The declining impact of piracy on maritime transport in the Indian Ocean: Statistical analysis of 5-year vessel tracking data

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ABSTRACT

The analysis of the declining impact of piracy on maritime routes and vessel behaviours in the Indian Ocean is here performed using Long Range Identification and Tracking (LRIT) reports. A 5-year archive of vessel position data covering the period characterized by the highest number of attacks and the subsequent decline provides a unique source for data-driven statistical analysis that highlights changes in routing and sailing speeds. The work, besides demonstrating the value of LRIT data for statistical maritime traffic analysis, can be used to ultimately provide quantitative support to the estimates of the additional fuel consumption due to piracy. In showing the return of the North–South traffic to the shortest path, the results testify to the effectiveness of the efforts put in place against piracy in the Western Indian Ocean.

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1. Introduction

Piracy at sea is an old problem that persists to modern times in a number of hot spots across the world. During the last decade, piracy emanating from Somalia has seen a surge, to become the most serious threat to global shipping, and a subsequent decline. The root causes of the piracy have been ascribed to the lack of government in Somalia as well as the lack of economic opportunities. Its impact was exacerbated because one of the world’s most important maritime trade routes lies along the Somali coast, namely the connection between Asia and the Persian Gulf with Europe, through the Gulf of Aden. Another important route is the North–South one along the East African coast. The Somali piracy therefore has had a big economic impact, quantified e.g. in [1,2], and the practice of hostage taking has also led to considerable human suffering [3].

Already in 2008, the United Nations Security Council (UNSC) issued a first resolution that, together with the already existing UN Convention on the Law of the Sea [4], empowered foreign navies to act against piracy in the waters around Somalia. Even after that, the area of pirate operations out of Somalia continued to expand in the coastal waters to most of the North-Eastern Indian Ocean. A series of other UN resolutions on Somali and wider piracy followed, the last one from 2012. International merchant shipping tended to avoid coming close to Somalia. As the neighbouring countries of Somalia in the region did not have the capacity or (earlier on) the priority to protect international shipping, foreign states have mounted operations to that end, often in international alliances. Foreign naval assets have been deployed to escort ships going to Somalia and passing through the Gulf of Aden, to monitor fishing, and to police the wide maritime area at risk to stop and apprehend pirates. The international naval alliances active around Somalia are: Combined Task Force (CTF) 151 under the 30-nations Combined Maritime Forces partnership [5]; NATO Operation Ocean Shield; and EU Naval Force Atalanta. In addition, countries have operated on an individual basis, such as China, India, Japan, Korea, Russia and Iran.

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3 CTF 151 was established in January 2009 with a specific piracy mission-based mandate under the authority of UN Security Council Resolutions 1816, 1838, 1846, 1851 and 1897.

4 Since August 2009, NATO is patrolling the waters off the Horn of Africa in full accordance with the relevant UNSC Resolutions, most recently Resolution 2020 (November 2011). [www.mc.nato.int/about/Pages/Operations%202020.aspx](http://www.mc.nato.int/about/Pages/Operations%202020.aspx).

5 The EU launched the European Union Naval Force ATALANTA (EU NAVFOR) in December 2008 within the framework of the European Common Security and Defence Policy (CSDP) under EU Council Joint Action 851, and in accordance with relevant UNSC Resolutions and International Law. [http://eunavfor.eu](http://eunavfor.eu).
Such foreign naval deployments are undesirable in the long term—for one thing, they are expensive to maintain. Therefore, a series of programs and projects have been set up to create the capacity to deliver maritime security by the countries in the region. Important donors include the EU (both as a block and by individual member States), U.S. and Japan. Often, projects are implemented through UN Agencies, in particular the International Maritime Organization (IMO) [6] and United Nations Office on Drugs and Crime (UNODC) [7]. Among other things, IMO induced the establishment of the Djibouti Code of Conduct by the UN with a rotating chair, currently held by the EU8.

Somalia (CGPCS) [12]. This is an informal collaboration spawned coordinated by the Contact Group on Piracy off the Coast of Somalia (UKMTO) [9], the Maritime Security Centre Operations (UKMTO) [9], the Maritime Security Centre—Horn of Africa (MSCHOA) [10], and the NATO Shipping Centre (NSC) [11]. MSCHOA was set up especially for the piracy off Somalia and forms part of Operation Atalanta, whereas the other two have a wider mandate.

At global level, all initiatives related to Somali piracy are coordinated by the Contact Group on Piracy off the Coast of Somalia (CGPCS) [12]. This is an informal collaboration spawned by the UN with a rotating chair, currently held by the EU9. A dedicated working group under CGPCS makes recommendations about Maritime Situational Awareness (MSA).

