Here Today, Here Tomorrow: Beached Timber In Gabon, A Persistent Threat To Nesting Sea Turtles

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Abstract
The African country of Gabon has seen decadal increases in commercial logging. An unforeseen consequence of this has been that many coastal areas, including several National Parks and Reserves, have suffered severe pollution from beached timber. This has the potential to adversely affect nesting sea turtles, particularly the leatherback turtle (*Dermochelys coriacea*) for which Gabon constitutes the world's largest rookery. In this study, we analyse aerial survey data (2003, 2007 and 2011) to determine the temporal persistence and spatial extent of beached timber, and by integrating spatial data on nesting, ascertain regions where beached timber poses the greatest threat to nesting leatherback turtles. There was no marked difference in the number of beached logs recorded across the study area during the period, with 15 160, 13 528 and 17 262 logs recorded in the three years, respectively. There was, however, a significant difference in abundance of beached logs among geographical areas. Analysis highlighted two coastal areas where nesting leatherback turtles were likely to be at greatest risk from beached timber. At one such site, Kingere, within Pongara National Park, where both logs and turtle densities are high, monitoring in 2006/07 and 2007/08 suggested that between 1.6% and 4.4% of leatherback turtles could be entrapped at this site. Given the dynamic nature of Gabon's coastal environment, and the potential limitations of aerial surveys, densities of beached timber could be greater than this analysis reveals. We also propose, that despite recent export restrictions of whole logs, their environmental persistence potentially represents a long-term problem.

Keywords: aerial survey, beach, logs, leatherback turtle, threat, timber

1. Introduction

Industrial logging in Central Africa has shown decadal increases and now contributes to a large proportion of land use in the region (Laporte et al., 2007). Historically, Gabon was able to resist such commercial pressure due to its natural oil and mineral reserves, but recently, pressure to expand commercial logging activities has increased (Laurance et al., 2006). Export revenue from timber and associated products contributed an average of 6.5% to Gabon's Gross Domestic Product (GDP) from 1995 to 2010 (World Bank, 2011). The commercial value of all exported timber products more than tripled in the decade up to 2008, although the exported cubic volume remained consistent since the peak export years of 1997 and 2000 (ITTO, 2010a). The fast-growing hardwood, okoumé (*Aucoumea klaineana*) is a key forest species in Gabon (Medzegue et al., 2007), and is the principal species associated with the export market (Collomb et al., 2000).

Traditionally, as part of the commercial export process, roundwood (whole logs) were transported by barge, or as rafts of timber, downriver towards the coast; Gabon's river systems have been associated with the transportation of cut timber since the onset of commercial logging at the beginning of the 20th century (Gray and Ngolet, 1999). However, logs that broke free during transport were carried to coastal waters and some became beached, forming large aggregations in several areas (Laurance et al., 2008). In a move towards sustainable forest management policies and steps to diversify the economy of Gabon, the export of roundwood was formally banned in May 2010 (ITTO, 2010b) thereby promoting the processing of timber beyond sawn lumber and veneers towards finished products.

