BIOLOGY LETTERS

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Opinion piece

Cite this article: Węgrzyn E, Rusev I, Tańska N, Miedviedieva I, Kagalo AA, Leniowski K. 2023 The use of social media in assessing the impact of war on cetaceans. *Biol. Lett.* **19**: 20220562.
https://doi.org/10.1098/rsbl.2022.0562

Received: 1 December 2022
Accepted: 20 March 2023

Subject Areas:
ecology, ecosystems, environmental science

Keywords:
war, cetacean mortality, citizen science

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THE ROYAL SOCIETY PUBLISHING

Conservation biology

The use of social media in assessing the impact of war on cetaceans

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War has always brought millions of silent non-human victims but the scale of this suffering is often either unknown, neglected or difficult to quantify. Further, the complexities associated with long-term and large-scale monitoring of marine species make it difficult to assess the impacts of war and the mortality of cetaceans resulting from warfare has not been investigated. Here we propose the use of a modified form of citizen science, namely gathering the information from social media. Dolphin stranding is such a poignant incident for most people, that the probability of eyewitness posting information on social media appears high. We test this idea by collecting data on cetacean strandings along the Black Sea published on the Internet over the three months of Russia's invasion of Ukraine in 2022. We also validate this method with a small-scale scientific study on cetacean mortality during the same period of time, conducted in 'Tuzlivski lymany' Nature National Park in Ukraine. Our dual approach has produced similar results, indicating a dramatic increase in cetacean mortality due to war operations in the Black Sea. We advocate the future use of social media to bridge the knowledge gap on the impacts of war on animals, in particular cetaceans.

1. War and animal victims

War has been common and constant human activity since the beginning of civilization and human suffering during warfare is so overwhelming that it leaves little opportunity to quantify the impact of armed conflicts on animals. Nonetheless, we have a scientific understanding that the ability to experience both physical and mental pain is shared across species [1], thus numerous animal taxa are not that different in this feature to humans [1]. Furthermore, war has always brought millions of silent non-human victims, but the scale of this suffering is often either unknown, neglected or difficult to quantify [2]. During wartime, a methodical collection of the data on animal welfare is challenging, if not impossible. As a result, scientific literature on the effects of warfare on animals is rather modest and additionally it often relates to more general terms, such as environment or biodiversity [3,4]. However, few investigations dedicated to animal welfare in the course of war clearly show that armed conflicts affect wildlife through a range of interactions—mines, explosives, chemicals, fires and increased hunting—kill numerous animals of endangered species [5].

2. Does war affect marine mammals?

To date, studies investigating the effect of warfare on animals often focused on African charismatic megafauna, such as great apes and elephants [5], creating bias in assessments of species' vulnerability to warfare and thus hindering our ability to understand how armed conflict affect different animal species. Warfare is waged both on land and at sea, but to our knowledge, the impact of war on

marine mammals, in particular the whales, has been investigated in only one study that found increased cortisol levels in baleen whales during the World War II [6]. The authors concluded that wartime activities, such as underwater detonation of ordinance, naval battles and increased vessel numbers, caused a stress response in cetaceans similar to that triggered by intensive whaling. However, the mortality of cetaceans resulting from warfare has not been investigated. The only reports come from investigations of relatively short-term military exercises described below. The negative effects of sonar signals on cetaceans resulting in mass strandings were first confirmed during naval exercises in the Bahamas in 2000 and since then cases of the detrimental impact of underwater noise on cetacean behaviour and survival have been reported [7]. Exposure to sonar signals may cause a prolonged 30.5% increase in metabolic rate [8] as well as ceasing foraging activity [9,10], which results in considerable energy deficit. Energy loss over 40% is a lethal threat to cetaceans and it may result from only 10 days of fasting [11]. There is the evidence that sonar signals disturb cetacean behaviour over distances as large as 90 nautical miles [10,12], thus we may suppose that the long-term and large-scale military actions during the war may leave little undisturbed space for cetaceans. Although it was reported that the sonar systems employed by the military to search for submarines, and actively screen whole ocean basins, generate devastating noise levels causing mass standings of different whale species during military exercises (reviewed in [13]), no study so far has aimed at estimation of the effect of war on cetacean mortality. This may be due to a fact that the monitoring of marine species is much more difficult than terrestrial species [14]. Moreover, such an investigation should be long term and cover a large area, possibly belonging to different countries bordering the hostilities' basin. This may seem impossible with conventional scientific approaches. However, citizen science appears a promising tool in such a challenge.

