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Unforeseen consequences of the COVID-19 pandemic: Increased frequency of kite-string injuries in magnificent frigatebirds (Fregata magnificens) in Rio de Janeiro state, Brazil

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Abstract

*Kite flying is a popular hobby and sport for children and adults. Despite being illegal in Rio de Janeiro state, Brazil, the use of abrasive threads remains widespread and poses a health risk to both humans and animals. In this study, we analysed the records of 462 magnificent frigatebirds (*Fregata magnificens*) submitted to rehabilitation centres or found dead along the southern coast of Rio de Janeiro state from October 2016 to August 2020. Of these, 244 individuals (52.8%) presented wing lesions consistent with kite-string injury, which can have a critical impact on the ability of frigatebirds to fly and will ultimately cause their death. Even when veterinary care is provided, only a small proportion of the individuals (2%) will fully recover the ability to fly in order to be released back to the wild. In 2020, an atypical increase in the number of individuals with kite-string injuries (~1,200% increase compared to other years) was noted in the weeks following the suspension of school activities and commerce in response to the COVID-19 pandemic. The number of frigatebirds with kite-string injuries recorded in a given week was positively correlated with internet searches for kite-related terms, which also peaked during the quarantine period of the COVID-19 pandemic. This illustrates how pandemic events may aggravate existing human-wildlife conflicts, and how preparedness plans need to incorporate measures to help communities cope with boredom and isolation during quarantine in ways that do not negatively impact the welfare and conservation of wildlife.*

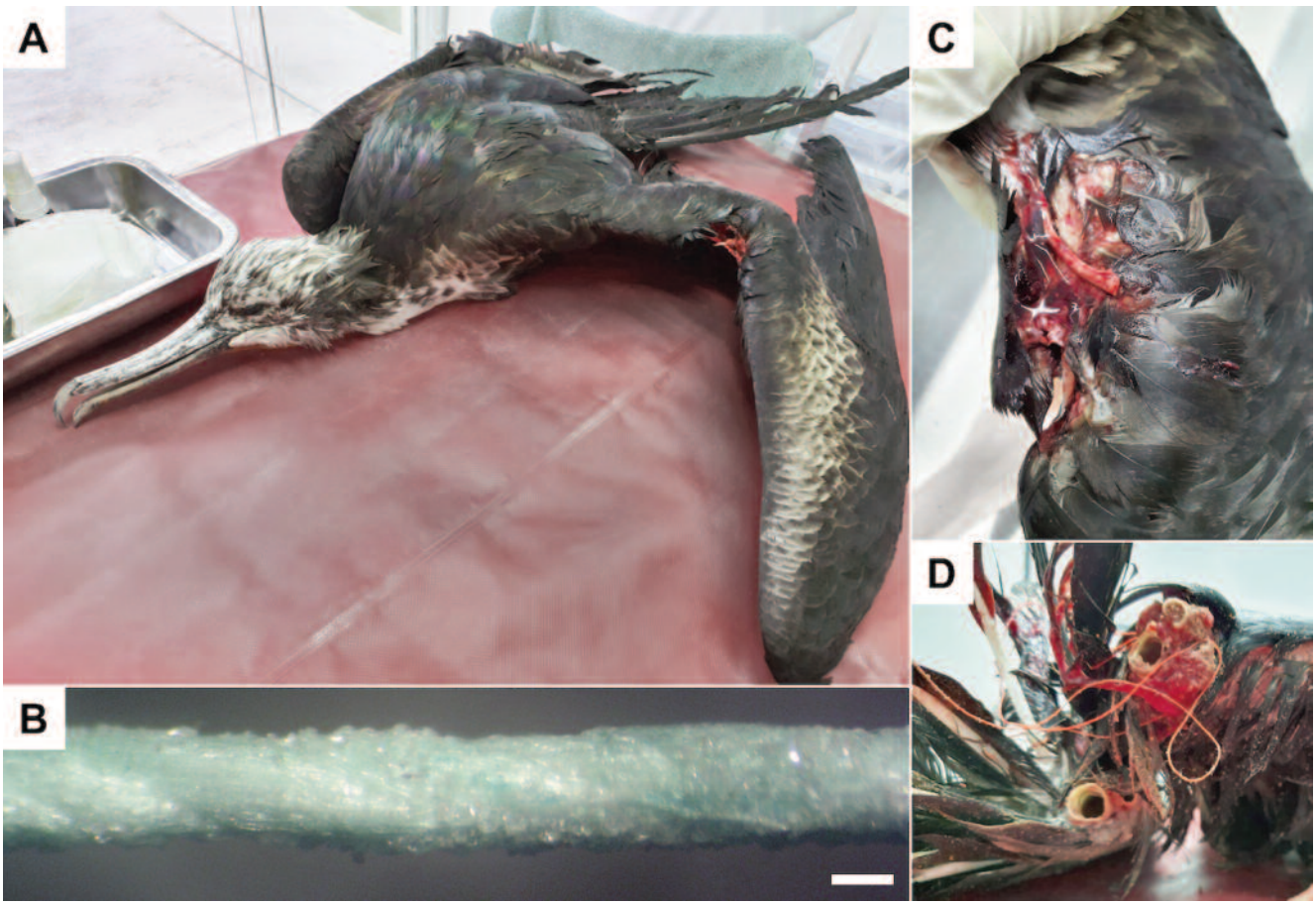
Keywords: *animal welfare, human-wildlife conflict, kite flying, manjha, pandemic, seabird*

