humpback whales were tagged using real-time satellite transmitters from Wildlife Computers, SPOT5 host version 5.02.1007; model AM-S193C with two AA lithium batteries. Parameters for SPOT5 transmitters included no limitations for time to allow constant transmission. The maximum number of transmissions per day was set at 250, allowing unused transmissions to be used on the next day. For transmissions to reach the satellite when the animal has surfaced, fast and slow repetition rates (seconds) were set by the manufacturer at ranges of 41.5–47.5 s and 86.5–92.5 s, respectively. We used tag-derived positions from Argos location classes 3, 2, 1, 0, A, and B with a range of errors in accuracy estimated between 150 m and 5 km radius for plotting general whale movements (see Zerbini *et al.* 2006, Hammerschlag *et al.* 2011). In addition, we tabulated the number of transmissions within each location class to inform us of the loss of transmissions in response to availability of satellites. The more accurate classes (1–3) require four or more messages received during a satellite pass for the best resolution (<150–1,000 m).

Factory transmitters consisted of a 2 cm diameter stainless steel tube case, 7.5 cm in length, coupled to a custom-made stainless steel spear with a 3 cm triangular double-edged blade tip containing two pairs of 5 cm barbs placed at 90º to each other (modified from Zerbini *et al.* 2006). Our tags were nearly 50% shorter than the tags currently used (over 29 cm in length). The longer tags anchor in the muscle and connective tissue (Gales *et al.* 2009) and we believe can cause more damage to the animal. Total tag weight (transmitter and spear) was 340 g for SPOT5 and 360 g for SPOT5s. We tagged whales from a 5 m long inflatable at a distance of 2–5 m from the whale. Tags were deployed using a modified pneumatic line-thrower (model ARTS, Restech Inc., Bodø, Norway) fitted with a ZOS Universal waterproof and fog-proof 1 × 40 riflescope. The use of the air-powered line thrower provides precision, avoiding the deployment of tags on undesirable or sensitive areas of the body. Air pressure ranged from 10 to 15 bars (10.2–15.3 kg/cm^2). Before deployment, tags (transmitter and spear) were coupled to a LK-carrier developed by LKARTS-Norway; the carrier consisted of a 50 cm long by 3 cm diameter PVC pipe with three 19 × 3.5 cm plastic fletching vanes in the rear. The transmitters were attached to the whales about 20–40 cm below the dorsal fin, in a thick layer of blubber to minimize potential injury to the animals. The majority of the whales reacted to the sound of the PVC carrier entering the water and not to the dart. We observed four tags detaching after acrobatic jumps by whales and assumed all other tags were detached at the end of the last transmission. In order to reduce infections, spears and tags were soaked with oxytetracycline-polylyxin topical ointment (Terramycin) before deployment. The Animal Care and Use Committee of the Smithsonian Tropical Research Institute approved the procedures.

Vessel Data Acquisition

Vessel data were acquired from the IHS Fairplay's AISLive network, a global Automatic Identification System (AIS) network used to track ship and vessel movements in real-time using Global Positioning System (GPS). AIS technology is used as a reliable tool for monitoring the effectiveness of restrictions to reduce ship-whale strikes in the United States (Silber and Bettridge 2010) and monitoring speed restrictions (Wiley *et al*. 2011). The system provides continuous ship-to-ship and ship-to-shore information including the name and type of vessel and cargo, position points (latitude and longitude), hour, dimensions, speed, heading, *etc*. The position accuracy (±10 m) is determined multiple times each minute by continuous GPS-linked updates (Silber and Bettridge 2010). All vessel points detected *via* AISLive receivers between 7.2º–9.0ºN and 79.8º–77.9ºW in the Gulf of Panama were analyzed from 21 August to 19 September, 2009, which was the peak of the humpback whale breeding season. In total, 49,903 records were obtained, but only 7,630 were used after filtering data fields for speed (<2–3 kn) and latitude coordinates more north of 8.8ºN because those points were inside a major precautionary area at the entrance of Balboa Harbour, where vessels continue transmitting data *via* AIS but are actually anchored or being serviced. Vessel records were further filtered by removing local vessels outside the defined study route and small sport fishing crafts, yielding 892 vessels with 7,621 coordinate points that were classified into five ship types for exploratory analyses (Table 1). Location points and speeds from local fishing vessels operating in the Gulf of Panama were obtained *via* the satellite-based global tracking and vessel monitoring system that transmits real-time GPS locations over the Globalstar Simplex data network to the Autoridad de Recursos Acuaticos de Panama-based tracking office (general vessel information, ID and tracks were restricted and not possible to plot).

