The effects of large beach debris on nesting sea turtles

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ABSTRACT

A field experiment was conducted to understand the effects of large beach debris on sea turtle nesting behavior as well as the effectiveness of large debris removal for habitat restoration. Large natural and anthropogenic debris were removed from one of three sections of a sea turtle nesting beach and distributions of nests and false crawls (non-nesting crawls) in pre- (2011−2012) and post- (2013−2014) removal years in the three sections were compared. The number of nests increased 200% and the number of false crawls increased 55% in the experimental section, whereas a corresponding increase in number of nests and false crawls was not observed in the other two sections where debris removal was not conducted. The proportion of nest and false crawl abundance in all three beach sections was significantly different between pre- and post-removal years. The nesting success, the percent of successful nests in total nesting attempts (number of nests + false crawls), also increased from 24% to 38%; however the magnitude of the increase was comparably small because both the number of nests and false crawls increased, and thus the proportion of the numbers of nests and false crawls in the experimental beach in pre- and post-removal years was not significantly different. The substantial increase in sea turtle nesting activities after the removal of large debris indicates large debris may have an adverse impact on sea turtle nesting behavior. Removal of large debris could be an effective restoration strategy to improve sea turtle nesting.

Keywords: beach debris, false crawl, habitat restoration, nesting, sea turtle

1. Introduction

Coastal areas provide critical habitats for a variety of wildlife, and conservation of this habitat is essential to maintaining high coastal biodiversity. Accelerated loss and degradation of coastal habitats by anthropogenic and natural forces have been major threats for the populations that rely on these habitats (Defeo et al., 2009). Marine debris has been identified as one source of habitat degradation and threat to coastal and marine species (Laist, 1997). Marine debris can result from various human activities, such as intense development and increased recreational use of coastal habitats, commercial fisheries, and use of other ocean based resources by rapidly expanding human populations, and natural events such as currents and tropical weather systems (Ribic et al., 2010). Debris that enters the ocean environment can be transported by ocean currents for long distances and then deposited on coastlines or ocean floors (Sheavly and Register, 2007).

Many studies provide evidence of the negative impacts of marine debris on coastal and marine species (see Gall and Thompson, 2015 for review). Sea turtles are among those 690 species whose populations have been affected by marine debris; six of all seven turtle species are affected (Laist, 1997). Death, injuries, and stranding of sea turtles as a result of accidental ingestion of and entanglement by marine debris are well documented (Laist, 1997; Schuyler et al., 2013). However, debris not only impacts turtles in the water but also on the beaches. Sea turtles spend most of their lives at sea, but they rely on sandy beaches for reproduction. During the nesting season, females emerge from the water to deposit clutches of eggs in the sand. Occasionally, turtles emerge from the water but do not deposit a clutch, and this is termed a false crawl (Miller, 1997). Presence of large debris on a beach could interrupt nesting activities by turtles causing false crawls. Frequent abortion or disruption on nesting attempts by leatherback turtles was observed in a beach in Gabon in Central Africa where active industrial logging caused accumulation of logs on the beach (Laurence et al., 2008). Additionally, nest placement may be affected by debris which could affect hatching success (Hays and Speakman, 1993). Large debris may act as sea walls and prevent adult and hatchling turtles from traversing the beach. Witherington et al. (2011) showed turtles nested closer to the water in areas where sea walls were present as compared to areas without walls. Another study in Gabon indicated that logs on the beach, combined with artificial lights, caused disorientation for leatherback hatchlings (Burgeios et al., 2009).

The objective of this study was to examine how large debris influences the nesting behavior of sea turtles and to assess the effectiveness of large debris removal as a restoration activity to improve sea turtle nesting habitat. A field experiment was conducted to compare the relative abundance of nests and false crawls before and after large debris removal from a portion of a loggerhead turtle nesting beach.

2. Material and methods

2.1 Study area

This study was conducted along approximately 5.7 km of beach on Eglin Air Force Base property on Cape San Blas in northwest Florida (Fig. 1). This area represents the southern tip of the St. Joseph Peninsula in Gulf County, Florida, and supports one of the greatest nesting densities of loggerhead sea turtles in the northern Gulf of Mexico, where a severe decline in loggerhead nests highlights the need for nesting habitat conservation (Lamont and Carthy, 2007; Lamont et al., 2012).