Introduction

Kite flying is a popular hobby and sport for children and adults all over the world, and sometimes includes kite fighting, where the objective is to cut the opponent's kite string by means of kite lines coated with a mixture of either ground glass and glue (known as 'manjha' or 'cerol'), or quartz powder and aluminum oxide ('linha chilena') (Babu *et al* 2015). As a result of the use of abrasive threads, an increasing number of kite-string injuries have been reported in both humans and animals (Ladeira *et al* 2012; Roy & Shastri 2013; Muvalia *et al* 2019). In India, kite-flying festivals pose a major threat to raptors, vultures, pigeons and parrots, amongst others, including endangered species, such as the white-rumped vulture (*Gyps bengalensis*) (Roy & Shastri 2013; Babu *et al* 2015). In Brazil, kite-string injury is also a frequent cause of admission of birds to rehabilitation centres, especially birds of prey (Joppert 2007; Brito 2017).

Although abrasive kite threads have been prohibited in Rio de Janeiro since July 2019 (state law no 8478), their use remains widespread. In the first semester of 2020, when school activities and commerce were suspended due to the COVID-19 pandemic, magnificent frigatebirds (*Fregata magnificens*) in Rio de Janeiro began experiencing kite-string injuries at unprecedented levels (Figure 1). In this study, we quantify the occurrence of kite-string injuries in frigatebirds along the southern coast of Rio de Janeiro state, and discuss the need to incorporate measures that help communities cope with boredom and isolation during quarantine in a manner that does not negatively impact the welfare and conservation of wildlife.

Figure 1



Kite-string injury in magnificent frigatebirds (*Fregata magnificens*) showing (A) juvenile with a kite-string injury to the left wing, (B) highly abrasive quartz powder-aluminum oxide kite string ('linha chilena'; scale bar = 0.2 mm), (C) kite-string injury with severing of the wing tendons and (D) kite-string injury with complete fracture of the radius and ulna.

Materials and methods

We evaluated data from the Santos Basin Beach Monitoring Project (Programa de Monitoramento de Praias da Bacia de Santos - PMP-BS), a beach-monitoring programme along the southern coastline of Rio de Janeiro state, from Paraty (23°22'03"S 44°43'27"W) to Saquarema (22°56'07"S 42°27'35"W) (*circa* 240 km of coastline, not including the inner coastlines of bays and coves; Figure 2).

Magnificent frigatebirds are known to breed at three islands within the study area (Alves *et al* 2004): Cagarra and Redonda Islands (*circa* 2,640 pairs; Cunha *et al* 2013) and Jorge Grego Island (756 individuals; Moraes-Ornellas & Ornellas 2012). The other nearest colonies are at Alcatrazes Island (*circa* 130 km south-west) and Francês Island (*circa* 100 km north-east) (Alves *et al* 2004). From 3 October 2016 to 23 August 2020, beaches were monitored on a daily basis, and a toll-free phone number made available (and publicised through folders, local media, social media and local authorities) for the local communities to report injured or distressed marine animals. The following information was recorded for each frigatebird that was found: location, date, context (daily beach survey or community call), status (live or dead), developmental stage (juvenile, adult, or unknown), and sex (male, female, or unknown).