3. Citizen science in a large-scale projects

Citizen science has been considered primarily as a component of educational tools, but it is also a means of collecting large amounts of data [15]. Where a large dataset could not be collected by scientists because of variable obstacles, one way to solve this problem is to engage a group of citizen scientists providing information for the larger ecological projects [16,17]. Citizen science is mostly implemented as projects, in which a number of non-scientist volunteers are consciously involved and they collect and deliver the data to scientists, who analyse the data and interpret the results [18]. Although volunteers are not experts in a given field, they are well trained and adhere to a methodological protocol. Some of these programmes have been implemented to record cetacean strandings and have proven to be a useful tool in monitoring cetacean populations [19] (http://ukstrandings.org) [20,21]. Further, we think that other approaches of linking citizen-collected data and scientists may also work. For example, scientists may collect information made available on the Internet by many people, who do not intentionally participate in a particular project, but do share public information on social media. Current statistics show that in 2022, there were 4.74 billion social media users around the world, equating to 59.3% of the total global population [22]. We propose that collecting data on cetacean strandings published in social media may provide substantial information that is extremely difficult to obtain over a long period of time and from a large area during typical scientific research, especially in war zones. Witnessing a dolphin stranding is such a poignant incident for most people that the likelihood that the eyewitnesses will publish information and/or photographs on social media is increasingly high. Additionally, dolphin carcasses do not stay on the beach for a long time due to tides, waves, storms, scavengers and trophy collectors, thus posts on social media by eyewitnesses seem the apt source of information. Moreover, posts on social media include tags, which make the information easier to find. The advantage of this approach is that there is no need to train volunteers and implement a complex project, which may not be feasible during wartime.

4. A combined approach of citizen and traditional science to validate the data

We are aware that outcomes based on citizen science may be not as precise as traditional scientific approaches; however, they have the potential to indicate a trend. We suggest that such surveys may be additionally validated by a small-scale traditional research. We test our idea of monitoring cetacean mortality during a war with the use of citizen information gathered from social media by searching the Internet within three months of Russia's invasion of Ukraine in 2022, which was partly waged in the Black Sea. To validate the above method, we compared the results of the large-scale investigation based on citizen science with the small-scale precise analysis of the number of stranded cetaceans before and during the war observed in 'Tuzlivski lymany' National Nature Park by scientists.

5. The Black Sea cetaceans

The Black Sea is inhabited by only three species of cetaceans: the harbour porpoise *Phocoena phocoena*, the short-beaked common dolphin *Delphinus delphis* and the common bottlenose dolphin *Tursiops truncatus*, all listed on the IUCN Red List of Threatened species (as EN, VU, EN, respectively) [23,24]. One of the three subspecies of the harbour porpoise, namely the Black Sea harbour porpoise *P. phocoena relicta* is restricted to Marmara and the Black Sea. In 2019, its population was estimated at 90 970 individuals [24]. In general, the biodiversity of the Black Sea is quite limited due to the geographical isolation, low salinity, high amount of hypoxic and anoxic waters below the 100–250 m depth [23]. The population of cetaceans in the Black Sea has declined dramatically over the past hundred years as a result of massive direct killing (banned in 1966 in the USSR, Bulgaria and Romania and in 1983 in Turkey), by-catch caused by fishing industry, water pollution and habitat degradation leading to reduced prey resources [23].