Today, early 2015, the piracy risk off Somalia is much suppressed, thanks to all measures discussed above. No ships have been hijacked since 2013. However, as Somalia is still not a stable and prosperous state, many of the root causes are still present, and the networks for piracy operations that have been built up in Somalia have probably not been dismantled. It is therefore believed that a minimum amount of foreign-led counter-piracy activities will need to be continued, in connection with the continuation of the capacity building work, which is meanwhile expanding its remit from pure counter-piracy to maritime security in general.

The rise and decline of piracy activities around Somalia in the last 6 years is reported in Table 1.

Various organisations collect and compile piracy incidence data: apart from UKMTO, MSCHOA and NSC, these also include IMO and IMB10. They all use somewhat different criteria to include an event in their statistics and somewhat different definitions in their categorisations of event type (“suspicious event”, “attack”, etc.), making cross–comparisons less than straightforward. According to [13], total attacks – or attacks in the remainder – are defined as “the combined number of all attacks mounted by suspect pirates; those repelled/aborted and those leading to ships being in pirate hands and crews taken hostage” whereas a disruption is “an action that renders a pirate group incapable of further pirate operation”. Suspicious events are piracy related actions that are reported and shared with the merchant shipping community, but do not constitute attack.

A breakdown of attacks into six-month periods is shown in Fig. 1. In this paper we analyse how the decline of piracy attacks is having an impact on vessel traffic along the North–South transport routes crossing the Indian Ocean, progressively restoring the navigation to conditions that minimise fuel consumption and time at sea.

2. Data and methods

Monitoring vessels at sea is an essential component of Maritime Situational Awareness, that is the understanding what is happening at sea and the possibility to project the current situational picture into the future. Knowing which vessels are located in a specific area, their state vector properties (e.g. position, velocity and direction), their type and the nature of activities they are carrying out (e.g. fishing, at anchor, sailing etc.) are essential to many governance responsibilities in the open sea, in particular to Search and Rescue (SAR) and security operations. In the context of piracy, the knowledge of what is happening at sea combined with met-oceanographic data and intelligence on potential Piracy Action Groups (PAGs) can be used to perform dynamic risk analysis [14]. In order to build the so called Maritime Situational Picture (MSP) in wide areas, data from many observation and self-reporting systems can be fused to track vessels at sea (see e.g. [15,16]). In the piracy context, the foreign naval forces operating in the area have used data from AIS and LRIT (see below) as well as call-in reports from the ships and their own observation systems to achieve the necessary MSA. AIS and LRIT are also being used in capacity building projects for maritime authorities in the region, e.g. under the EU-funded Piracy, Maritime Awareness and Risks (PMAR) project [17].

2.1. Data set

Main ship-reporting data currently used to achieve near real-time tracking of vessels are automatic ship position reports from the Automatic Identification System (AIS) [18] and Long Range

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Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Suspicious events</th>
<th>Total attacks</th>
<th>Of which pirated</th>
<th>Disruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>59</td>
<td>163</td>
<td>46</td>
<td>14</td>
</tr>
<tr>
<td>2010</td>
<td>99</td>
<td>174</td>
<td>47</td>
<td>65</td>
</tr>
<tr>
<td>2011</td>
<td>166</td>
<td>176</td>
<td>23</td>
<td>65</td>
</tr>
<tr>
<td>2012</td>
<td>74</td>
<td>35</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>2013</td>
<td>20</td>
<td>7</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>2014</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

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7 For the BMP, the HRA is bounded by Suez and the Strait of Hormuz to the North, 10°S and 78°E.


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Identification and Tracking (LRIT) [19]. AIS, originally designed for collision avoidance, is based on self-organising terrestrial cells whereby vessels broadcast their dynamic information (e.g. position, Speed Over Ground—SOG, Course Over Ground—COG, Rate of Turn etc.), static information (e.g. vessel type, size and identifiers) and voyage related information (e.g. Estimate Time of Arrival, destination and draft) over VHF. Such messages can be received by terrestrial receivers out to the radio horizon, which is normally several tens of nautical miles. Sometimes, under particular environmental conditions, AIS messages can be received much further away, even in the order of hundreds of nautical miles. The same messages can be received by Low Earth Orbit (LEO) satellite based receivers when they pass over, complementing ground based tracking information in open sea areas. AIS data collection is therefore limited in coverage, spatially for terrestrial receivers and temporally for satellite receivers. However, AIS can be detected by anyone in the neighbourhood of a vessel, increasing the vulnerability to security threats like piracy. For this reason, in special security areas, AIS can lawfully be switched off [8] leading to incomplete or even missing tracks. A more secure vessel tracking system is the LRIT as it is based on point-to-point satellite communication rather than public broadcasting. For this reason, LRIT offers the possibility to safely retrieve tracking information over areas affected by piracy. Furthermore, LRIT data are characterised by an almost uniform spatial coverage, and a uniform temporal sampling with a typically 6-hourly reporting interval. Although this is consistently lower than the few seconds to minutes of AIS (when in range), in wide areas this does not represent a serious limitation since the merchant vessels of interest in this study do not often change course over ground.

