Piracy Incidents in the Gulf of Aden: A Spatial Analysis of Event Distribution in Relation to Key International Security Measures

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Introduction

Piracy in the Gulf of Aden has been a persistent security challenge due to the region's strategic importance as a key maritime corridor. Connecting the Indian Ocean to the Red Sea and the Suez Canal, it serves as a vital shipping route for global trade between Asia, the Middle East, Africa, Europe, and North America. In response to piracy threats, international security measures have been implemented over the years, including the establishment of the Internationally Recommended Transit Corridor (IRTC) in 2009 and the deployment of multinational naval patrols such as Combined Maritime Forces (CMF), EU NAVFOR's Operation Atalanta, and past NATO missions like Operation Ocean Shield.

Despite the continued decline in piracy incidents in recent decades, the threat still disrupts global trade, increases shipping costs, and at times, threatens humanitarian aid deliveries in the region. This study analyzes piracy patterns in the Gulf of Aden, focusing on changes in the spatial distribution of events before and after the 2009 IRTC implementation. Findings contribute to maritime security, shipping risk assessment, and humanitarian aid protection.

Background and Methods

To examine the spatial trends of piracy attacks in the Gulf of Aden, I isolated the study area and employed Kernel Density Estimation (KDE) in RStudio to visualize clustering patterns of attacks across a 1994–2020 dataset. KDE was chosen because it highlights high-risk areas by generating a continuous surface of piracy density, making it easier to interpret spatial trends over time. After identifying 2009 as a key turning point due to the introduction of the IRTC, I conducted a comparative spatial analysis by dividing the dataset into two periods: pre-2009 (343 events) and post-2009 (242 events).

To further quantify changes in attack clustering, I applied the G-hat nearest neighbor distribution function ($\hat{G}(d)$). This method measures the cumulative distribution of nearest-neighbor distances, allowing for an assessment of whether pirate attacks were more or less clustered before and after the IRTC's implementation. The analysis was geographically bound by a polygon representing the sea area within the study region (created in QGIS). By comparing the $\hat{G}(d)$ curves for both time periods, I determined whether piracy events became more spatially concentrated or dispersed following the introduction of structured naval patrols and transit corridors.

Data

This research uses a dataset of piracy incidents in the Gulf of Aden from 1994 to 2020, detailing attack dates, locations, types, and outcomes. The dataset, titled "Crime at Sea: A Global Database of Maritime Pirate Attacks (1993–2020)," was sourced from maritime security reports, including records from the International Maritime Bureau (IMB) and other piracy incident databases. It was accessed through GitHub.

Summary statistics	Mean center: 47.52, 13.25 Mean shore distance: 70.51 km Min NNDist: 0 km Max NNDist: 125 km

Hypotheses

H_0: The spatial distribution of pirate attacks in the Gulf of Aden remained the same before and after the implementation of the Internationally Recommended Transit Corridor (IRTC) in 2009, with no significant change in clustering patterns.

H_1: The spatial distribution of pirate attacks changed significantly after the implementation of the IRTC in 2009, with attacks becoming more or less clustered compared to the pre-IRTC period.

Results

Figure 1: Piracy attack locations before and after the IRTC, shipping lane locations, and IRTC lanes

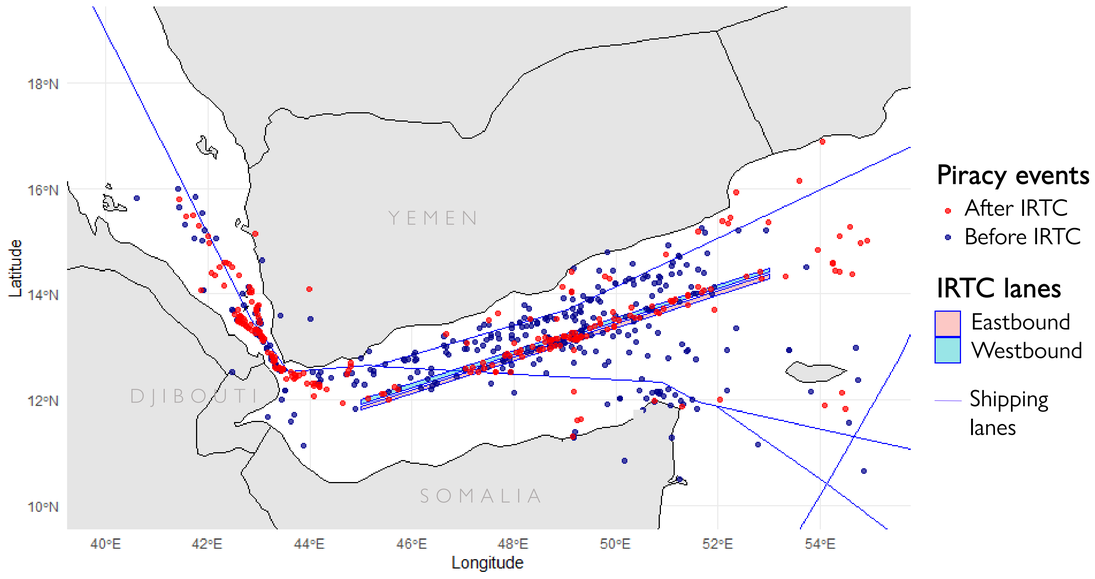


Figure 2: G-hat nearest neighbor distribution of piracy attack locations before and after the implementation of the IRTC *Clustering increased after IRTC, as seen by the steeper curve.*