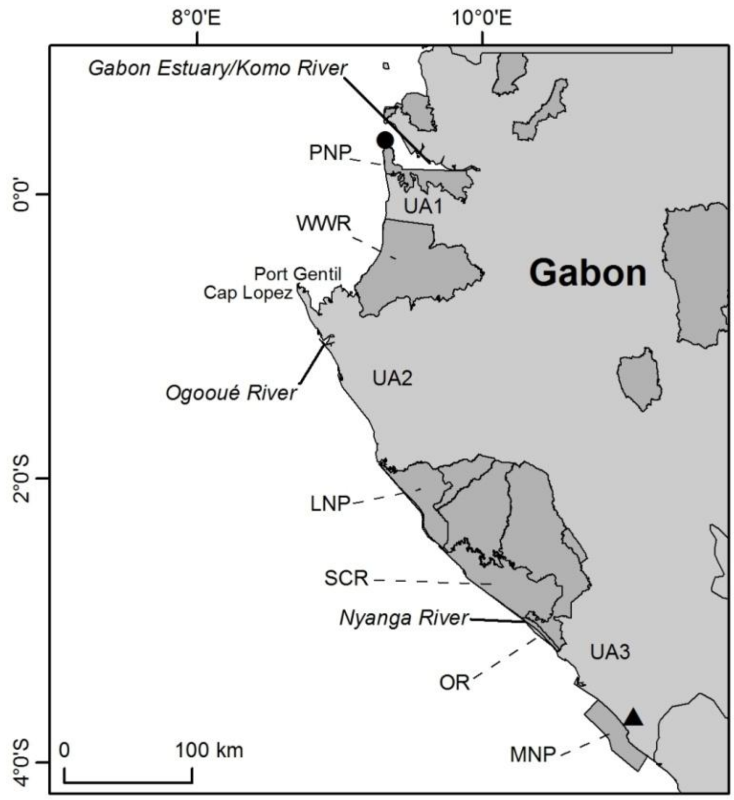

Fig. 1. Gabon National Parks, Reserves and Rivers. National Parks and Reserves are shown in mid grey, unclassified areas in light grey; PNP: Pongara National Park, UA1: unclassified area 1, WWR: Wonga Wongue Reserve, UA2: unclassified area 2, LNP: Loango National Park, SCR: Sette Cama Reserve, OR: Ouanga Reserve, UA3: unclassified area 3, MNP: Mayumba National Park. The river mouths of the Komo, Ogooué and Nyanga are indicated by solid black lines and labelled in italics. The start and end locations for all surveys are shown as a filled circle and filled triangle respectively.

In 2002, a system of National Parks was created in Gabon with the aim of protecting key areas of biodiversity-rich coastal and terrestrial habitats (Fig. 1). In total, 13 National Parks encompassing more than 25 000 km^2 or 10% of its territory were designated. These protected coastal zones, together with many other beaches of Gabon, represent some of the world’s most important nesting sites for sea turtles. These include the globally important breeding aggregation for the leatherback turtle (*Dermochelys coriacea*), with the northern and southern extremes of the Gabonese coast (Pongara and Mayumba National Parks) receiving the highest densities of nesting activity (Witt et al., 2009): 23% and 33% respectively (this study: 2003 aerial survey data). Gabon's beaches also support nesting olive ridley (*Lepidochelys olivacea*) and green sea turtles (*Chelonia mydas*) (Fossette et al., 2008; Maxwell et al., 2011).

Beached logs represent a threat to nesting sea turtles through obstruction, entrapment and disorientation (Laurance et al., 2008; Bourgeois et al., 2009). An initial assessment of the threats posed to Gabon's nesting sea turtles by beached timber was made by Laurance et al (2008) using a single year's aerial survey data (January 2003), together with ground surveys of a 4.2 km section of Pongara National Park (March 2005). This analysis suggested that beached log densities were spatially highly variable, peaking in the vicinity of Pongara and Mayumba National Parks and that 8 - 14% of all nesting attempts (97.6% involving leatherback turtles) at Pongara Natonal Park were negatively affected.

Our study builds upon this initial assessment with rigorous and comprehensive statistical analyses of multiple year aerial survey data (February 2003, 2007 and 2011). We couple this analysis with ground surveys of leatherback/log interaction impact assessments from three disparate coastal regions (spanning 38 km of coastline) over two nesting seasons. In addition, we formulate a threat index to quantify the interaction between nesting leatherbacks and beached timber for the majority of the Gabonese coast.

We demonstrate that the temporal and spatial extent of beached timber, and therefore the associated threat to leatherback turtles, highlighted by Laurance et al. (2008), is persistent and has the potential to remain so, until remedial action to remove beached timber is taken. We concur with the initial findings of Laurance et al. (2008) regarding impacts to leatherback turtles at Pongara National Park, but also demonstrate that this threat is a national issue within both protected and unprotected areas.

2. Methods

2.1. Aerial surveys and data management

Aerial surveys were flown along the Gabonese coast using a variety of high-wing light aircraft on 12th February 2003, 23rd / 24th February 2007 and 23rd / 24th February 2011; these surveys were timed to coincide with leatherback turtle nesting activities (Witt et al., 2009). To quantify the potential for discrepancies between counts derived from aerial survey analysis and ground counts, a further limited aerial survey was flown on 30th January 2012 that was spatially concordant with a ground-based validation survey. The aircraft were flown at an approximate groundspeed of 180 to 190 km hr^{-1} at an altitude of 50 to 60 m, with the aircraft positioned 100 to 200 m offshore. Surveys were flown in a southeast direction from northern to southern Gabon, parallel to the coastline. The start location for all surveys was Pointe Pongara, south of the capital, Libreville (Fig. 1). The survey end location in 2003 was 42 km northwest of the southern limit of Mayumba National Park's border with the Republic of Congo. Aerial survey end locations for 2007 and 2011 were further to the southeast near the Gabon-Congo border. A 50 km section of coast to the east of Cap Lopez, Port Gentil was excluded from all surveys as this area consisted of mangroves and mudflats that would not support nesting leatherback turtles (Fig. 1).