The dataset used in this study includes LRIT positions of ships flying the flag of states contributing to the EU LRIT Cooperative Data Centre (CDC), i.e. all EU Member States, Iceland, Norway, and Overseas Territories of EU Member States. During part of the 5-year period analysed here, in 2009 and 2010, the LRIT reporting frequency was increased over its nominal 6-hourly rate in the HRA as a special measure to better track the ships.

2.2. Route extraction and analysis

The algorithm developed is based on event detection and trajectories clustering and adapted from previously published work on AIS such as [20,21]. First the LRIT messages are organised by IMO number, building “vessel” objects. Then, SOG and COG – not present in the LRIT message itself – are computed from consecutive positions. Subsequently, by defining two arbitrary polygons, all the direct vessel trips between such areas are isolated. In order to filter out itineraries presenting intermediate ports of call, the direct trajectories connecting such polygons must not contain additional “stops”. Such “stop” events are detected by analysing the estimated velocities. The outcome of the algorithm is the group of trajectories that represent the routes connecting the pre-defined polygons. The pseudo-code is reported in Algorithms 1 and 2.

Algorithm 1. Patterns_Discovery.

Require: LRIT_messages // LRIT messages identified by IMO number (IMO#), lat, lon etc.
Require: Vessels // List of vessel objects identified by the relevant IMO number
Require: v_th // Speed velocity below which the vessel is considered stationary
Require: Poly1 & Poly2 // Polygons between which the flow is extracted
Require: Route _Poly1_to_Poly2 & Route _Poly2_to_Poly1 // Routes connecting the relevant polygons

1. for all LRIT_messages do
2. // Update vessel object identified by the message IMO number with new state vector [lat, lon, SOG, COG,T]
3. vessel← Vessels(find(vessel.imo ← IMO#))
4. vessel(track(end + 1: ))← [lat, lon, SOG, COG,T]
5. if [lat, lon] is in Poly1(or Poly2) then
6. // Update vessel.objects with ‘Poly1’(or ‘Poly2’)
7. vessel_routes← ‘Poly1’(or ‘Poly2’)
8. Patterns_Manager (vessel, Route _Poly1_to_Poly2, Route _Poly2_to_Poly1)
9. else if SOG < v_th then
10. // Update vessel.routes with the label ‘Unclassified_Stop’
11. vessel_routes← ‘Unclassified_Stop’
12. end if
13. Vessels(find(vessel.imo = LRIT.imo))← vessel
14. end for
15. return Vessels, Route _Poly1_to_Poly2, Route _Poly2_to_Poly1

Algorithm 2. Patterns_Manager.

Require:vessel // The vessel under analysis
Require: Route _Poly1_to_Poly2 & Route _Poly2_to_Poly1
1. if vessel/routes (end-1) = ‘Poly1’&vessel/routes (end) = ‘Poly2’ then
2. // Update Route _Poly1_to_Poly2 with trajectory between the two polygons, time of travel and vessel.imo
3. Route _Poly1_to_Poly2← [vessel(track from Poly1 to Poly2), vessel.Poly1-vessel.Poly2, vessel.imo]
4. elseif vessel.routes (end-1) = 'Poly2'&vessel.routes (end) = 'Poly1'
then
5. // Update Route _Poly2_to_Poly1 with trajectory between the two polygons, time of travel and vessel.imo
6. Route _Poly2_to_Poly1 ← [vessel(track from Poly2 to Poly1), vessel.T_Poly2-vessel.T_Poly1,vessel.imo]
7. end if
8. return: Route _poly1_to_poly2, Route _poly2_to_poly1

3. Results

Algorithms 1 and 2 have been applied to the 5-year archive LRIT data in the Indian Ocean to map maritime trajectories covering the North–South and South–North routes along the East African coast (Fig. 2—left, red and green, respectively).

The results have been aggregated over periods of six months (see Fig. 2—right). The analysis is then applied to the subsequent periods of six months from July 2009 to July 2014 (Fig. 3), which saw the peak and the subsequent decline of attacks (see Fig. 1). The period of six months was selected for being matched to the pace of the behavioural changes of the merchant ships in the area. Inspection of the data on monthly basis shows no clear seasonal trends.