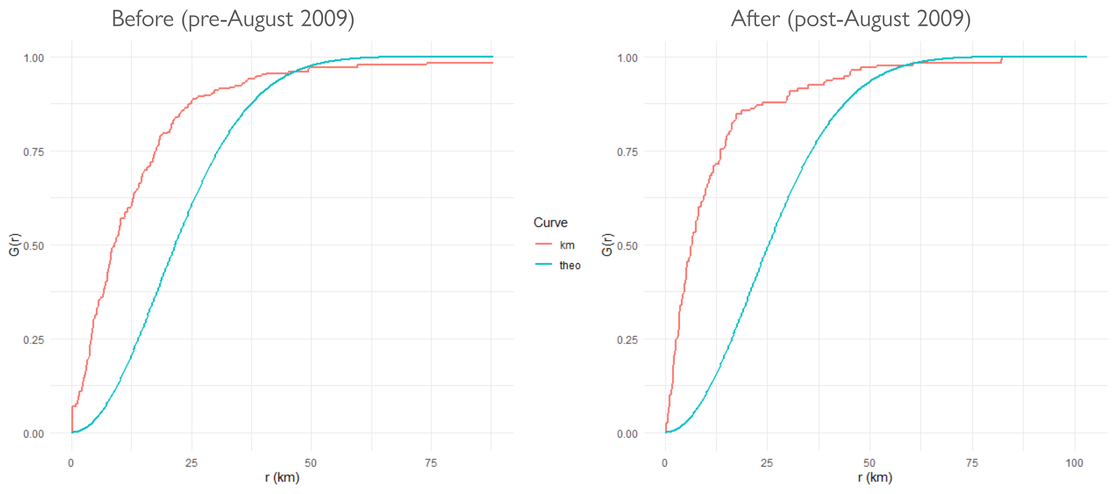


Figure 3: Sum of type of piracy attacks and attempted attacks per year, 1994-2020

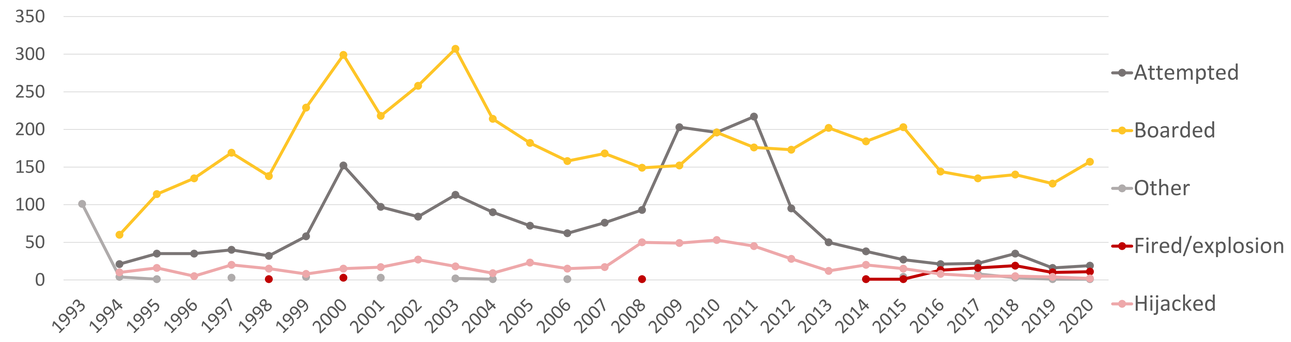
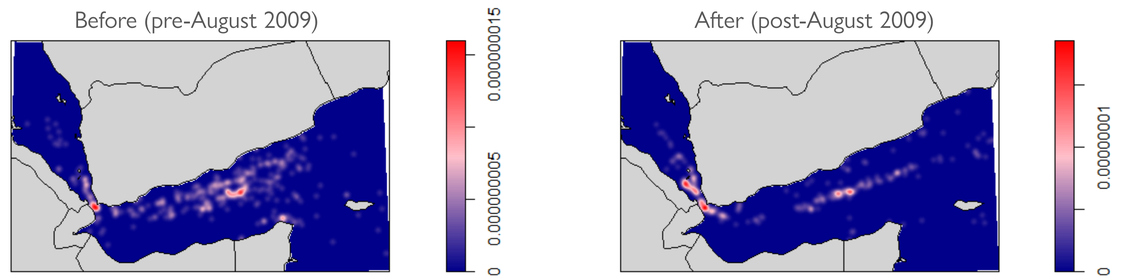


Figure 4: KDE of piracy attack locations before and after the implementation of the IRTC (km)



Conclusion

- The mean nearest neighbor distance of piracy attack locations decreased by 11.49% after the IRTC implementation (from mean of 14.29 km to 12.64 km), indicating that piracy events became more clustered after the 2009 IRTC implementation.
- H_1 is accepted based on the steeper G-hat curve from the "after" dataset, and due to the decrease in mean NN distance.
- The increased clustering of events suggests that piracy activity became more concentrated within specific high-risk zones, despite the additional security protections put into place. This could potentially be due to shipping routes becoming more concentrated within a smaller zone, leading to clearer targets for pirates.
- A major limitation is that successful vs attempted piracy attacks were analyzed together. Future analysis should be done to isolate and compare different types of attacks (attempted vs. successful).
- Future research could examine maritime data, for example to analyze to what extent shipping routes became more concentrated post-IRTC, and to quantify the portion of ships attacked in different periods of time.

References

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