Upon arrival at the rehabilitation facility, frigatebirds were examined by veterinarians, and classified as: (i) confirmed kite-string injury (when the rescuer witnessed the animal being injured or when a fragment of kite string was entangled around the wing); (ii) suspected kite-string injury (animal presenting with lacerative injury to the anterior margin of the wing, associated with partial or complete rupture of tendons or ligaments, or exposed wing fractures with evidence of linear laceration); (iii) other injury (eg blunt force trauma, penetrating wounds, wing luxation, etc); (iv) no trauma; or (v) not determined (when carcases were too decomposed). It should be noted that fishing-line injuries are very rare in frigatebirds because, unlike other seabirds, they do not dive nor land on water; furthermore, fishing-line injuries can be distinguished because they involve compression or strangulation the entire circumference of the limb, whereas kite-string injuries are a characteristic clear cut to the frontal portion of the limb (and if there is damage to the back side of the limb, it either follows the same sharp cut line or is related to the bone fracture rupturing the soft tissues). Birds received

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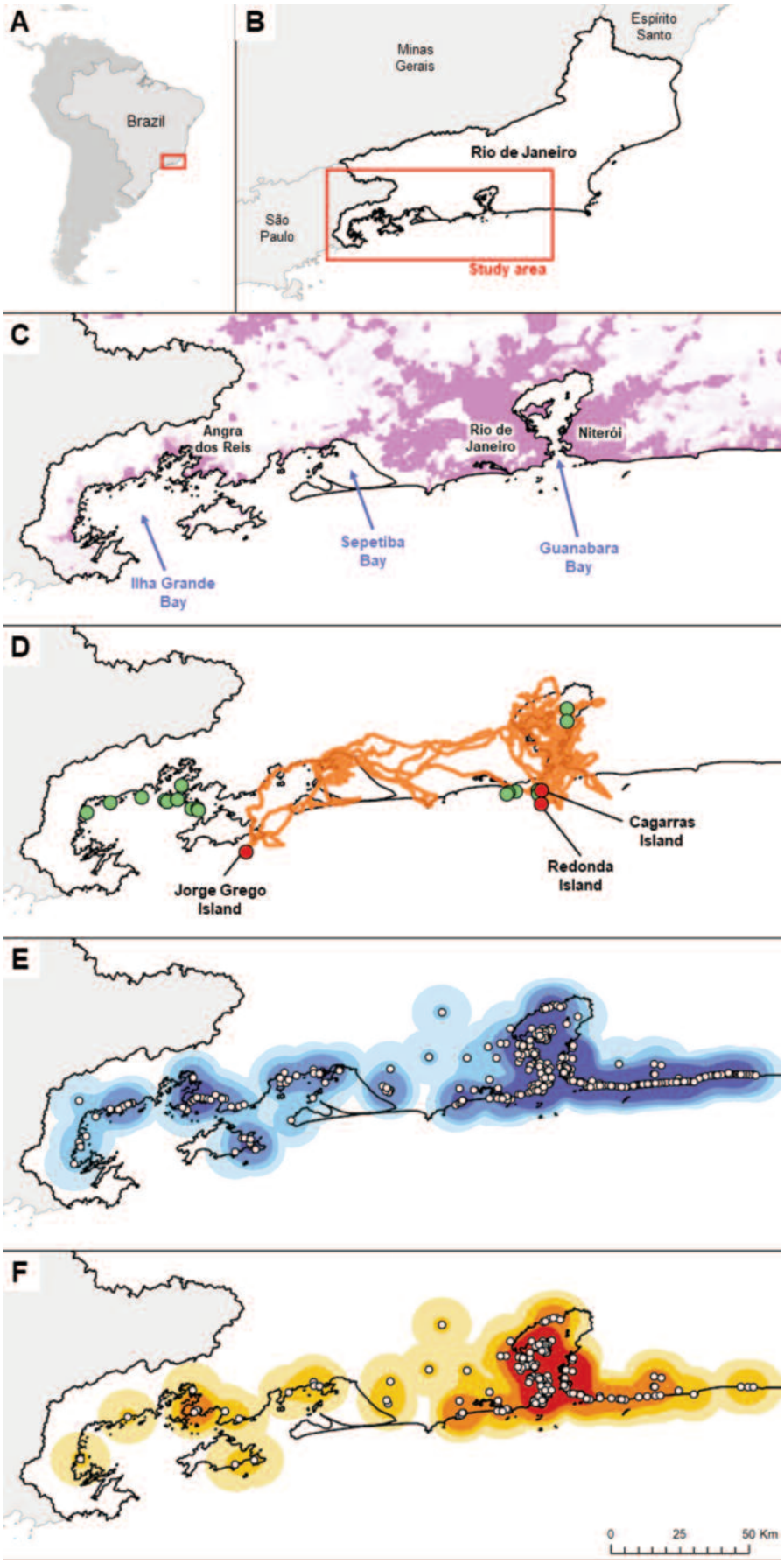
Figure 2