Continuous video footage was captured using an analogue video camera recording to tape in 2003 and 2007 (subsequently digitised to .avi format) and in High Definition (HD) using a digital video camera in 2011 and 2012 (.m2ts format). A hand-held Global Positioning System (GPS) receiver was used to record waypoints of the aerial survey comprising longitude, latitude, altitude, date/time, distance from start and speed. Small differences occurred in total distances flown among survey years from discrepancies in aircraft flight path or where the video recording was stopped to change tape (2003 and 2007) or memory card (2011) or if surveys occurred across two days (2007 and 2011). Date and time stamps were burnt to the recorded video footage, this was then viewed at half frame speed, or where log densities required, with the frame paused. All logs that lay on the shore between the surf-zone/foreshore interface and back-shore/coastal vegetative terrain were counted. Logs that lay further inland were deemed to be outside of the area of extreme storm activity and as they had little potential to be re-mobilised into the marine/beach environment, were not included in the count. The method for counting leatherback turtle nests from aerial surveys is fully described in Witt et al. (2009).

Log counts and leatherback turtle nesting counts were imported into the Geographical Information System (GIS) ArcView 9.2 (ESRI, Redlands, USA http://www.esri.com). This was used to generate distribution maps and to identify protected and unclassified land areas, as well as to perform spatial analysis. GPS waypoint data were used to partition the flown survey route into sections, or data bins, for analytical purposes. Mean data bin length varied slightly among survey years; 2003: 617 m (standard deviation (SD) 46 m), 2007: 516 m (SD 15 m) and 2011: 525 m (SD 16 m). Therefore, direct comparisons among years using log counts per data bin were not conducted.

To facilitate statistical analysis, the 2007 and 2011 surveys were clipped to the same spatial extent of the 2003 survey. To standardise data to a common spatial resolution we created a raster of discrete 25 km^2 coastal polygons that encompassed the spatial extent of the 2003 aerial survey path. The aerial survey raw data bins for 2003, 2007 and 2011 surveys were then aggregated into the raster squares to which they were spatially coincident. Log densities km^{-1}, and leatherback turtle nest densities km^{-1}, for each 25 km^2 were then calculated.

A threat index ((logs km^{-1} * nests km^{-1}) / Σ (logs km^{-1} * nests km^{-1})) was formulated from the 2003 raw bin count data to represent the potential for interaction between nesting leatherback turtles and beached logs. To identify coastal areas with the highest threat indices we calculated relative estimates of density using a kernel smoothing approach (Worton, 1989; Laver and Kelly, 2008). This provides an estimate of the probability density function for a spatially referenced variable using a defined smoothing parameter and optional weighting to the variable. So as not to over-smooth the resulting kernel a smoothing parameter of 5 km was chosen.

All statistical analysis was undertaken with R (R Development Core Team, 2008). A Linear Mixed Effect (LME) model (R package: nlme (Pinheiro et al., 2012)) was used to investigate the relationships of year and classified/unclassified area and log densities. Results were validated using residuals vs. fitted values diagnostic plots.

2.2. Ground-based surveys

Ground-based log surveys were conducted for a 9 km section of Pongara National Park on 18th / 19th September 2010 (N 0.306, E 9.301 to N 0.226, E 9.314; all coordinates given as decimal degrees according to WGS 1984), on 13th / 14th July 2011 (N 0.306, E 9.302 to N 0.223, E 9.313) and on 9th February 2012 (N 0.294, E 9.304 to N 0.228, E 9.313); the latter being carried out within ten days of an aerial survey. For 2012, all logs that lay on the shore between the surf-zone/foreshore interface and back-shore/coastal vegetative terrain within this 9 km section were counted. For 2010 and 2011, the lengths and diameters of all beached logs within the first 2 km of this section were recorded. Where measurement of length was not possible due to the log, or portion of the log, being embedded in the sand, the log was recorded as ‘buried’.