6. The large-scale monitoring of cetacean mortality during the war based on the information from social media

Dead dolphins and porpoises were also found on the beaches around the Black Sea before the war, mostly as casualties of the fishing industry as they had visible signs of fishing

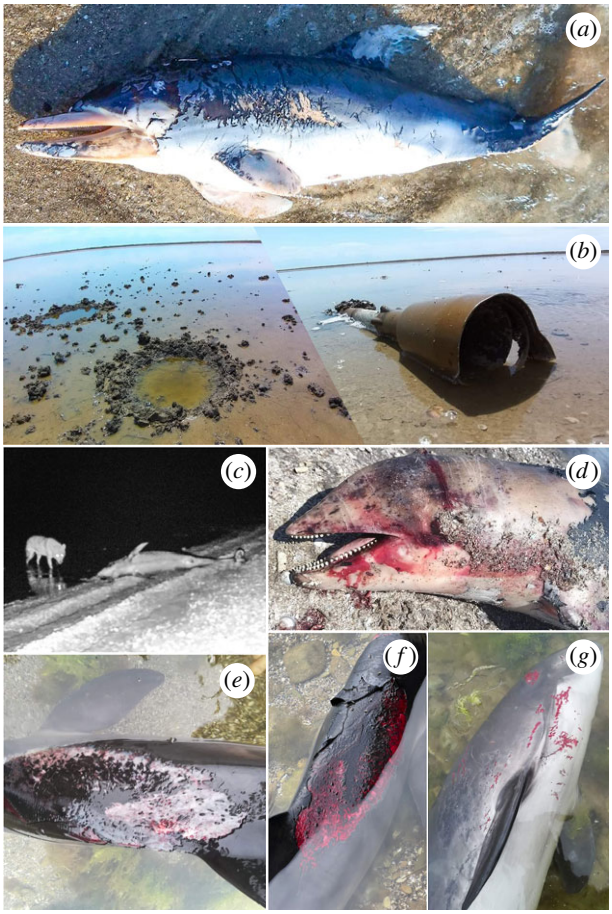

Figure 1. Photos of stranded cetaceans on the Black Sea coastline between 27 April and 31 July 2022. (*a*) A carcass of the common dolphin with no signs of fishery nets (all fins are intact), (*b*) Black Sea shoreline in 'Tuzlivski lymany' NNP after shelling, (*c*) a jackal feeding on a harbor porpoise carcass (caught on a camera trap left by 'Tuzlivski lymany' NNP staff), (*d–f*) harbour porpoises with wounds due to explosions and (*g*) the harbour porpoise with skin lesions and broken blood vessels in the eye (barotrauma) due to a decompression sickness. Photo credits: Ivan Rusev.

nets and their flippers were often cut off by fishermen [23]. However, fishing in the Black Sea has completely ceased since the war started, the carcasses no longer have their fins cut off or any other signs of being trapped in fishing nets (figure 1*a*) leaving no doubt that countless cetacean carcasses documented by citizens of all countries surrounding the Black Sea in 2022 are the victims of war.

The data for our large-scale monitoring project were collected from 27 April to 31 July 2022 along the Black Sea coast (including the Sea of Azov). During this time, the explosions in the northwestern part of the Black Sea and its coastline were regularly observed (figure 1*b*). The explosions were caused by a naval battle for Snake Island, which was carried out using a combination of long-range rocket and drone attacks, anti-ship missiles as well as air and artillery strikes. Another source of explosions were numerous naval mines, air bombardments as well as shelling the port of Odesa and its surroundings. The information on the presence of cetacean carcasses along the Black Sea coast, both in Ukraine and in other Black Sea countries (Bulgaria, Romania, Georgia, Turkey and Russia), was collected using Internet sources (publications and social media) as well as through personal contacts with scientists and volunteers. We pulled together all records of strandings in one category 'cetaceans' because, in a number of instances, witnesses were not able to identify a specific species, either due to their lack of knowledge or the stage of decomposition of the corpse. If the information on the species was available, we provided it in table 1.

We collected data on approximately 2500 cetacean corpses found on the Black Sea coast during the three months of the investigation (table 1). The mean number of dead cetaceans per kilometre of shoreline was 0.5 (min. = 0.2, max. = 1.0, s.d. = 0.3) and data for individual Black Sea countries are provided in table 2. To estimate whether strandings increased during wartime, we compared our findings with pre-war data. The citizen science project on cetacean strandings conducted before the war in Romania and Turkey revealed 20 and 18 beached cetaceans, respectively, during the analogous three months of monitoring, i.e. May–July 2019 [19]. This translates into 0.08 dead cetaceans km^{-1} of Black Sea shoreline in Romania and 0.014 dead cetaceans km^{-1} in Turkey during peacetime. Comparing the pre-war results above with our wartime survey (0.7 beached cetaceans km^{-1} in Romania and 0.2 in Turkey, table 2) shows that cetacean mortality has increased by 8.8–14.3 times depending on the location.