Geographic distribution of kite-string injuries in magnificent frigatebirds (*Fregata magnificens*) showing (A, B) location of the study area relative to South America and Rio de Janeiro state, (C) human population density (pink shades; derived from Doxsey-Whitfield *et al* [2015]), (D) roosting sites (green dots) and breeding sites (red dots) of magnificent frigatebirds (derived from Alves *et al* [2004]) and movements of an adult female from Redonda Island during September 2018 (orange dots), (E) density of all magnificent frigatebirds recorded (injured and not injured) and (F) density of magnificent frigatebirds with kite-string injuries.

Table 1 Summary of the number of magnificent frigatebirds (*Fregata magnificens*) recorded along the southern coast of Rio de Janeiro state (October 2016–August 2020).

Injury	Juvenile	Adult female	Adult male	Unknown age/sex	Total
Confirmed kite-string injury	1 (1: 0)	10 (9: 1)	2 (2: 0)	0	**13 (12: 1)**
Suspected kite-string injury	47 (43: 4)	92 (88: 4)	92 (90: 2)	233 (2: 231)	**231 (221: 10)**
Other injury	33 (24: 9)	38 (33: 5)	40 (37: 3)	5 (2: 3)	**116 (97: 19)**
No trauma	26 (22: 4)	34 (33: 1)	39 (34: 5)	3 (2: 1)	**106 (90: 12)**
Undetermined (advanced decomposition)	25 (0: 25)	20 (0: 20)	18 (0: 18)	64 (30: 34)	**127 (0: 127)**
Total	**132 (90: 42)**	**194 (163: 31)**	**191 (163: 28)**	**72 (34: 38)**	**589 (420: 169)**

Results presented as 'all individuals (live individuals: dead individuals).'

Table 2 Summary of the rehabilitation outcomes of magnificent frigatebirds (*Fregata magnificens*) rescued alive along the southern coast of Rio de Janeiro state (October 2016–August 2020).

Injury	Spontaneous death	Euthanasia	Release	Total
Kite-string injury (confirmed or suspected)	80 (36%)	140 (62%)	5 (2%)	**225**
Other injury	43 (49%)	30 (34%)	14 (16%)	**87**
No trauma	40 (42%)	10 (11%)	45 (47%)	**95**
Total	**163 (40%)**	**180 (44%)**	**64 (16%)**	**407**

Results are presented as 'number of individuals (percentage).'

veterinary care, and the rehabilitation outcome (release, euthanasia, or spontaneous death) was recorded.

School and commerce in Rio de Janeiro were suspended on 16 and 24 March 2020, respectively; commerce re-opened on 27 June 2020, and school activities were still suspended as of 23 August 2020. Google Trends (https://trends.google.com/) was used to obtain a weekly index of internet searches by users in Rio de Janeiro state from 3 October 2016 to 23 August 2020 by averaging the results for three search terms: 'pipa' (Portuguese for 'kite'), 'cerol', and 'linha chilena.' Human population density at the locations where frigatebirds were found was derived from Global Population of the World v4 (Doxsey-Whitfield *et al* 2015). The geodesic kernel density of frigatebirds recorded by the beach-monitoring programme during the study period was obtained using the Kernel Density tool as implemented in ArcGIS 10 (ESRI, Redlands, USA), with a cell size of 0.001 km^2 and a search radius of 10,000 km. Data from an ongoing satellite tracking study are represented in this study for comparative purposes. The tracked individual was an adult female captured in August 2018 at Redonda Island, which was fitted with a Harier-4 GPS-UHF tracker weighing 12–14 g (Ecotone Telemetry, Gdynia, Poland) using the backpack harness with Teflon tape; the data represented in this study were obtained from 1 to 30 September 2018.

Data normality was evaluated with the Kolmogorov-Smirnov test. Chi-squared tests were used to test whether the categories of trauma were evenly distributed among the individual variables (context, status, developmental stage, and sex). The Kruskal-Wallis test with Bonferroni-corrected Mann-Whitney pair-wise tests were used to compare human population density among categories of trauma. Linear regression analysis was used to evaluate the relationship between the weekly number of frigatebirds with kite-string injuries and the index of kite-related internet searches.