Daily counts of leatherback turtle tracks were made during the early morning by beach patrols at three coastal regions during the nesting seasons from 2006/07 to 2010/11. Counts were made at Pongara National Park (N 0.352, E 9.355 to N 0.221, E 9.313) (19 km), Sette Cama Reserve, (S 2.798, E 10.027 to S 2.825, E 10.065) (5 km), and Mayumba National Park (S 3.729, E 10.975 to S 3.782, E 11.017) (7 km) and (S 3.908, E 11.080 to S 3.863, E 11.028) (7 km). All encountered tracks were assessed for whether they had been impacted by logs, each track being categorised: 0) no impact, 1) nesting was definitely abandoned due to logs, 2) nesting was probably abandoned due to logs, 3) the turtle was blocked by logs but was able to nest above the High Tide Line (HTL), 4) the turtle was blocked by logs but was able to nest below the HTL, 5) the turtle was blocked by logs after nesting, whilst returning to sea. Additional monitoring of turtle entrapment was undertaken in the 2006/07 and 2007/08 season at Kingere, (S 0.298 E 9.303 to S 0.221 E 9.313) (a 7 km section of Pongara National Park).

3. Results

3.1. Spatial density patterns and threat index

In total, 15 160, 13 528 and 17 262 logs were recorded in 2003, 2007 and 2011, respectively, along the ca. 550 km coastline (Table A1). Log densities were greatest in the north and towards the south of the Gabonese coastline; areas both associated with river estuaries (Fig. 1). Within protected areas, Pongara National Park had the highest recorded number of logs km^{-1} for all years; whereas, Mayumba National Park had the lowest (Table A1).