Data Processing and Analyses

Satellite transmission coordinate points from individual whales were plotted against vessel track points (AIS data) regardless of ship type in ArcGIS 10.0 using the ArcMAP Tracking Analyst Tool and Query Builder Dialog Box (ESRI, Redlands, CA) that allows the concatenation of points displaying a subject of features in a map layer and video. Interactions between whales and ships were quantified by defining time (hours and minutes) or daily queries to identify crossing tracks between whales and vessels observed on each individual track video in real time. Whale transmission data were processed using the Satellite Tracking and Analysis Tool (STAT), which allows data filtering and editing

Table 1. Ship data summary used for plotting ship tracks from 21 August to 19 September 2009 in the Gulf of Panama, Panama.

Ship type	No. ships	No. coordinates
Cargo	654	4,040
Dredge	1	248
N/A[a]	31	421
Tanker	173	1,138
Vessel[b]	33	1,774
Fishing (local)	–	1,180
Total	892	8,801

[a]Ships not identified or categorized in database.
[b]Includes sail, fishing (nonlocal), pleasure, military, towing, passenger, and tug vessels.

Argos location classes and the integration of environmental data layers of interest (*i.e.*, bathymetry, transmission quality, speed, and distances) with animal tracking (see Coyne and Godley 2005). Due to the accuracy of the satellite positioning, whale speed data were filtered to a maximum of 30 km/h (see Noad and Cato 2007).

Whale-vessel interactions or "close encounters" were defined as the number of occurrences per elapsed time that an individual whale crosses or passes a vessel track within a distance of 200 m or less. This distance is intermediate between 100 and 300 m considered for several regulations for approaching whales (Corkeron 1995, Stamation *et al*. 2010) and reports of whale reaction to sound (Watkins 1986). Any transmission relies completely on the capacity of the SPOT5 to monitor the wet/dry sensor of the transmitter to allow sufficient time to transmit; the transmission is initiated when the sensor indicates a dry condition. This condition may be affected by the behavior of the animals.

Results

Cargo ships constituted the largest number of vessels in the area during the study (73.3%), followed by tankers (19.4%) (Table 1). All plotted tracks delineated four potential routes or axes: three major routes between Azuero Peninsula and Las Perlas Archipelago (A, B, and C) and one (D) directly linked to a dredging vessel with a sand extraction concession located just 1–3 km (8.23°N, 79.00°W) off the southern edge of the MPA (Fig. 1). The widths of vessel traffic routes varied considerably from 8 km to 57 km toward the entrance of the Gulf of Panama (parallel to 7.5°N), encompassing an estimated area of 11,669 km^2 of the traffic area (red lines in Fig. 1).

During our study, the tagged humpback whales moved freely within the Gulf of Panama and in particular used Las Perlas Archipelago and surrounding shallow waters during wintering (Fig. 1). Nineteen humpback whales were tagged between 23 and 26 August during the peak of the 2009 wintering season. However, four SPOT transmitters never transmitted. The shortest and longest transmission times were 1 and 24 d, respectively (Table 2). Maximum distance traveled was 2,023 km in 24 d; this whale (No. 16) stayed in the vessel–whale interaction area for nearly 20 d and reached 4°N near Malpelo Island within 2 d.