According to research conducted on 14 different cetacean species, the carcass recovery rates accounted for up to 6.2% of the total number of natural or human-induced deaths [25]. A similar value was yielded in an experimental study involving the release of tagged dead short-beaked common dolphins (found by-caught in fishery), where only 8% of the bodies were recovered ashore [26]. The remaining corpses sink to the bottom of the sea or are eaten by other animals (figure 1*c*). As a result, the actual magnitude of dolphin and porpoise mortality due to military operations in the Black Sea can only be estimated from the 2500 stranded carcasses. The Black Sea coastline is 5800 km long, however, more than 1000 km from the Azov–Black Sea coast of Ukraine was inaccessible because of hostilities and/or occupation. The collected data of 2500 dead cetaceans refer to 4800 km of coastline, so we can assume about 3000 beached corpses along the entire coastline (5800 km). Thus, the rough and conservative estimation of cetacean mortality during the three months of military operation in the Black Sea is about 37 500 to 48 000 individuals, assuming carcass recovery between 6.2% and 8% (if a smaller percentage of dead cetaceans have been swept ashore the magnitude of mortality would be greater). This represents one-sixth to one-fifth of the Black Sea population, which was approximately 253 000 cetaceans prior to the war [27]. Thus, in the long term, cetaceans in the Black Sea may face extinction.

Dolphins and porpoises washed ashore and photographed by citizen scientists exhibited fresh war-related injuries on their bodies (figure 1*d–f*). Another reason for their death appears to be starvation and hypothermia—the recent examination of six dead dolphins by the Romanian scientist Dr Razvan Popesku (2022, personal communication) revealed that four of them had micro-lesions inside the melon (which is damage typical of sonar exposure) and their fat layer was less than 1.5 cm showing a long period of feeding incapacity (R Popesku 2022, personal communication). Three out of these six individuals were injured by explosions. A thin layer of subcutaneous fat in stranded cetaceans indicates that they had not eaten for many days and lost the insulation of the body's core from the cold water. Prolonged fasting along with various types of environmental pollution reduces the condition of cetaceans, making them susceptible to viruses, such as *Morbillivirus*,

Table 1. Data on cetaceans stranded on the Black Sea coast between 27 April and 31 July 2022. If the number of carcasses is not specified, it means that the information published on the Internet did not contain a specific number of cetaceans found ashore. If the description of stranding said 'many' instead of the number, we assumed 10 individuals (such records are marked with an asterisk).

date	no. of cetaceans carcasses	species	country	source of information
27 Apr 2022	18	different species	Russia	Internet
24 Apr 2022	1	*Delphinus delphis*	Bulgaria	Internet
30 Apr 2022	1	*Delphinus delphis*	Romania	Internet
	3	*Phocoena phocoena*		
28 May 2022	3	*Phocoena phocoena*	Bulgaria	Internet
29 Jul 2022	1	*Delphinus delphis*	Bulgaria	Internet
13 May 2022	100	*Delphinus delphis* dominates and other species	Turkey	Internet
05 May 2022	200	different species	Russia	Internet
08 May 2022	1	not specified	Romania	Internet
11 May 2022	26	different species	Romania	Internet
12 May 2022	not specified	not specified	Russia	Internet
17 May 2022	10	*Delphinus delphis* dominates and other species	Ukraine	Internet
18 May 2022	250	*Delphinus delphis* and *Phocoena phocoena*	Russia	Internet
21 May 2022	1	*Delphinus delphis*	Ukraine	Internet
23 May 2022	1	*Delphinus delphis*	Bulgaria	Internet
25 May 2022	1	*Phocoena phocoena*	Ukraine	Internet
28 May 2022	1	*Phocoena Phocoena*	Bulgaria	Internet
30 May 2022	282	*Delphinus delphis* and *Phocoena phocoena*	Russia	Internet
01 Jun 2022	1	*Phocoena phocoena*	Ukraine	Internet
02 Jun 2022	2	*Tursiops truncatus*	Bulgaria	Internet
02 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
02 Jun 2022	1	*Delphinus delphis*	Turkey	Internet
02 Jun 2022	10	*Phocoena phocoena*	Ukraine	Internet
03 Jun 2022	13	not specified	Turkey	
05 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
05 Jun 2022	10*	*Phocoena phocoena*	Bulgaria	personal contact
05 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
06 Jun 2022	450	different species	Russia	Internet
07 Jun 2022	not specified	not specified	Bulgaria	Internet
07 Jun 2022	not specified	not specified	Bulgaria	Internet
08 Jun 2022	50	*Delphinus delphis* and *Phocoena phocoena*	Bulgaria	Internet, personal contact
08 Jun 2022	1	*Delphinus delfis*	Romania	Internet
10 Jun 2022	2	*Phocoena phocoena*	Bulgaria	Internet
10 Jun 2022	15	*Phocoena phocoena*	Bulgaria	Internet
11 Jun 2022	1	*Phocoena phocoena*	Ukraine	Internet
11 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
11 Jun 2022	1	*Delphinus delphis*	Bulgaria	Internet
10 Jun 2022	15	*Phocoena phocoena*	Bulgaria	Internet