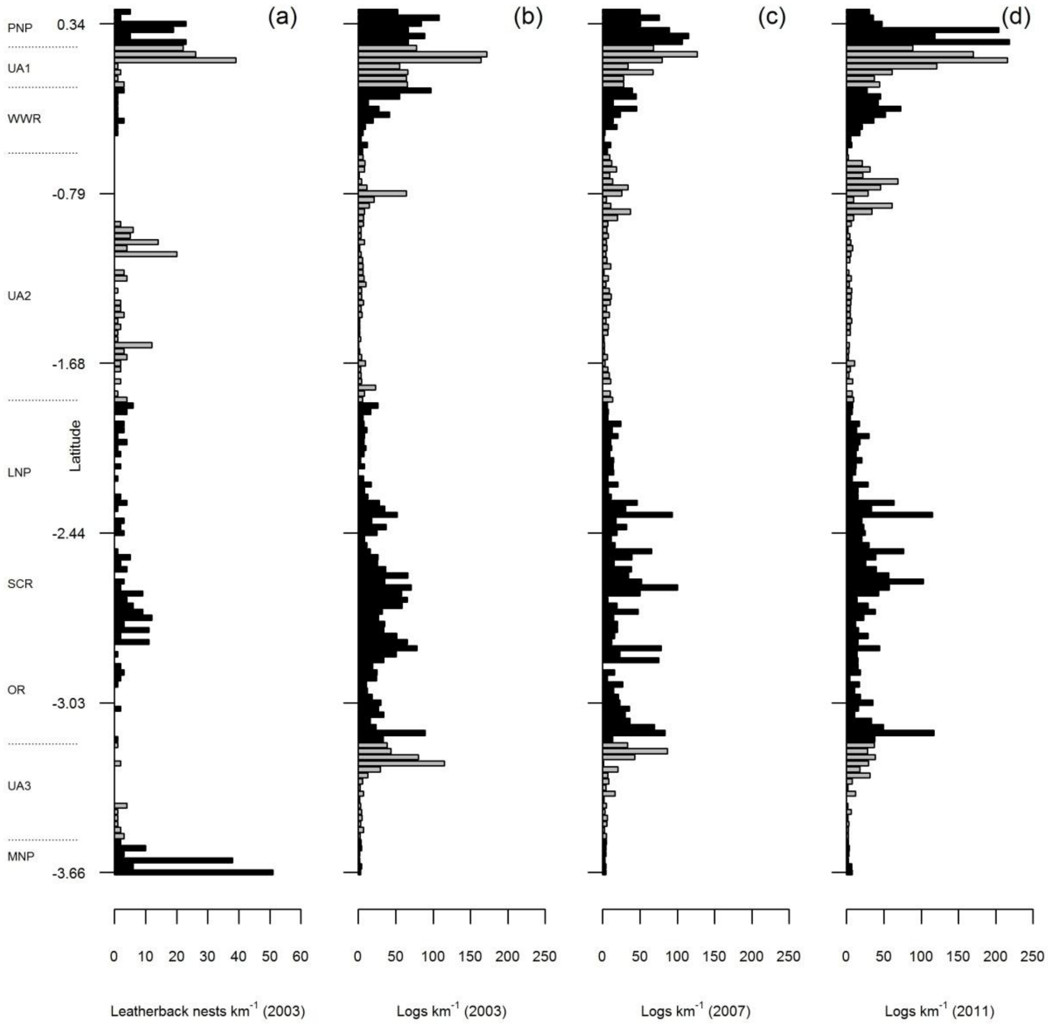

Fig. 2. Spatial density patterns by latitude. (a) Leatherback turtle nests km^{-1} for 2003 (Witt et al. 2009) . Beached logs km^{-1} for (b) 2003, (c) 2007 and (d) 2011. Data were standardised to a common spatial resolution of discrete 25 km^2 squares derived from the 2003 survey. National Parks and Reserves are shown as black bars and unclassified areas as mid grey bars. For abbreviations see Fig. 1.

Spatial mapping of standardised log densities (logs km^{-1} / 25 km^2) showed that across all survey years, there was a consistently high density of beached logs within Pongara National Park and unclassified area 1 (Fig. 2, 3). Log densities for Wonga Wongue Reserve and for unclassified area 2 were greater to the north of these areas (Fig. 2). Log densities for the Gamba Complex of reserves (including Loango National Park, Sette Cama Reserve and Ouanga Reserve) were greater in the centre and to the south of this complex (Fig. 2). Mayumba National Park demonstrated a consistently low density of beached logs (Fig. 2).

Standardised log densities were not influenced by the main effect of year ($Chi^2_1 = 0.40$, $p = 0.53$) or by any relationship with survey year and area ($Chi^2_8 = 5.38$, $p = 0.72$). There was, however, a significant difference in the density of beached logs recorded among areas ($Chi^2_8 = 77.56$, $p < 0.001$) (Fig. 3).

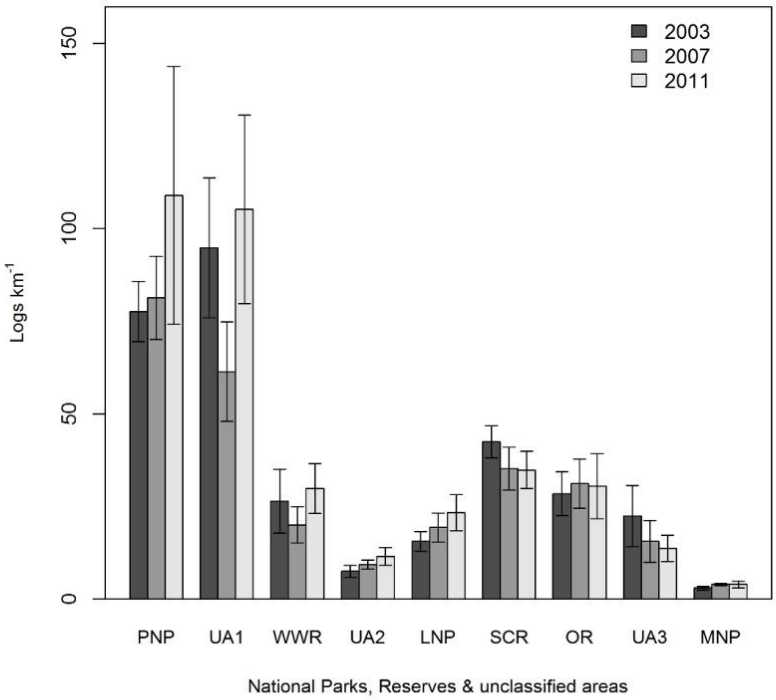

Fig 3. Mean logs km^{-1} (Mean ± SE) for 2003 (dark grey bars), 2007 (mid grey bars) and 2011 (light grey bars). A LME indicated that log densities were not influenced by the main effect of year ($Chi^2_1 = 0.40$, $p = 0.53$) or by any relationship with survey year and area ($Chi^2_8 = 5.38$, $p = 0.72$). There was a significant difference in the density of beached logs recorded among areas ($Chi^2_8 = 77.56$, $p < 0.001$). For abbreviations see Fig. 1.

Mapping of standardised leatherback turtle nest densities indicated that Mayumba National Park, the northern end of unclassified area 1 and Pongara National Park had the highest densities of leatherback turtle nests (Fig. 2) with 33%, 24% and 23% of all leatherback nesting activity occurring in these areas, respectively.

Risk mapping, however, identified the 75% volume contour of the kernelled density distribution of the threat index as including: 22 km of Pongara National Park, 16 km of unclassified area 1, and 21 km (non-contiguous) of Sette Cama Reserve (Fig. 4).