The study area has distinct sections due to the bathymetry and current dynamics of the region. The eastern portion of the study site is an accreting beach that is relatively wide, whereas beaches in the remaining parts of the study area are narrower and eroding (Lamont and Carthy, 2007, Lamont and Houser, 2014). Man-made and natural debris have accumulated in the study area over time. Man-made debris includes construction materials such as concrete, pipes, and metal fencing that remained on the beach after demolition of old military structures. Most of the natural debris is coarse wooden debris (CWD), including fallen trees and stumps, which is a result of the beach eroding into the adjacent stand of pine flatwoods.

The study beach was divided into three sections: north, middle, and east (Fig. 1). The north (1.3 km) and middle (1.7 km) beaches represent narrow, eroded, and high debris-density beaches. All debris in the north beach was natural debris from the adjacent stand, whereas the middle beach had a mixture of natural and man-made debris. The east beach (2.7 km) represented a comparably well-preserved beach with a smaller amount of debris and a larger beach width.

2.2 Nesting and debris surveys and debris removal

Sea turtle nest surveys were conducted every morning during the nesting season from May 1 through November 1, 2011–2014 (two nesting seasons in each pre- and post-debris removal conditions) on foot, by ATV, or by using a 4-wheel drive vehicle. All turtle crawls were identified to species and the location of each nest and false crawl was recorded using a hand-held GPS.

The type, GPS locations, and size (area) of all large emergent debris on the beach that required mechanical removal were recorded from June – August, 2012. The Marine Debris Act

(33 USC 1951 et seq. as amended by Title VI of Public Law 112-213) defines marine debris as *"Any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or Great Lakes."* However, because the focus of our study was physical site occupancy by debris, both man-made and natural debris on the beach were measured. Sandy beach areas representing potential turtle nesting sites were delineated by taking GPS measurements along the dune/vegetation line and shoreline at low tide. All emergent debris in the middle beach, except for a large concrete pad that broke the excavator, was removed by heavy machinery in December 2012, outside of the nesting/hatching seasons for sea turtles and shorebirds, to minimize the disturbance to those species.

2.3 Analysis

A 45 x 45 m grid shapefile which covers the sandy beach area between the shoreline and dune line in all three sections (north, middle and east) of the study area was created using ArcGIS 10.3 (Fig. 2). Grid cells were removed if more than half of their area was outside of the sandy beach. The number of debris, areas of debris coverage, and numbers of loggerhead nests and false crawls in each grid cell were calculated. The correlation (*r*) between the nesting parameters (number of nests and false crawls) and the debris amount and coverage areas was assessed.

The number of nests in each beach section during the nesting season for pre- (2011−2012) and post- (2013−2014) debris removal conditions was determined. The reason that two years of survey data in each condition (pre- and post-debris removal) were used for analysis was to capture some inter-annual variability in nesting number of sea turtles (Broderick et al. 2001).

Using chi-square tests for difference in proportion, it was examined whether distribution of turtle nests and false crawls in the three beach sections changed after removing large debris from the middle beach. Nesting success was defined as the proportion of nesting crawls to total number of crawls (number of nesting crawls + number of false crawls). Using the pre- and post-removal data in the middle beach, where large debris was removed, a chi-square test was conducted to examine whether the proportion of successful nesting attempts changed.

3. Results

In total 643 pieces of debris (77 pieces in the north, 483 pieces in the middle, and 20 pieces in the east beaches), were located and measure. These debris covered 2,047.9 m^2, or 0.77% of the study area (Fig. 2A). The majority (624 of 643) were natural debris, covering 94% of the debris-covered area. The most frequently observed debris was CWD; therefore each piece of debris was typically long and narrow, with a mean length and width of 5.8 m and 0.5 m respectively. The density (number/km) of the debris was 58.5, 277.6, and 7.4 respectively on the north, middle, and east beaches, covering 1.00%, 2.42%, and 0.03% of each beach area.