(*Continued*.)

Table 1. (*Continued.*)

date	no. of cetaceans carcasses	species	country	source of information
11 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
11 Jun 2022	1	*Delphinus delphis*	Bulgaria	personal contact
12 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
13 Jun 2022	25	different species	Bulgaria	Internet
13 Jun 2022	1	*Delphinus delphis*	Romania	Internet
14 Jun 2022	1	*Phocoena phocoena*	Romania	Internet
17 Jun 2022	1	not specified	Bulgaria	Internet
18 Jun 2022	60	different species	Bulgaria	Internet
18 Jun 2022	638	different species	Russia	Internet
19 Jun 2022	62	different species	Bulgaria	Internet
20 Jun 2022	1	*Phocoena phocoena*	Bulgaria	Internet
27 Jun 2022	62	not specified	Romania	Internet
27 Jun 2022	10*	not specified	Georgia	Internet
27 Jun 2022	1	not specified	Romania	Internet
27 Jun 2022	10*	not specified	Bulgaria	Internet
01 Jul 2022	1	*Delphinus delphis*	Turkey	Internet
27 Jul 2022	3	*Delphinus delphis*	Ukraine	personal contact
25 Aug 2022	1	*Delphinus delphis*	Bulgaria	Internet
28 Mar 2022–30 Aug 2022	36	*Phocoena phocoena*	Ukraine (NNP Tuzlivsky limani)	data of the NNP Tuzlivsky limany
	3	*Delphinus delphis*		
28 Mar 2022–30 Aug 2022	5	*Tursiops truncatus*	Ukraine (only Odesa and surrounding area)	Internet, personal contact with volunteers, ecologists, scientists,
	10	*Delphinus delphis*		
	95	*Phocoena phocoena*		

Table 2. Data on cetaceans stranded on the Black Sea coast between 27 April and 31 July 2022 by country.

country	coastline length (km)	no. of stranded cetaceans between 27 April and 31 July 2022	no. of stranded cetaceans per kilometre of coastline
Bulgaria	354	150	0.4
Georgia	310	100	0.3
Romania	225	160	0.7
Russia	1700[a]	1700	1.0
Turkey	1329	250	0.2
Ukraine	300[b]	120	0.4

[a]For the purpose of this study, this 1700 km coastline includes the Azov Sea and the Crimea peninsula.

[b]Ukraine's coastline available for monitoring from the border with Bulgaria to the mouth of the Boh River. The rest of the Ukraine's coastline is either under occupation or subject to hostilities.

due to a weakened immune system. *Morbillivirus* was PCR-confirmed in two out of six dolphins washed ashore around the Black Sea and examined by Dr Razvan Popesku (2022, personal communication).

