Article

Cetacean Strandings along the Bulgarian Coast of the Black Sea in 2010–2022

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Abstract: Cetacean strandings are valuable sources of data about their life history, health status, population trends, and impact of threats. We examined the strandings along the Bulgarian coast of the Black Sea for a period of 13 years from 2010 to 2022. A total of 1528 cetacean strandings of all three species inhabiting the basin were recorded: 1031 harbour porpoises Phocoena phocoena, 199 bottlenose dolphins Tursiops truncatus, 97 common dolphins Delphinus delphis, 19 delphinids and 182 unidentified. The highest numbers were observed in 2016 and 2022. Monthly peaks for harbour porpoise and bottlenose dolphin were in July and August and for common dolphin in May. An unusually high mortality of porpoise neonates was recorded in 2015 and 2016. The overall sex ratio showed a slightly higher share of males at 120:100. This bias was the most pronounced for males of common dolphins. Spatial distribution varied interspecifically but was predominantly along the southern coast. Bycatch signs were detected in 80 animals including during the turbot fishing ban period, suggesting the existence of illegal fishing operations. All of this highlights the need for better reinforcement and control to ensure both the conservation of endangered cetaceans and the sustainability of fisheries. Improvement in data collection is needed to improve the quality of information.

Keywords: Black Sea; harbour porpoise; bottlenose dolphin; common dolphin; cetacean strandings

1. Introduction

The Black Sea hosts three species of cetaceans which due to geographic isolation and on the basis of morphological and genetic evidences are nominated as endemic subspecies: Black Sea harbour porpoise (Phocoena phocoena relicta, Abel, 1905) [1–3], Black Sea bottlenose dolphin (Tursiops truncatus ponticus Barabash-Nikiforov, 1940) [4,5] and Black Sea common dolphin (Delphinus delphis ponticus Barabash-Nikiforov, 1935) [6,7]. During the 20th century, Black Sea cetaceans were subject to industrial exploitation that continued until 1983 with estimated takes of millions of animals [8]. Nowadays, Black Sea cetaceans are facing different threats such as pollution, biological invasions, overfishing, and bycatch in fishing gear [9–11] that are affecting their conservation status. All three subspecies are listed in the IUCN Red List of Endangered species in the Endangered (harbour porpoise and bottlenose dolphin) and Vulnerable (common dolphin) categories [12–14] and are protected by national legislations of the six Black Sea coastal states as well as by international law. Being apex predators in the marine ecosystem of the Black Sea, cetaceans fulfil key ecological, economic and cultural functions [15].

Cetacean stranding studies are the oldest method of obtaining scientific data on marine mammals and are an important source of information on their distribution, seasonal dynamics, mortality, morphology, health status, life history, and even some population parameters [16]. The systematic recording of stranded cetaceans is obligatory to detect mass mortality events that can be caused by human activities like bycatch in fishing gear [17] or natural hazards like epizootics [18]. The importance of stranded cetaceans as a source of scientific data is underlined by numerous resolutions adopted during Meetings of Parties.
of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and contiguous Atlantic area (ACCOBAMS) to which Bulgaria is a party. On the shores of the Black Sea, most of the cetacean stranding surveys have focused on specific regions of the riparian countries like the southern Sea of Azov [19], the Turkish western Black Sea coast and the Zonguldak area [20,21], the southern part of Crimean Peninsula [22,23] or on topics such as prey [24], temporal distribution [25], interaction with fisheries [26] and population genetic structure [27].

This paper presents recorded cetacean strandings along the Bulgarian coast in the western Black Sea for a period of 13 years (2010–2022). The study aims to investigate inter-annual and monthly dynamics with observed peaks, species and sex ratio, and spatial distribution with identified hotspots. We compare observed results along the Bulgarian coast with those from studies in other parts of the Black Sea to detect differences and similarities. The data complement existing studies in the basin, contributing to a better knowledge and understanding of cetaceans’ strandings in the region.