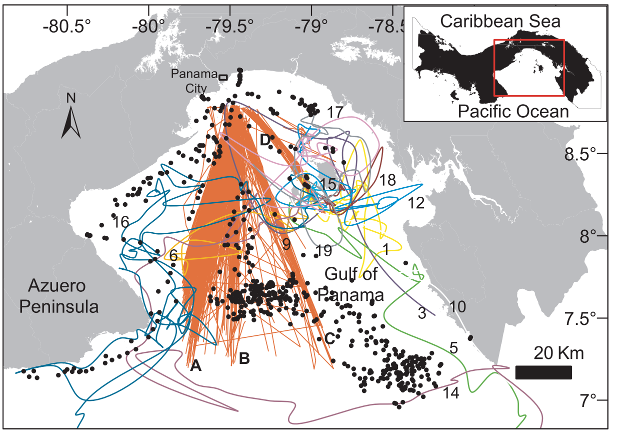

Figure 1. AIS traffic tracks of 892 vessels (red lines) entering or leaving the Gulf of Panama from 21 August to 19 September 2009 plotted against tracks of 12 individual humpback whales (*Megaptera novaeangliae*) tagged between August 21 and 26, 2009 in Las Perlas Archipelago, Pacific Panama. Tracks for whales with less than 50 km of distance traveled (n = 3) were not plotted. Four potential existing routes indicated as A–D and local fishing vessels indicated as black dots.

Table 2. Summary of data from SPOT satellite transmitters for humpback whales (*Megaptera novaeangliae*) tagged during August 2009 in Las Perlas Archipelago, Panama.

No.	PTT	Tagged date	Transmission days	Distance traveled (km)
1	87721	27	22	1,039
2	87722	25	1	17
3	87723	25	11	2,001
4	87724	25	0	N.D.
5	87725	26	7	1,228
6	87726	25	2	326
7	87727	25	1	36
8	87730	27	0	N.D.
9	87731	25	1	71
10	87734	26	8	823
11	87735	25	0	N.D.
12	87736	26	8	471
13	87737	25	0	N.D.
14	87738	25	11	1,180
15	87739	23	6	184
16	87740	26	24	2,023
17	87741	27	17	680
18	87742	23	7	271
19	87743	23	13	740

Three other humpback whales traveled as far as Buenaventura, Colombia (3ºN), visiting other known breeding areas within days (*sensu* Stevick *et al.* 2011) while staying within an average maximum distance of 63.5 km (range 11–199 km) from the mainland: individual No. 5 traveled 1,228 km in 7 d, No. 10 traveled 823 km in 8 d, and No. 14 traveled 1,180 km in 11 d (Table 2). The latest one (No. 14) passed westward across the gulf towards Azuero Peninsula for several days before heading south. The remaining whales (73%) never left the Gulf of Panama during the study period (Fig. 1).

Overlaying the real-time video of whale coordinates over vessel tracks showed that whales were normally in the path of many vessels that were moving at cruising speed and using the same space inside the observed traffic tracks of *ca.* 11,669 km^2 (Fig. 1). Along route D, all whales interacted with a vessel (beam 22 m, length 121 m, draft 6.3 m), which used the MPA several times a day as shortcut and at a maximum speed of 15 kn. The area encompassing routes A, B, and C between parallels 8.8ºN and 7.5ºN was used by 33% of the whales during the study period (Fig. 1). Fishing vessels moved nearly everywhere in the Gulf of Panama (Fig. 1).

A detailed analysis of AIS vessel data and whale satellite tracks showed that 53% of whales had close encounters with a ship. Among these whales, we measured 98 interactions within the 200 m radius involving 81 different vessels in 11 d (Fig. 2, Table 3). Those 81 vessels represented 9.2% of the total