Constant explosions in the Black Sea caused by mines, the naval battle for Snake Island and shelling the port of Odesa and its surroundings also triggered rapid ascent of dolphins and porpoises to the surface of the water, which caused decompression sickness, with typical symptoms in a form of skin lesions (figure 1*g*) similar to those observed in human divers [12]. Experimental studies using tagged individuals revealed that northern bottlenose whales *Hyperoodon ampullatus* responded to sonar signals through abnormally deep and long dives [28]. The combination of acoustic disturbance (causing deep dives) and explosions (causing rapid ascents) during military operations in the Black Sea may lead to frequent and lethal decompression incidents in dolphins and porpoises.

Lastly, according to the information published on social media, a considerable number of cetaceans washed ashore were still alive but injured so heavily that their rescue was impossible. It is likely that these sentient animals [29,30] suffer significantly before they die of these injuries inflicted by war.

7. The small-scale validation study by scientists

Because regular monitoring of the 5800 km of the Black Sea shoreline by scientists is simply not possible, we have decided on a small-scale project conducted in the National Nature Park 'Tuzlivski lymany' comprising 44 km of shoreline of the Black Sea in Ukraine (figure 2). The study

Figure 2. A map indicating the location of our small-scale project on cetacean strandings during Russia's invasion of Ukraine in 2022. The study area (a costal line of the National Nature Park 'Tuzlivski lymany') is indicated with a red colour.

area was monitored between 27 April and 31 July 2022. During this period 32 dead or nearly dead stranded dolphins and porpoises were discovered, corresponding to 0.7 dead cetaceans km^{-1}.

We also monitored and registered cetacean strandings in the same study area of the National Nature Park 'Tuzlivski lymany' for 7 years prior to the war (2015–2021). The monitoring of strandings was part of the conservation activities and research projects conducted on the protected area of the Black Sea lagoons 'Tuzlivski lymany'. Our archival peacetime data for the analogous months (May–July) in years 2015–2021 show an average of two stranded dolphins/porpoises (min = 0, max = 5), that is 0.05 dead cetaceans km^{-1} of shoreline. Comparing this to 0.7 dead cetaceans km^{-1} observed during the war indicates a 14-fold increase in wartime mortality, and that is statistically significant ($chi^2 = 26.47$, d.f. = 1, $p < 0.0001$). The findings from 'Tuzlivski lymany' are in line with our large-scale social media survey results (an increase of 8.8 to 14.3-fold).

Wartime strandings recorded in our small-scale scientific investigation in 'Tuzlivski lymany' National Nature Park (0.7 dead cetaceans km^{-1}) also match strandings reported in our large-scale investigation with the use of information from social media ($\bar{x} = 0.5$ dead cetaceans km^{-1}, min. = 0.2, max. = 1.0, s.d. = 0.3), in particular they resemble stranding levels in Romania (table 2).

8. Conclusion

Our scientific study of the mortality of cetaceans in 'Tuzlivski lymany' National Nature Park concurs with the analysis of Internet-based sources. Both assessments show a similar number of stranded cetaceans per kilometre of the Black Sea coastline and indicate a sharp increase in cetacean mortality since the beginning of the war. The convergence of the results suggests that the analyses based on the information gathered from social media fairly accurately reflect the mortality of cetaceans.

Although war adversely affects wildlife in numerous ways, its impact appears to be far less discussed in the scientific literature than the impact of large-scale agriculture and industry. This will not change unless the fate of animals on the battlefield is exposed. We believe that citizen science is a powerful tool for highlighting the plight of animals in wartime. The sixth mass extinction is already well underway [31]. A deadly mix of climate change, environmental pollution and importantly, as we highlight here, human war and conflict are having a devastating impact on animals and our planet. The scale of non-human mortalities as a result of war needs to be quantified and documented in order to help inform future conservation and management efforts of these victims.

Data accessibility. This article has no additional data.

Authors' contributions. E.W.: conceptualization, formal analysis, investigation, methodology, writing—original draft and writing—review and editing; I.R.: investigation; N.T.: investigation; I.M.: investigation; A.A.K.: investigation; K.L.: conceptualization, formal analysis, methodology and writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. We declare we have no competing interests.

Funding. We received no funding for this study.

Acknowledgements. We kindly thank Matthieu Authier and three other anonymous reviewers for their comments and suggestions, which helped to improve our manuscript.

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