Results

Five hundred and eighty-nine magnificent frigatebirds were recorded during the study period (Table 1). Due to the advanced decomposition of some carcases, only 462 individuals were evaluated for trauma, of which 244 (52.8%) had wing lesions consistent with kite-string injury (Figure 1). It is worth noting that 14 cases classified as 'Other injury' were the result of interaction with fishing gear (fishing lines or hooks). Records of frigatebirds were widely distributed throughout the study area, but individuals with kite-string injuries were predominantly concentrated along the densely populated margins of Guanabara Bay (Figure 2). Frigatebirds with kite-string injuries were found at locations with significantly higher human population density (median = 953 inhabitants km^{-2}, n = 244) than frigatebirds with other injuries (296 inhabitants km^{-2}, n = 116) or without trauma (226 inhabitants km^{-2}, n = 102; $H = 12.96$, df = 2; $P = 0.002$).

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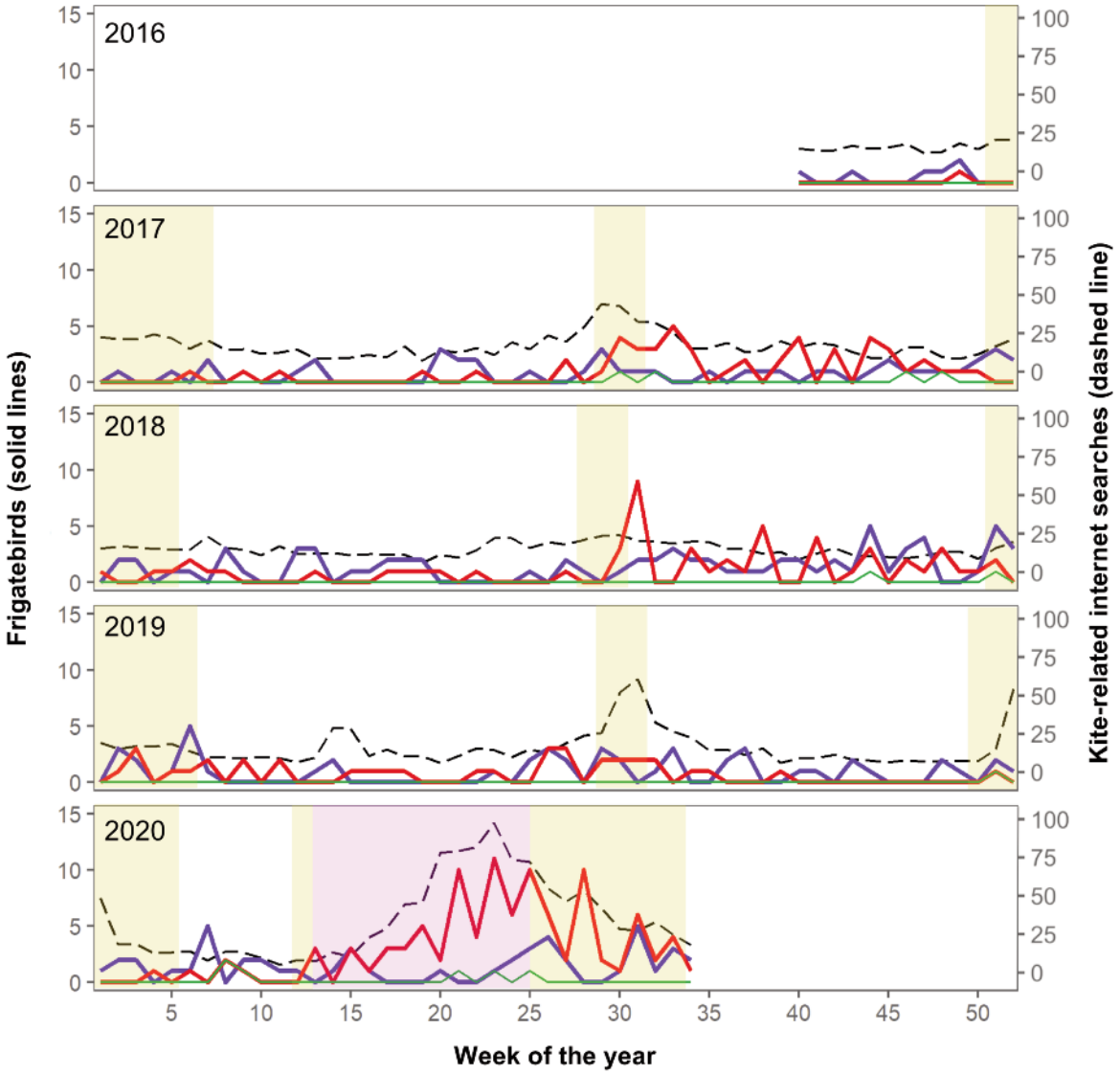
Figure 3