The time evolution of the routes is clearly correlated to the number of piracy attacks and disruptions recorded in the Indian Ocean: after 2010, progressively more vessels take advantage of a gradually reduced risk of being attacked and return to travelling along the shortest path.

In order to evaluate the extent of re-routing in the area we define the “inner”, “middle” and “outer” routes respectively as the shortest path (through the red area in Fig. 4), the passage North of Madagascar through the Mozambique Channel (light blue area) and the one East of Madagascar (green area). In Fig. 5 the proportion of inner, middle and outer routes shows the consistency of the trend re-establishing the shortest path as preferred route when the number of attacks starts reducing in the second half of 2011. It is worth noting that the inner and outer routes differ about 450 NM on average.

A similar trend can be observed with respect to the aggregated speed distribution along the route (see Fig. 6). Sailing at higher speed reduces the likelihood of being boarded by pirates if under attack. Such likelihood is minimised for speeds greater or equal to 18 knots. On the other hand, an increase of speed has a substantial impact on fuel consumption: as the risk of being attacked reduces, the speed is restored to more economical values in the area.

A quantitative analysis of vessel speed distributions in the five-year period is shown in Fig. 7 where the trend of the median vessel speed can be compared to the number of attacks reported in the Indian Ocean. A clear correlation between the restoring of lower speed values and the reduction of risk of being attacked can be clearly observed.

4. Discussion and conclusion

The recent decline of piracy attacks in the Indian Ocean is due to a number of countermeasures put in place at international level and is progressively restoring the routes crossing the area to minimum distance patterns. In this paper, this process is demonstrated using LRIT positioning data archives from July 2009 to July 2014. Unlike other positioning systems such as AIS, which was commonly switched off in the area during times of high risk in order to reduce the vulnerability of being tracked by pirates, LRIT continued to provide uninterrupted position reports to the competent authorities. For this reason, LRIT is used in this study to reveal the evolution of vessel traffic and behaviours in the area. It is shown that in particular, vessel re-routing to avoid high risk areas has significantly decreased, with the result of saving on average 450 NM of navigation. Moreover, sailing at increased speed to minimise the risk of being successfully boarded by pirates had almost stopped at the end of the period. By making use of ship tracking data only, the paper shows the concurrence of re-routing and increased vessel speed, demonstrating how their progressive

Fig. 2. Representation of northbound (green) and southbound (red) traffic crossing the Indian Ocean and connecting the two yellow polygons (left). The right-hand picture shows traffic extraction following the scheme on the left during the second semester 2009. The piracy high risk areas extending over the Somali Basin began to be avoided by most of the ships, extending the average length of both routes. Tracks not belonging to the main Northbound or Southbound routes are coloured blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
Fig. 3. Time series of traffic crossing the Indian Ocean in the 5-year period showing the effect of piracy and its progressive decline in deviating maritime traffic. Each figure shows 6-month colour-coded trips following the representation in Fig. 2—left. Operational authorities requested an increase of LRIT reporting frequency (Under specific circumstances and over pre-defined areas, operational authorities can request vessels to report LRIT positions at intervals that are shorter than the nominal 6 h), from ships in 2009 and 2010 in order to better track them remotely in the High Risk Area. The increase of tracking points can be erroneously perceived as an apparently higher volume of traffic with respect to other periods.

Fig. 4. Examples of LRIT tracks following the “inner” (passing through the red area – left), “middle” (through the light blue area – middle) and “outer” (through the green area – right) routes. (For interpretation of the references to color in the figure legends, the reader is referred to the web version of this article.)

Fig. 5. Ratio between the three routes and total number of transits in the 5-year period. Since the second half of 2012 the shortest path (inner route) is preferred over the outer one.
reduction is correlated with the declining number of piracy attacks. Both re-routing and sailing at higher speed are proxies for fuel consumption, so it can be concluded that maritime transport costs associated to these aspects and due to piracy in the Indian Ocean have considerably reduced from the first half of 2011 to mid-2014. The work gives the basis to further analyse and quantitatively estimate such financial implications, which could contribute to evaluate the efforts put in the fight against piracy in the Indian Ocean.

Previously published work has concentrated in using tracking data for anomaly detection [22], discovering knowledge out of tracking data such as routes [20,21] or fishing activities [23], investigating seasonal-scale variations [24]. The temporal variations analysed in this paper cover a period of five years, a timescale commensurate with the evolution of the piracy threat in the Indian Ocean.

The work demonstrates how spatial data mining – applied for the first time to LRIT data to discover half-yearly variations of traffic – can be used to understand the impact of geopolitical issues to maritime trade routes, a key element for policy and decision makers.

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