2. Materials and Methods

2.1. Study Area

Bulgaria has a coastline with a total length of 432 km on the western side of the Black Sea from Cape Rezovo (41.983611° N, 28.034722° E) in the south at the border with Türkiye and Cape Sivriburun (43.738743° N, 28.579123° E) to the north at the border with Romania (Figure 1). The largest cities on the coast are Varna and Burgas where Regional Inspectorates of Environment and Water (RIOEW) are based. Administratively, there are 14 municipalities with coastline. Sandy beaches represent 34.5% (149 km) of the Bulgarian coast [28], providing favourable conditions for stranded cetaceans to remain for longer periods. The largest sandy beaches include Durankulak-Krapets and the Kamchia River mouth in the north and Sunny beach/Nessebar, Pomorie-Aheloy, Alepu, and Gradina in the south [29]. The most pronounced cliff formations are in the north around Cape Kaliakra and in the central part around Cape Emine. In the southernmost part of the coast, sand beaches are smaller and usually secluded in rocky coves.

Figure 1. Study area.
2.2. Data Collection and Processing

Data were collected from different sources—dedicated and opportunistic surveys along sandy beaches; publications in social media; citizen science reports via mobile app blackseawatch.org; reports by RIOEWs in Burgas and Varna and ecology experts of coastal municipalities. In 2013 and 2014, trainings on basic data collection for cetacean strandings were provided for experts from RIOEWs and municipalities including the distribution of a Manual for Data Collection from Stranded Cetaceans along the Bulgarian Black Sea Coast [30]. The manual was a direct implementation in Bulgaria of ACCOBAMS Resolutions 1.10, 3.25, and 4.16 dealing with national cetacean strandings networks, live strandings, and coordinated response. The data collection protocol that we used was based on the protocol of the Mediterranean Database of Cetacean Strandings (MEDACES), which is the official repository for strandings data in the ACCOBAMS area including the Black Sea. For each cetacean stranding, the following information was recorded: date, location (geographic coordinates), stage of decomposition, species, sex, and body length from the tip of the rostrum to the tail fluke notch. The level of decomposition was identified based on standard protocol [31] with five stages: alive (1); freshly dead (2); decomposed but organs basically intact (3); advanced decomposition (4); and mummified remains (5). In order to avoid the duplication of cases collected from different sources, each reported case of stranded cetacean was inspected thoroughly and double-checked by species, location, and day of reporting. Cases in which the location was the same beach and the time of report overlapped with up to three days before or after were removed from the dataset. For the data collected from social media publications, the sex and state of decomposition were recorded only when pictures were available to allow the verification of these. The same approach was used for species identification. We used several cues to detect probable traces of human interaction, with the most probable being bycatch in fishing gear. These were either net marks or cut pieces of flesh (especially longissimus dorsi muscles) for fresh carcasses. For higher decomposition states, indicators were missing pectoral, dorsal fins or tail flukes and remaining pieces of fishing gear (ropes, nets). We used the $\chi^2$ test to test the significance of differences in species ratio when comparing with other studies in the Black Sea, using these as expected values. Maps were made using the “Heatmap” tool of QGIS 3.16.5. On occasions when multiple cetaceans were stranded in a day at a specific beach/location, peak daily numbers were calculated as individuals per kilometre.

3. Results

In the study period of 13 years, we collected data for a total of 1528 cases of stranded cetaceans (Supplementary Table S1). In 87% (1346) of the cases, stranded cetaceans were identified to the species level, 19 were identified to the level of family (Delphinidae), and the species were not identified in the remaining 182 cases. Regarding data sources, the prevailing data were from citizens (46%) and RIOEWs (42%). Data collected by dedicated surveys accounted for 5%, and the remaining 7% arrived from municipalities’ reports. The Black Sea harbour porpoise had the largest share with 1031 individuals followed by the Black Sea bottlenose dolphin with 199, and the lowest numbers were those of the Black Sea common dolphin with 97 (Table 1). Annual maximums of the bottlenose and common dolphins were recorded in 2022, while for the harbour porpoise, it was in 2016. Two well-defined annual peaks were observed in the number of total strandings—in 2016 and 2022. In 2015, 2017, and 2018, the total number of strandings was similar and still in the upper end. Minimum numbers were recorded in 2011, 2010, and 2014. The Black Sea harbour porpoise has been the most numerous species recorded in all the years except 2011 and 2013 when the Black Sea bottlenose dolphin displaced it.
Table 1. Species distribution of cetacean strandings along the Bulgarian Black Sea coast in the period 2010–2022.