In total, 160 loggerhead nests were recorded in the three beach sections (areas where debris remained plus areas where debris was removed) from 2011 to 2014. Of the 160, 76 of these nests were deposited in pre-removal years (2011−2012) and 84 nests were deposited in post-removal years (2013−2014; Figs. 3 and 4). The observed number of false crawls was 301 during the four-year period: 170 during the pre-removal years and 131 during the post-removal years (Figs. 3 and 4).

The number of nests observed in each 45m grid cell was not significantly correlated with both number of debris (r = -0.05) and area covered by debris (r = -0.06) in the grid cell during the pre-removal nesting seasons (2011−2012; Fig. 2B). Similarly, the number of false crawls observed in each grid cell was not significantly correlated with both the amount of debris (r = 0.10) and the area covered by debris (r = 0.08).

The number of nests observed from pre-removal years (2011−2012) to post-removal years (2013−2014) tripled from 9 to 27 nests in the middle beach where large debris were removed. However, such an increase was not observed in the two other sections. The number of nests declined by 46% in the north beach (24 nests in 2011−2012 and 13 nests in 2013−2014) and the number was nearly equivalent (43 nests in 2011−2012 and 44 nests in 2013−2014) in the east beach (Fig. 4). In comparing pre- and post-removal states, the distribution of nests in the three beach sections was significantly different (χ^2 = 12.5, p < 0.01). During pre-removal years, number of nests placed in the middle beach was 12% of the nests placed in the entire study area, but it increased to 32% after the removal. The number of false crawls from pre-removal and post-removal years increased 55% in the middle beach, from 29 to 45, but it decreased 52% (from 42 to 20) in the north beach and 33% (from 99 to 66) in the east beach (Fig. 4). The change in the distribution of the false crawls from pre- and post-removal was also significant (χ^2 = 13.03, p < 0.01). The substantial increase in number of nests resulted in overall increase in nest success rate from 24% to 38% in the middle beach, but this change was not significant (χ^2 = 2.16, p = 0.14).

4. Discussion

The results showed that the presence of large debris on a sandy beach could alter the spatial distribution of sea turtle nests by influencing turtle nest site selection. Whereas negative impacts of marine debris on sea turtles has been recognized, few studies have focused on the impacts of beach debris on sea turtle reproduction (Laurence et al., 2008; Bourgeois et al., 2009; Witherington et al., 2011), and the authors did not recognize any study that experimentally tested the effect of large debris on sea turtle nesting activities as was done in this study. Although the grid pattern analysis did not support a strong correlation between sea turtle nesting activities and the presence and coverage of beach debris, the results from the field experiment showed removal of large debris may contribute to increases in nesting activity (both number of nests and false crawls). In fact, the number of nests largely declined (46%) on a control beach (north beach) which is consistent with the recent, steep declining loggerhead nesting trend in this area (Lamont et al., 2012). It should be noted that there are other factors which may contribute to variations in abundance and distribution of nesting activity on this beach. At the study site, in line with conclusions from elsewhere in the sea turtle nesting areas, a broad range of factors may cause different nesting densities on adjacent beaches, including current direction, wave height, lighting and offshore bathymetry (Godley et al. 2001, Lamont and Houser 2014). The changes in nest distribution observed in this study may have also been affected by these factors; however the fact that substantial increased in nesting activity occurred only in the section where debris was suggests debris removal was a significant factor contributing to these changes. Although the increase of false craws after the debris removal was not expected, it happened likely because removal of large debris close to the water line allowed turtles to crawl on the beach whereas the area was previously blocked. The nest success at the post-debris removal (38%) was higher than that of pre-removal stage (24%); however, because both number of nests and false crawls increased, the observed magnitude of the increase (14%) in the success rate was not substantially large and statistically insignificant.