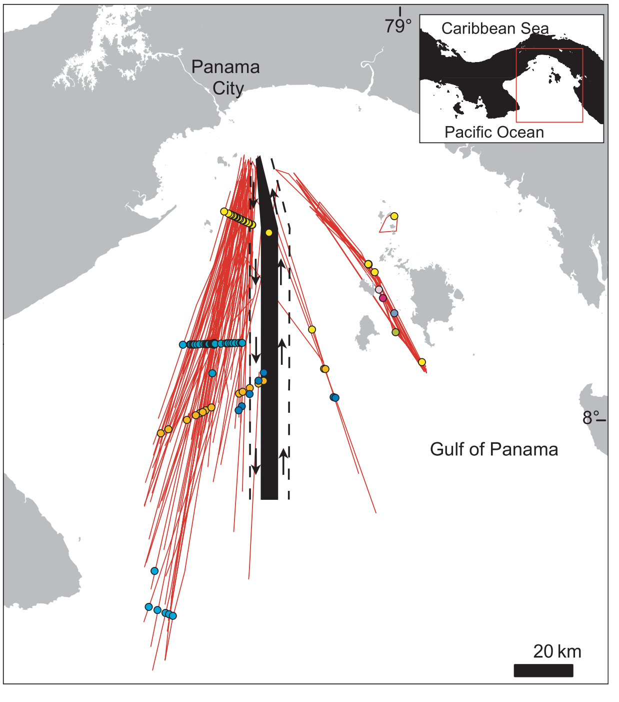

Figure 2. Tracks of 81 vessels and the spatial distribution of the 97 interactions with eight different whales (see Table 3) plotted over the suggested two-way Traffic Separation Scheme for ship routing of *ca*. 120 km (65 nmi) between parallels 8.8ºN and 7.0ºN in the Gulf of Panama, Panama. Each dot represent an interaction and each color an individual whale.

Table 3. Number of different vessels that a whale came within 200 m and the amount of time (number of hours and minutes) taken to travel the indicated distance in a particular date, in the Gulf of Panama, Panama.

Whale PTT	Date	Vessels	Time	Distance (km)
87726	26 August	13	8:20	39.8
87726	26 August	2	2:52	0.37
87738	26 August	5	2:43	15.87
87738	26 August	2	1:33	0.5
87736	26 August	1	4:44	27.4
87740	26 August	1	1:32	8.7
87743	28 August	1	11:00	16.3
87739	29 August	1	0:09	0.16
87740	30 August	1	0:54	26.7
87740	30 August	37	3:27	20.6
87741	2 September	2	1:08	29.8
87741	5 September	1	7:10	5.2
87721	7 September	1	6:08	17.7
87741	8 September	1	6:40	36.9
87741	9 September	22	4:10	17.2
87741	9 September	1	3:10	11.6
87740	11 September	5	4:02	8.9
87740	12 September	1	6:37	8.8

(see Table 1). Daily interactions ranged from 1 to 38 vessels for individual whales for the same period, with one whale (87740) experiencing 45 encounters in 4 d (Table 3). Those encounters occurred during highly variable time frames from nearly 10 min to 11 h and overall distances of 0.5 km to nearly 40 km (Table 3). These results suggest that whale behavior is highly variable once they enter the traffic area. Indeed, whale 87726 traveled 0.37 km in 2:52 h with two potential interactions while whale 87738 did 15.87 km in a similar time frame and had five interactions (Table 3). One whale (87740) covered a distance of 20 km in more than 3 h and had 37 interactions with vessels while another (87739) had only one interaction in the shortest distance and period recorded. Additionally, the 97 close encounters involved 68% cargo and 28% tanker vessels. Mean characteristics (and ranges) of cargo vessels, were length 186.6 m (99–317), beam 27 m (14–42) m, draft 8.9 m (5.5–12.4), and speed 15.8 kn (9.4–22.6), while those of tanker vessels were 159.7 m (121–229), 26.4 m (20–32), 8.3 m (5.5–11.9), and 13 kn (7–15.8), respectively. Only 1% of encounters included passenger cruisers at mean speeds of 10.9 kn.

Total number of transmissions for all location classes varied among the whales from 10 to 114 with a noticeable reduction in number for the three most accurate classes (Table 4). These results illustrate not only the limitation imposed by the satellite technology but also the behavior of the whales.

Humpback whale maximum speeds averaged 11.2 kn (range 2.2–16.2 kn). In contrast, all cargo and tanker vessels reached maximum speeds in route inside the Gulf of Panama (Fig. 3); tankers averaged 15 kn and cargo ships 17 kn (with maximums >22 kn). Similar speeds were attained at the entrance of the Gulf of Panama by vessels moving to the north. Mean speed recorded for fishing vessels was 3.8 kn, with maximums >8.7 kn (Fig. 3).

Table 4. Total and daily average number of transmissions for all (0-1-2-3-A-B) and best (1–3) quality location classes.