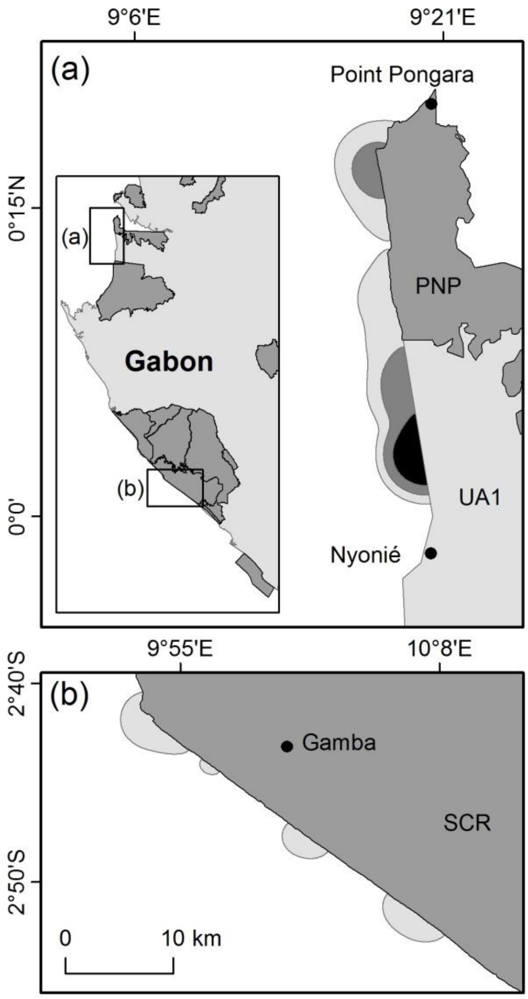

Fig 4. Threat maps for nesting leatherback turtles. Weighted kernelled distribution of threat indices with a 5 km smoothing factor for (a) Pongara National Park and unclassified area 1 and (b) Sette Cama Reserve. 25%, 50% and 75% polygons of the density distribution are shown with black, mid and light grey fill respectively. National Parks and Reserves are shown in mid grey and unclassified areas in light grey. Maps (a) and (b) are drawn to the same spatial resolution and are located according to the inset of part (a).

3.2. Ground-based surveys

Within the ground surveyed section of Pongara National Park, a total of 1561 (212 logs km^{-1}) were recorded for 2012. This compared with 1254 logs (170 logs km^{-1}) for the 2012 aerial survey analysis, with the aerial survey being specifically undertaken temporally close to the ground survey; this represents an aerial survey undercount of 20%.

Within a 2 km sub-section, for 2010, mean log length was 9.31 m (SD 2.32) with a mean diameter of 0.73 m (SD 0.25); 219 logs (68.7%) out of a total of 319 could not be measured and were classified as buried. In 2011, for the same 2 km sub-section, mean log length was 8.52 m (SD 3.02) with a mean diameter of 0.66 m (SD 0.20); 210 logs (57.2%) out of a total of 367 could not be measured and were classified as buried.

Daily counts of leatherback turtle activities and impacts to nesting associated with beached logs indicated that, on average, across 2006/07 to 2010/11 nesting seasons, 17% (Pongara National Park), 6% (Sette Cama Reserve) and < 1% (Mayumba National Park) of all recorded leatherback turtle beach movements were likely to have been impacted in some way by beached logs (Table A2). At Kingere (a 7 km section of Pongara National Park), however, where there was a high density of logs and nests, the impact was greatest. In 2006/07, 22 females were discovered entrapped in logs (8 dead, 14 rescued). This number was lower in 2007/08 (2 dead, 2 rescued) but nesting was at a lower level in the latter season. A total of 3043 and 1506 leatherback turtle tracks were counted at Kingere in 2006/07 and 2007/08 respectively, likely resulting in 3013 and 1491 clutches, respectively (Witt et al 2009). If we assume all females lay 6 clutches each (Miller, 1997) then we can estimate that mortality, without intervention, at this site would have been 4.4% of all nesting females in 2006/07 and 1.6% in 2007/08.

4. Discussion

River transportation and storage of logs is an inexpensive logistic solution for the industry (Sedell et al., 1991), but it may alter channel structure and cause allied habitat degradation. The impacts to marine and coastal habitats from beached timber arising from this practice are understudied. Gabon's river systems have been associated with the transportation of harvested timber for over a century, and therefore the coastline of Gabon, and its species and habitats, have had the potential to have been impacted by beached timber for a considerable time.