Both large man-made and natural debris were present in the study area. As it was observed at a number of other sea turtle nesting beaches (Laurence et al. 2008, Bourgeois et al. 2009, Triessnig et al. 2012), both large man-made and natural debris were covering sandy beach areas in the study site. Natural debris on the beach could occur as a result of processes in the ecosystem such as tropical storms and ocean currents, human activities such as industrial logging, or a combination of both. In our study area, natural debris (mainly CWD) comprised most of the debris-covered area. Although natural debris could eventually degrade, large and heavy man-made debris (mainly construction materials such as concrete, tubes, and metals found in our study area) are non-degradable, and thus could permanently occupy the site unless removed. Further, debris could eventually be covered by sand and become visually undetectable, making it difficult to remove. In this study, only emerged debris which appeared on the surface were measured, but debris buried completely under the sand were found during the measurement and removal process. Presence of submerged debris could also influence sea turtle nesting by preventing turtles from digging nest chambers in which to deposit eggs, which may contribute to an increase in false crawls.

Area-wise, debris covered a small proportion of the entire study beach (2% of the beach area in the most severely debris-covered section), but removal of debris resulted in a substantial increase in nesting activities. This is likely because these large and typically long pieces of debris block turtle crawls thereby preventing them from nesting. Although only nesting activities (number of nests and false crawls) were examined in this study, large debris may also negatively influence hatchling success and survival (Hays and Speakman, 1993; Burgeios et al., 2009), which is another important aspect of sea turtle reproduction. Further, implications from this study may be extended to other species, such as shorebirds which nest and forage on sandy beaches, because large debris could occupy their nesting and foraging areas. Last, it should be noted that caution is required when removing large debris on the shoreline because accumulation of CWD could serve as an erosion control in some instances (Eamer and Walker, 2010). In addition, timing of removal is an important consideration in order to avoid sea turtle and shorebird nesting and hatching seasons and minimize disturbance to existing wildlife populations.

5. Conclusions

Marine debris is an indicator of habitat quality for sea turtle nesting sites (Triessnig et al. 2012). The results of this suggest that removal of large debris may open nesting habitat that was previously unavailable for sea turtle nesting. Given that degradation of sandy beaches is expected to further intensify in the coming decades due to continuously increasing human populations (James, 2000; Arizma et al., 2008), it could be an effective conservation method, especially in critical habitats for imperiled species such as sea turtles.

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Figure 1. Map of Cape San Blas in St. Joseph Peninsula, Florida, in which the boundary of the three beach sections (north, middle, and east) of the study area is shown. The inset box shows the location of the study area within the state of Florida, USA.