Whale PTT	Total all	Daily average all	Total best	Daily average best	Location classes 0	1	2	3	A	B
87721	88	4.0	27	1.2	5	15	9	3	23	33
87723	105	9.5	13	1.2	6	8	4	1	34	52
87725	75	10.7	31	4.4	12	8	4	19	31	1
87726	19	9.5	4	2.0	3	4	0	0	4	8
87727	22	22.0	6	6.0	2	0	1	5	7	7
87731	10	10.0	1	1.0	1	1	0	0	3	5
87734	45	5.6	16	2.0	3	5	10	1	10	16
87736	23	2.8	2	0.2	1	1	0	1	5	15
87738	65	5.9	4	0.3	1	3	1	0	18	42
87739	24	4.0	6	1.0	0	4	1	1	5	13
87740	114	4.7	11	0.5	2	8	3	0	18	83
87741	49	2.8	3	0.2	1	3	0	0	12	33
87742	28	4.0	9	1.3	5	2	0	7	14	0
87743	39	3.0	2	0.2	1	0	2	0	8	28

Discussion

Humpback whales from both the Northern and Southern Hemispheres are common in the tropical eastern Pacific during the wintering season. Each year over the course of nearly seven months, hundreds of whales arrive in tropical Central and South America, but only recently has attention been focused on documenting mortality that occurs during regional migration (Florez-Gonzalez *et al.* 2007, Van Waerebeek *et al.* 2007). Humpback whales are the second most species affected by vessel collision (Laist *et al.* 2001, Jensen and Silber 2004, Van Waerebeek *et al.* 2007).

Panama has a long maritime history and currently is among the 20 most transited areas of the world (Kaluza *et al.* 2010), and transit is expected to increase in the near future including post-Panamax vessels 366 m long, 49 m beam, and 15 m draft. Currently, the country has not implemented traffic separation schemes (TSS) for routing vessels (*sensu* IMO 2010) while *ca.* 17,000 commercial vessels transits the Gulf of Panama annually including an average of 14,500 vessels only transiting the Panama Canal. However, it was only recently that Panama started gathering information about cetacean mortality, recording 13 deaths between 2009 and May 2011, mostly humpback whales (Autoridad de Recursos Acuaticos de Panama, unpublished data). This is likely a highly underestimated number, especially considering that a functional stranding network is not in place and the causes of death are difficult to obtain. The present study suggests that the range of movements of humpback whales in the Gulf of Panama at the peak of the wintering season coincides with major commercial maritime routes. In addition, industrial and artisanal fishing vessels (trawler, longliner, seine-net, *etc.*) constantly were observed navigating the northern, southern, and eastern bounds of the Gulf of Panama though at lower speeds.

The number of potential whale–vessel encounters reported here (98 vessel interactions in 11 d for eight whales) is restricted to our spatial-temporal scale of the analyses and represents an underestimation because of limitations imposed

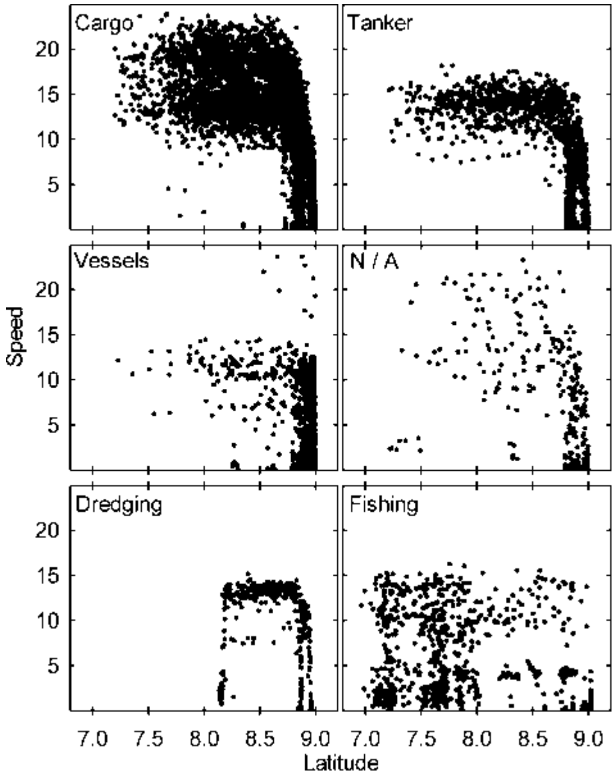

Figure 3. Unfiltered data for vessel speed of six ship types plotted against latitudinal tracks from 21 August to 19 September 2009 in the Gulf of Panama, Panama.