Analysis of aerial survey data obtained from the Gabonese coast indicates that there has been no significant change in the relative density of beached logs amongst 2003, 2007 and 2011. With a ban on the export of roundwood in May 2010 (ITTO, 2010b) it would be reasonable to expect the fresh input of whole logs to the marine environment to have largely ceased. Given the nature of hardwood timber to resist decay, this relatively consistent density of logs potentially represents a long-term problem.

The relative density of logs was spatially variable among coastal areas. Log densities were highest in areas adjoining river estuaries. To the north of the country, the rivers of the Komo (the Gabon Estuary) and the Ogooué discharge to the coastal regions of Pongara National Park, Wonga Wongue Reserve, unclassified area 1 and the northern part of unclassified area 2 (Fig. 1). Likewise, to the south of the country, the Nyanga River discharges to the coastal regions of Sette Cama Reserve, Ouanga Reserve and the northern end of unclassified area 3 (Fig.1). The Ogooué River is the principal river of Gabon and drains the vast majority of the country (McShane, 1990) and for decades has served as a significant internal transport link to the main Gabonese port of Port Gentil (Gray and Ngolet, 1999). The increased spatial density of beached logs, associated with river mouths, is likely an artefact of the historic transportation practice related to the movement of felled timber, allied with the coastal morphology of these regions. Predominant wind direction is southerly (Peterson and Stramma, 1991) and both the Southern and Northern Equatorial Counter currents flow in an easterly direction. Mean tidal ranges are small (1.0 – 1.2 m) and the swell has a long period, generally from a south-westerly direction (Giresse, 2010). These factors may singularly, or collectively, increase the likelihood for logs to remain in situ after becoming beached and limit their propensity for remobilisation.

The beaches of Gabon are subject to alteration by storm wave erosion and fine weather accretion; where remobilisation and transport of sand occurs, this is generally in a northerly direction (Giresse, 2010). Ground-based surveys gave clear evidence of the effect of this accretion process on beached timber, with more than half of all logs surveyed unable to be measured. Aerial video footage also highlighted this accretion and erosion process; in some coastal sections, only small radial segments of log circumference would be visible, or if burial and erosion had occurred, part buried logs would protrude from the sand. This process of concealment and exposure could account, in part, for the fluctuation in the relative densities of logs within areas, between aerial surveys; although, the potential for some remobilisation and shift in log distribution should not be dismissed.

Leatherback turtle nesting densities were highest in Mayumba National Park, the northern end of unclassified area 1 and Pongara National Park. Areas identified as posing the highest threat to nesting leatherback turtles through beached logs were Pongara National Park, the 16 km northern end of unclassified area 1, and sections of Sette Cama Reserve. Of the three sites subject to long term monitoring, impacts of beached logs on leatherback turtle nesting were highest within Pongara National Park and Sette Cama Reserve. It is clear that there is the potential for increased mortality in high impact areas such as Kingere and possibly other areas not yet subject to ground survey. Logs have the potential for multiple impacts on marine turtles (Laurance et al. 2008). Reduced nesting success may also result from higher numbers of clutches being laid below the high tide line. Logs are also a problem for hatchlings when making their way to the sea, not only physically but also through blocking visibility of the sea and increasing predation and dehydration risk due to extended transit time down the beach. Buried logs have been seen to hinder the nesting process, and the decomposition of logs may influence the chemical and biochemical composition of beaches thereby affecting incubation conditions. Finally, the presence of logs has the potential to affect erosion/accretion dynamics with unknown impacts.

The method of data capture used in this study requires video images to be interpreted by eye and as such there is the potential for a degree of observer error. This interpretation can be hindered by variation in video quality, with loss of image definition and contrast. Image interpretation is also compromised by variation in aircraft height, look angle and camera zoom. The physical character of the logs, i.e. size, part buried or in stacks, and the beach environment i.e. shadows, flotsam or overhanging trees, can also contribute to the potential for undercounts of logs; particularly in areas of higher log densities. Underestimates of log density from aerial surveys, as compared to ground-based surveys, were highlighted by the 20% undercount between the two methods in 2012. Given this potential for aerial survey underestimation it must be considered that the assessment of threat from logs to nesting leatherback turtles may be conservative, particularly in areas of higher log densities. Similarly, there is no way to quantify the number of fully buried logs that may exist within the beach environment, or the threat that these may pose to nesting turtles.