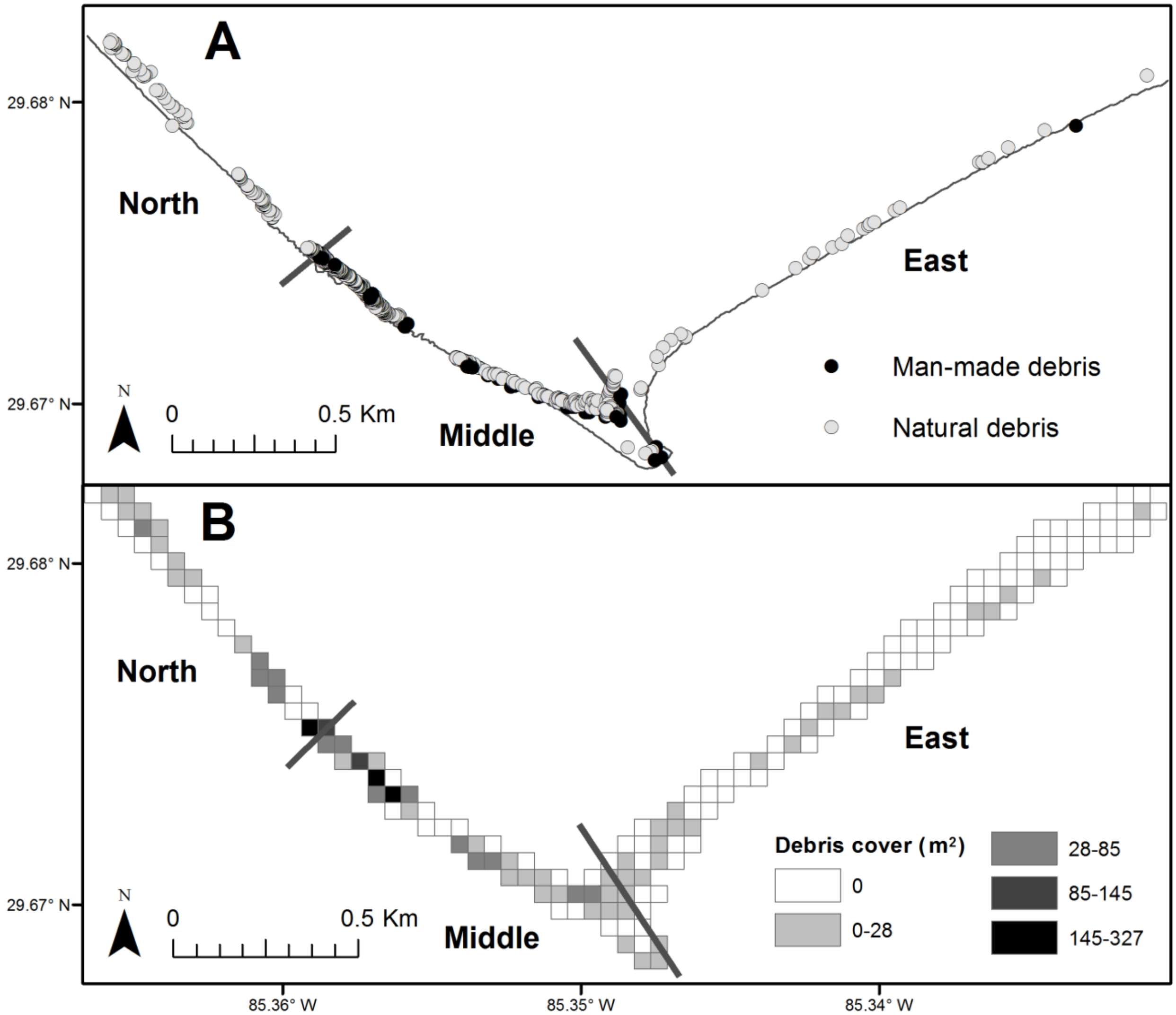

Figure 2. Location of observed large debris in Cape San Blas in St. Joseph Peninsula, Florida, from July-October, 2012 in which type of the debris (man-made or natural) were indicated by gray scale (A), and debris-covered area (m^2) within each 10 m^2 grid cell (B) in three beach sections (north, middle, and east) in the study area.