by the days of transmissions, total number of tagged animals and number, quality and accuracy of transmissions. It is essential to note that the accuracy of locations based on satellite tracking highly depends on the quality of the transmissions and hence the behavior of the whale while moving (swim speed and path directness) and surfacing (breathing and social interactions), including the response to stimuli from human activities like previous exposure to ships, noise and certainly the proximity to vessels, as well as the age composition of the pods (Stevick 1999, Felix 2004, Scheidat *et al.* 2004, Stamation *et al.* 2010). This is the case for humpback whales that surface hundreds of times without producing a good satellite transmission and do not have straightforward movements or constant speed. Nevertheless, the spatial-temporal scale of our analyses clearly indicates a potential threat to 53% of monitored humpback whales. This information can be used to consider the implementation of local regulations to avoid or reduce vessel collision with whales, particularly during the Southern Hemisphere migration, in accordance with the International Maritime Organization (IMO) and the International Whaling Commission (IWC), which consider the reduction of ship strikes of whales a priority.

Vessels require long distances to slow their speed and avoid collisions; in particular, large traditional hull vessels require thousands of meters to alter their course in most sea conditions (Silber *et al*. 2009). Most lethal or severe injuries to whales involve vessels traveling at 14 kn or faster; rarely do injuries occur at vessel speeds below 10 kn (Laist *et al*. 2001, Vanderlaan and Taggart 2007). Thus, a 10 kn or slower speed restriction has been implemented along the Atlantic coast of the United States (extending 20 mi out from major ports) for vessels 65 ft or larger to protect North Atlantic right whales during the migratory season. Countries such as Brazil, Canada, Chile, France, New Zealand, Spain, and the United States have implemented actions and are evaluating the possibility of modifying shipping routes and vessel speeds (IWC 2010).

Ship surveillance systems need to be integrated for improving detectability and tracking in highly transited areas and should consider the joint use of SAR (Synthetic Aperture Radar) and AIS (Lehner *et al*. 2009). We recommend gathering all data based on radar and satellite coordinates for vessels, regardless of size and tonnage, to develop regional realistic shipping routing maps along a minimum 50 km (27 nmi) wide free maritime corridor parallel to the Central American and South American coastline and to evaluate potential temporal changes to existing routes by implementing Traffic Separation Schemes (*sensu* IMO 2010) for approaching major ports during the wintering season of humpback whales (in particular during the migration from the southern hemisphere). Voyage planning and information provided in advance by regional or local authorities can be used to anticipate potential whale interaction along these routes (Silber *et al*. 2009). In addition, Panama should consider, for example, establishing a two-way Traffic Separation Scheme (TSS) for ship routing of *ca*. 120 km (65 nmi) between parallels 8.8ºN and 7.0ºN, with each traffic lane being 2 nmi wide, separated by 3 nmi (Fig. 2, *sensu* IMO 2010). By implementing a TSS in the Gulf of Panama, the vessel traffic area will be reduced by 92.9%; the suggested ship routing (only the traffic lanes) covers an area of *ca.* 829.4 km^2 compared to current nonrouting scheme of *ca.* 11,669 km^2. Consequently, the chance of whale-vessel collisions would be reduced by 94.8% (*i.e*., with only five interactions detected inside the TSS) based on our analyses (see Fig. 2).

A speed reduction is considered a reasonable policy to reduce threats of ship strikes (*sensu* Silber *et al*. 2010, Wiley *et al.* 2011). A maximum vessel speed can be seasonally restricted to 10 kn for ships navigating north or south between parallels 8.2ºN and 8.8ºN inside the Gulf of Panama for a distance of *ca*. 66 km or 35.5 nmi (only 55% of TSS), at least between August and December. A vessel cruising at typical speeds of 15–20 kn requires *ca.* 2:22:12–1:43:47 h to transit the seasonal 35.5 nmi TSS, whereas at 10 kn it would require *ca*. 3:33:36 h. Consequently, local maritime authorities would have to consider transit times and schedule reliability, which are two issues critical for designing impeccable liner services (Notteboom 2006), but also maritime economics related to seasonal shipping cycles (*sensu* Stopford 2009), waiting time, delays, maritime passages, port characteristics, and regional interconnectivity (Notteboom 2006, Wilmsmeier *et al*. 2006). Certainly, it is necessary to develop an international management strategy to reduce collisions (*sensu* Elvin and Taggart 2008).

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