<table>
<thead>
<tr>
<th>Year</th>
<th>Delphinidae</th>
<th>Delphinus delphis</th>
<th>Phocoena phocoena</th>
<th>Tursiops truncatus</th>
<th>Unidentified</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>2</td>
<td>7</td>
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<tr>
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<td>1</td>
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<td>6</td>
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<tr>
<td>2012</td>
<td>4</td>
<td>5</td>
<td>45</td>
<td>20</td>
<td>5</td>
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</tr>
<tr>
<td>2013</td>
<td>7</td>
<td>6</td>
<td>21</td>
<td>22</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>2014</td>
<td>2</td>
<td>10</td>
<td>9</td>
<td></td>
<td>4</td>
<td>25</td>
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<tr>
<td>2015</td>
<td>4</td>
<td>102</td>
<td>13</td>
<td>35</td>
<td>4</td>
<td>154</td>
</tr>
<tr>
<td>2016</td>
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<td>13</td>
<td>280</td>
<td>19</td>
<td>22</td>
<td>335</td>
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<td>3</td>
<td>10</td>
<td>113</td>
<td>22</td>
<td>19</td>
<td>167</td>
</tr>
<tr>
<td>2018</td>
<td>14</td>
<td>90</td>
<td>24</td>
<td></td>
<td>18</td>
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<td>1</td>
<td>4</td>
<td>50</td>
<td>9</td>
<td>5</td>
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</tr>
<tr>
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<td>1</td>
<td>10</td>
<td>93</td>
<td>8</td>
<td>4</td>
<td>116</td>
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<td>1</td>
<td>20</td>
<td>169</td>
<td>34</td>
<td>56</td>
<td>279</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>97</td>
<td>1031</td>
<td>199</td>
<td>182</td>
<td>1528</td>
</tr>
</tbody>
</table>

The monthly distribution of strandings shows that cumulatively speaking, the months with the highest numbers of strandings for harbour porpoises and bottlenose dolphins were July and August, while the peak month for common dolphins was May (Figure 2).

Figure 2. Monthly distribution of cetacean strandings along the Bulgarian Black Sea coast in 2010–2023.

The peaks observed in July and August were a result of the high number of strandings recorded during these months in the triennium 2015–2017. This same triennium included the highest monthly peak for the entire study period recorded in July 2016 with 207 cases. In the second highest year (2022), the peak values were observed earlier—in May and June (the second monthly peak for the whole period with 108 strandings). The highest daily peak was recorded on 17 July 2016 when 31 porpoises were registered, 23 of these in close locations at Pomorie-Aheloy and Burgas. Furthermore, this peak was observed during a period of five days (13–17 July), when 87 strandings occurred, 83 of which were
porpoises. A second peak but with a smaller total was observed in early August 2015 when in three days (7th to 9th), 43 cetaceans were stranded and 32 of these were porpoises. The only other year when a daily peak of more than 10 cetaceans was reported was in 2022 when on 21 June, eleven were washed ashore: four common dolphins, four porpoises, and three unidentified.

Data on carcass decomposition were collected for 1069 (70%) of all stranded cetaceans. The highest shares were of strandings in states 4 and 3, while there was only five alive strandings (Figure 3). The prevailing advanced decomposition state concurs with the observed peaks in warm months from May to August. One unexpected result was that the highest number of live stranded cetaceans was common dolphins—species considered mostly offshore.

![Stranded cetaceans according decomposition state](image)

**Figure 3.** Distribution of cetacean strandings along the Bulgarian Black Sea coast in 2010–2023 according to state of decomposition.