Laurance et al. (2008) suggest that initiatives to remove timber from critical nesting beaches may be the most effective way to reduce impacts to sea turtles. However, this would require support from the Gabon government due to legal restrictions (Laurance et al., 2008). To have the greatest effect initiatives should be focussed on the areas of unclassified area 1, Pongara National Park and Sette Cama Reserve where threat to nesting leatherback turtles is greatest. Due to the general inaccessibility of the coastline and scale of the problem, > 5900 logs lay along 43 km of the coastline within Pongara National Park and unclassified area 1 (this study: 2011 aerial survey data), removal may be difficult to achieve. However, this may be a solution in areas where immediate local access is available and log densities are modest e.g. Sette Cama Reserve and unclassified area 3. If commercially viable extraction using access from the sea were plausible, and limited in respect of its negative impacts to nesting beaches and turtles, this may prove a worthwhile consideration in higher impacted areas. Timber experts have indicated that 35% of the logs examined in the 2 km ground survey area in Pongara National Park were still of exploitable quality in 2010, with an 11% reduction by 2011 (Cardiec et al. unpublished data). Although costly, an alternative solution in high impact areas may be to dismember logs and remove them from the beach to decay.

International awareness has increased over the direct and indirect, regional and global impacts of unsustainable harvesting of timber from tropical rainforests. Deforestation and its associated impacts to ecosystems are well documented; downstream effects on marine and coastal species and habitats are less so, but are clearly an unforeseen consequence of these terrestrial activities. The aggregation of many thousands of logs along the biodiversity-rich coastal habitats of the central African Atlantic coast attributable to rainforest logging has led to insidious implications for nesting sea turtles, particularly the leatherback turtle, for which the beaches of Gabon support globally important breeding aggregations.

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Supplementary tables

Table A1. Total log counts, distance flown and number of logs km^{-1} for the survey years 2003, 2007 and 2011 assigned to their respective classified or unclassified status.

	Survey Year: 2003			**Survey Year: 2007**			**Survey Year: 2011**		
	log count	**distance (km)**	**mean logs km^{-1}**	**log count**	**distance (km)**	**mean logs km^{-1}**	**log count**	**distance (km)**	**mean logs km^{-1}**
Pongara National Park	2061	26	79	2245	26	85	3062	25	121
Unclassified area 1	3492	36	97	2191	36	61	3858	37	104
Wonga Wongue Reserve	1274	48	26	1031	50	21	1524	42	36
Unclassified area 2	1257	163	8	1683	162	10	2136	152	14
Loango National Park	1247	83	15	1391	84	17	1679	83	20
Sette Cama Reserve	3252	80	40	2567	77	33	2720	79	34
Ouanga Reserve	1258	42	30	1433	42	34	1434	42	34
Unclassified area 3	1257	55	23	905	56	16	776	55	14
Mayumba National Park	62	20	3	82	23	4	73	23	3
Entire coast	15 160	554	27	13 528	555	24	17 262	539	32

Table A2. Mean proportion (percentage, standardised for survey effort) of leatherback turtle beach movements impeded by logs, at sites for the nesting seasons 2006/07 to 2010/11 within Pongara National Park, Sette Cama Reserve and Mayumba National Park. Impacts to leatherback turtles were assessed using the following criteria: 0) no impact, 1) nesting was definitely abandoned due to logs, 2) nesting was probably abandoned due to logs, 3) the turtle was blocked by logs but was able to nest above the High Tide Line (HTL), 4) the turtle was blocked by logs but was able to nest below the HTL, 5) the turtle was blocked by logs after nesting, whilst returning to sea.

Area	**Category**	**Mean proportion as % of all categories**	**Range**
Pongara National Park	1	1.6	0.4-2.5
	2	0.5	0.1-1.2
	3	9.5	4.1-17.0
	4	2.9	1.7-3.5
	5	2.7	1.6-4.0
	total 1-5	17.2	
Sette Cama Reserve	1	0.5	0.0-0.9
	2	0.6	0.0-1.2
	3	3.6	0.0-7.2
	4	0.2	0.0-0.3
	5	1.3	0.0-2.6
	total 1-5	6.2	
Mayumba National Park	1	< 0.1	0.0-0.1
	2	< 0.1	0.0-0.1
	3	0.2	0.0-0.4
	4	< 0.1	0.0-0.1
	5	0.1	0.0-0.2
	total 1-5	0.3	