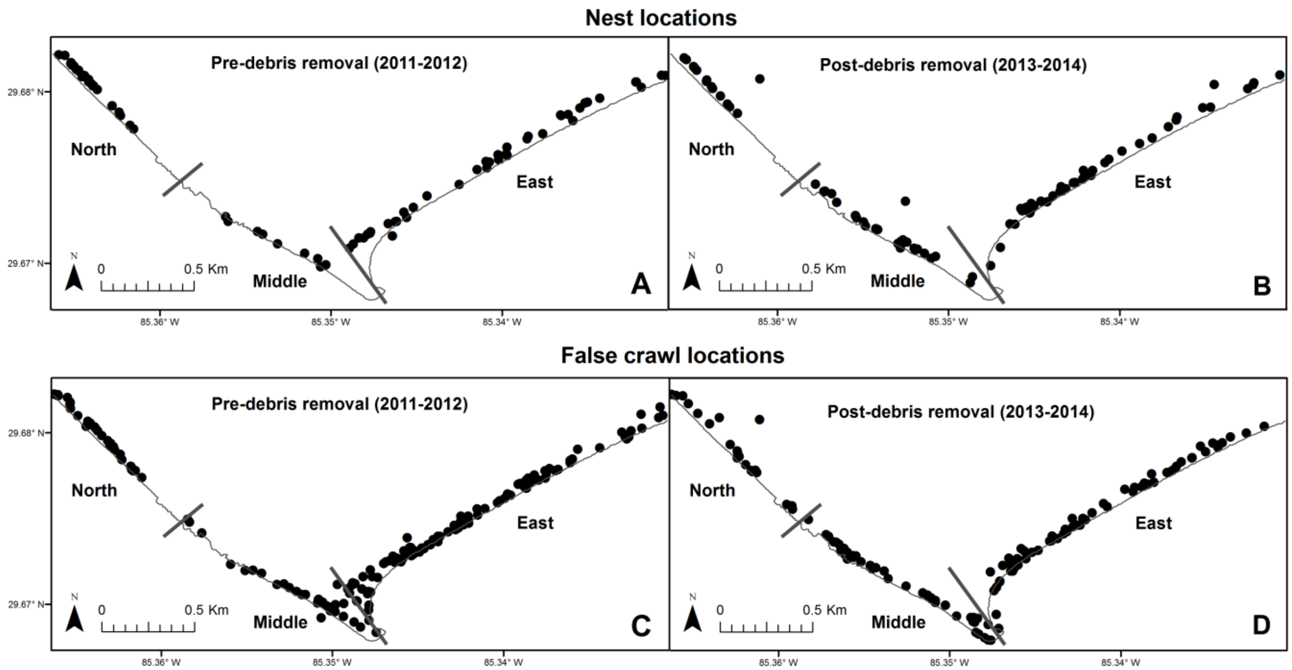

Figure 3. Mapped locations of loggerhead nests (A and B) and false crawls (C and D) during nesting seasons before (2011-2012) and after (2013-2014; bottom figures) the large debris removal in the middle beach in Cape San Blas in St. Joseph Peninsula, Florida. Points which appeared in substantially interior land due to GPS location errors are not shown in the map.

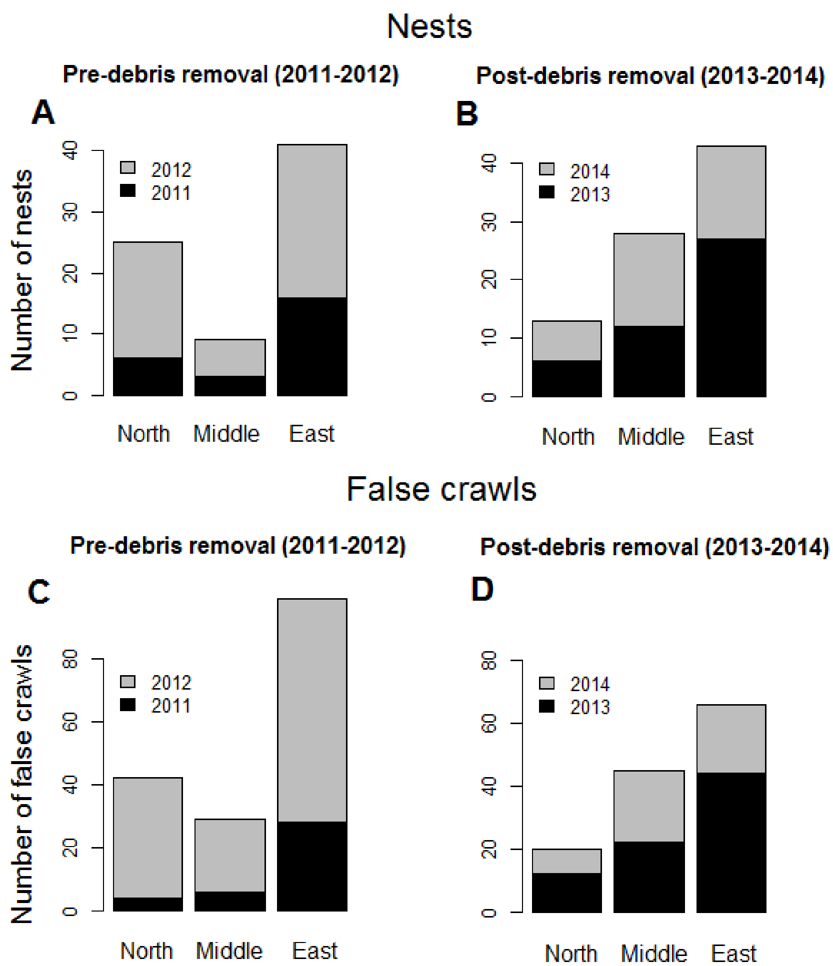

Figure 4. Bar plots of number of loggerhead nests (A and B) and false craws (C and D) in three beach sections in Cape San Blas in St. Joseph Peninsula, Florida for two years before and after the large debris removal in the middle beach.