Sex identification was recorded in 214 cases representing a mere 14% of total strandings. The overall sex ratio showed a slightly higher share of males at 120:100. The prevalence of males was observed for all three species. It was the most pronounced for the common dolphin, reaching 72%. The sex ratio was identical for bottlenose dolphins and harbour porpoises at 114:100, respectively (Figure 4).

Body length data were collected in 769 (50%) cases. The Black Sea harbour porpoise body length varied between 40 and 170 cm (mean = 89.07, SD = 27.76, SE = 1.18); males were in the range of 50–133 cm, and females were in the range of 50–170 cm. The body length of common dolphins was between 60 and 194 cm (mean = 136.58, SD = 38.25, SE = 4.93). Males were in the range of 60–194 cm, and females 140–165 cm. Bottlenose dolphins’ body length was in the range of 67 to 300 cm (mean = 194.53, SD = 49.88, SE = 4.39). Males were in the range of 60–194 cm, and females were in the range of 140–165 cm. Stranded Delphinidae were in the range of 110–200 cm, and those unidentified varied between 50 and 220 cm.
Figure 4. Stranded cetaceans by sex along Bulgarian Black Sea coast in 2010–2023.

The spatial distribution of strandings showed a somewhat similar pattern in all three species. Locations without any strandings were the main cliff areas around Capes Kaliakra and Emine as well as south of Varna. Strandings of harbour porpoises were the most numerous, which were distributed along the whole shoreline with sandy beaches. Concentrations of harbour porpoises’ strandings were along the southern coast around Nessebar and Aheloy-Pomorie continuing south to Tsarevo (Figure 5). Peak daily numbers were recorded at Burgas north—3.3 ind./km on 17 July 2016 and 2.27 ind./km on 16 July 2016 at Aheloy-Pomorie. A secondary and much smaller concentration was detected around Varna. The spatial distribution of Black Sea bottlenose dolphins’ strandings was uniform along the southern shore, and in the north, it was clustered around Varna and north of Cape Shabla. The main concentration of bottlenose dolphins’ strandings partly overlapped with those of the porpoises in the south. It was centred around Pomorie-Aheloy and included also beaches around Nessebar and Sozopol (Figure 6). Another similarity with the spatial distribution of porpoises was the secondary much smaller concentration around Varna. The peak daily number was recorded on 26 July 2012 when five dolphins were stranded, three of these next to Pomorie, making the rate there 0.6 ind./km. Black Sea common dolphins were the least numerous species recorded in strandings, but on the other hand, they showed the clearest pattern of distribution (Figure 7). Three hotspots where common dolphins washed ashore were around Nessebar and Varna and just north of Cape Shabla. The peak daily number was four dolphins on 21 June 2022. Three of these were at Shabla beach, accounting for a rate of 0.75 ind./km. Unidentified cetaceans’ spatial distribution coincided partially with that of porpoises, but the largest concentration was south of Cape Maslen, stretching to Tsarevo (Figure 8). Representatives of Family Delphinidae were concentrated around Varna Pomorie, Sozopol and Ahtopol.

Evidence of bycatch in fishing gear was detected in only 80 cases (5%). The highest share was of porpoises and bottlenose dolphins, 58 and 19, respectively, with the remaining three being two common dolphins and one unidentified delphinid.
Figure 5. Spatial distribution and heatmap of strandings of Black Sea harbour porpoise along the Bulgarian Black Sea coast in 2010–2022.

Figure 6. Spatial distribution and heatmap of strandings of Black Sea bottlenose dolphin along the Bulgarian Black Sea coast in 2010–2022.
Evidence of bycatch in fishing gear was detected in only 80 cases (5%). The highest share was of porpoises and bottlenose dolphins, 58 and 19, respectively, with the remaining three being two common dolphins and one unidentified delphinid.
4. Discussion

The overall species ratio observed in our study, including only individuals with confirmed species of harbour porpoise, bottlenose dolphin, and common dolphin, was 77.7:15.7:7.3%, respectively. The species ratio in our study was not significantly ($\chi^2$ test, $p > 0.05$) different from that observed in two other studies: along the Romanian coast for the period 2010–2016 where it was 80:15.5:5%, respectively [25], and along the southwestern Crimean coast at Kalamita Gulf between 2008 and 2013, where it was 71.5:21:7.5%, respectively [32]. Our results were significantly different ($\chi^2$ test, $p > 0.05$) when compared to those of a four-year (2018–2021) study around Zonguldak in Türkiye with a species ratio of 42.8:50%, respectively [21] and a five-year (2005–2009) study along southern Crimea where it was 52:38:10%, respectively [23]. The observed differences in species ratio can be attributed to geographic differences in the study area and its corresponding bathymetry. This is highly relevant for the study area of Zonguldak where the shelf area is much narrower compared to the Bulgarian coast. This can explain the high share of stranded common dolphins observed in that study.

The body length of 151 (97%) out of 156 porpoises that were measured in 2016 was below 118 cm, putting this group in the age category of yearlings as that is the length which porpoises in the Black Sea can reach in their first year [33]. In addition, 148 (95%) of those were below 100 cm and can be classified as neonates. A similar high share (94%) of porpoise neonates was also observed in the previous year (2015). In the other years, their share was not higher than 72%. An unusually high mortality of Black Sea harbour porpoise neonates was the main reason for the peak number of strandings in 2016, and it was also reported for the western coast of Türkiye [34]. Earlier stranding studies in the Black Sea have ascribed the larger shares of neonates to bycatch of their nursing mothers [35,36]. The peaks of neonates we observed in 2015 and 2016 can hardly be described with that cause as the share of stranded female porpoises in these two years was smaller than males. Our hypothesis was that an epidemic disease (e.g., porpoise morbillivirus) affected mostly neonates, representing the most vulnerable age class.

A life history study of Black Sea bottlenose dolphins showed that they can reach a length of 188 in the first year [37]. From the collected data on body length for the bottlenose dolphins in our study, we can divide these to 51 juveniles up to one year old, while the other 78 animals were older than that.

The sex ratio of harbour porpoises observed in our study was similar to that along the southwestern coast of Crimea [32]. Unlike harbour porpoises, the sex ratio of bottlenose dolphin strandings in our study was quite different when compared to the Crimean coast where it was female-biased. In Romania, for the period 2010–2016, the sex ratio in all three species was similar to that observed in our study [25]. The common dolphin was the species with the most pronounced difference in sex ratio in our study with 72% being males. That data concur well with data from the southwestern coast of Crimea where only adult males were recorded. A possible reason for the higher share of female bottlenose dolphins that washed ashore in Crimea could be the existence of a resident population there documented by a successful photo-identification study [38]. Another important habitat for bottlenose dolphins around Crimea is suitable calving and nursing grounds that can explain the higher share of females. The identical sex ratio of all three species observed along the Bulgarian and Romanian coasts can be ascribed to similarities in marine habitat and oceanographic features.

The observed species ratio of stranded cetaceans with signs of bycatch in fishing gear has shown a higher share of bottlenose dolphins when compared with results from most bycatch studies in the Black Sea [11,39]. On the other hand, it is important to underline that the share of dead cetaceans reaching the shoreline can be as low as 8% [16]. Furthermore, our strandings data for 2019 have shown only 69 cases, while in the same year, a bycatch survey that involved five fishing vessels (only 4.3% of all licensed vessels for turbot in Bulgaria) recorded 105 bycaught cetaceans, all except one being porpoises [40]. On seven occasions, it was revealed that *longissimus dorsi* muscles were removed, indicating use for
consumption. Observed carcasses with traces of bycatch in early stages of decomposition (2 and 3) between 15 April and 15 June when the turbot fishing ban was effective have indicated the existence of illegal fishing operations in 2012 and 2016–2021. Recorded peak values of strandings in July and August coincide with higher values of bycatch observed in Bulgarian turbot fishery in the summer. Despite that, only 36% of stranded cetaceans which indicated fishery interaction in our study were in that period. Quick decomposition in the warm months is the most probable reason for not detecting traces of bycatch during that period.

The observed spatial variations in the strandings of the different species reflect the differences in their spatial distribution to some extent. Black Sea harbour porpoise is the dominating species in stranded cetaceans along the Bulgarian coast. That is in line with the preferred shelf habitat and with the results from an abundance and distribution study in that period [41]. The recorded concentration of strandings along the southern coast concurs well with the observed higher density in that part of Bulgarian shelf waters. Important factors affecting the location where floating carcasses wash ashore are the direction of sea currents and coastal exposure. The southern part of the Bulgarian coast combines these two factors through a northeastern exposure and north to south direction of the sea current. The limited hotspots of stranded bottlenose dolphins and common dolphins largely result from the lower abundance estimates of these species in Bulgarian shelf waters.

The high numbers of stranded cetaceans in summer could result from two related facts. The first is the largest share of harbour porpoises, and the second is the seasonal distribution of the species in the Black Sea. It is a well-documented fact that the species migrates from the southeastern to the northwestern part in the warmer part of the year and vice versa in the cold seasons. Last but not least, the raised public awareness and sensitivity to cases of stranded cetaceans is also an important factor to consider. The Bulgarian Black Sea coast is a major summer holiday destination, and the number of visitors on the beaches increases significantly in that season. Respectively, that corresponds to a higher search effort even if not intentional. That factor should also be considered when looking into the higher overall numbers in later years of the study (after 2014) with the only exception being 2012.

The second-highest peak of stranded cetaceans observed in 2022 coincided with the start of the Russian war in Ukraine. An unusually high number of live stranded cetaceans was observed. A switch of bycatch maximum from summer to spring in Bulgaria was also recorded. Higher rates of strandings were reported also in the other Black Sea countries. In Türkiye, it was associated with a bycatch of common dolphins in February–March, but that was not confirmed as the main reason for the high numbers recorded in May–June in the other countries [42].

5. Conclusions

The large number of cases with incomplete data on species identification, body length, and most of all sex shows that improvement in data collection is needed. The development of civil society and its increased awareness of cetacean strandings is only a part of the solution. This should be complemented with higher expertise by the public authorities and building an active operating national strandings network involving diverse stakeholders. The low local capacity is further underlined by the lack of a dedicated laboratory to perform a full necropsy of stranded cetaceans. This is the best way for multidisciplinary studies (including the cause of death, life history, and health status) of these apex predators whose Black Sea populations are of high conservation importance. The small share of stranded cetaceans in decomposition state 2 (fresh carcass) has limited these opportunities, but the few that arose were missed. The observed small share of cetaceans with confirmed signs of bycatch could be explained by a great share of individuals in an advanced state of decomposition, but the indication of illegal fishing activities described in Section 4 highlights once again the well-described problem of IUU (illegal, unreported, and unregulated) fishing in the Black Sea. Better enforcement and control are obligatory to ensure both the conservation
of endangered cetaceans and the sustainability of fisheries in the long run. Last but not least, improving international coordination and establishing a joint Black Sea register on marine noise (generated by oil and gas exploration, naval exercises, and other sources) will ensure early warning system for probable cases of mass strandings. All Black Sea countries should contribute to establishment of a functional Emergency Task Force on strandings as proposed by ACCOBAMS.

**Supplementary Materials:** The following supporting information can be downloaded at [https://www.mdpi.com/article/10.3390/oceans5030025/s1](https://www.mdpi.com/article/10.3390/oceans5030025/s1), Table S1: Recorded stranded cetaceans along Bulgarian Black Sea coast in the period 2010–2022.

**Author Contributions:** Conceptualization, D.P.; methodology, D.P. and G.M.; software, D.P.; validation, G.M.; formal analysis, D.P.; investigation, D.P. and G.M.; resources, D.P. and G.M.; data curation, G.M.; writing—original draft preparation, D.P.; writing—review and editing, G.M.; visualization, D.P.; supervision, G.M.; project administration, D.P.; funding acquisition, D.P. All authors have read and agreed to the published version of the manuscript.

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