Time series of the number of magnificent frigatebirds (*Fregata magnificens*) with kite-string injuries (red line; suspected and confirmed cases combined; green line: only confirmed cases) and without kite-string injuries (blue line) relative to the index of kite-related internet searches (dashed black line), periods of school holidays or suspension (yellow shaded areas) and commerce closure due to the COVID-19 pandemic (pink shaded area) in Rio de Janeiro state, Brazil.

The occurrence of trauma was not unevenly distributed relative to the age group (n = 458, χ^2 = 4.329, df = 2; P = 0.115), sex (n = 427, χ^2 = 0.048, df = 2; P = 0.976), and context (n = 462, χ^2 = 5.064, df = 2; P = 0.079). Kite-string injuries were more frequent in live (55%) than in dead individuals (26%) (n = 462, χ^2 = 14.539, df = 2; P < 0.001). The rehabilitation outcome of live frigatebirds was markedly different depending on whether they had lesions consistent with kite-string injury (n = 407, χ^2 = 102.745, df = 4; P < 0.001), with individuals with kite-string injuries experiencing similar levels of spontaneous death but being euthanased more frequently and released less frequently (Table 2).

From 2017–2019, the number of frigatebirds with kite-string injuries showed a tendency to increase around weeks 30–35 of each year, during or shortly after school winter holidays. In 2020, an atypical increase both in kite-related internet searches and in frigatebirds with kite-string injuries was noted between weeks 13–25 (29 March to 27 June), when commerce was suspended due to the COVID-19 pandemic (Figure 3). Sixty-one frigatebirds with kite-string injuries were recorded during this period, representing a 1,207% increase compared to the same period in 2017–2019 (mean = 4.7 individuals, range: 2–6). There was a significant positive correlation between the weekly number of frigatebirds with kite-string injuries and the index of kite-related internet searches (R^2 = 0.362; P < 0.001, n = 203 weeks).

Discussion

Frigatebirds are gliding seabirds that have the lowest body mass to wingspan ratio of all birds, allowing them to soar at high altitudes efficiently on weak ocean thermals (Weimerskirch *et al* 2003). Despite feeding primarily on marine prey, frigatebirds do not dive nor float on water; instead, they capture prey while gliding near the sea surface or harass other seabirds to force them to regurgitate and then steal their meal (Schreiber & Burger 2001). As such, these birds are reliant on the integrity of their wings in order to get their food. When frigatebirds injure their wings they may fall into the sea and drown; if they survive the fall, they may later starve due to an inability to fly. Additionally, the particularly fragile anatomy of their wings (narrow propatagial membrane, thin skin and hollow bones) render frigatebirds exceptionally susceptible to kite-string injuries.

Compared to other bird species (Roy & Shastri 2013; Babu *et al* 2015), injuries in this study were characterised by deep lacerations and muscle avulsion, with extensive damage to tendons, bones, nerves and blood vessels. Kite-string injuries that require tenorrhaphy (suturing of tendons) will often require a long period of post-surgical immobilisation and physical therapy, since tendons are poorly vascularised and heal slowly. In our experience, even when veterinary care is provided, only a small proportion of the individuals will recover the ability to fly (in this study, only 2% of the frigatebirds admitted with kite-string injuries could be released). Due to the unfeasibility of providing a sufficiently large permanent enclosure that would allow a frigatebird to take flight, individuals that are not fit for release after rehabilitation are euthanased.

Kite-injured frigatebirds were most frequently recorded in areas of high human population density, especially along the margins of Guanabara Bay. The frigatebird population from Cagarra and Redonda Islands are known to forage in large numbers at Guanabara and Sepetiba Bays, often flying over the city of Rio de Janeiro to cross from Guanabara Bay to Sepetiba Bay and *vice versa* (Figure 2[D]; L Cunha, personal observation 2020). Our results suggest that kites with abrasive threads might become a key cause of mortality for this population. As our data are derived from a Beach-Monitoring Project, with a monitoring effort that emphasises coastal environments, it is likely that the geographic distribution observed in this study underrepresents the occurrence of injured frigatebirds due to lower monitoring effort at inland environments (eg individuals that suffered severe injuries while flying over Rio de Janeiro city and which immediately fell in urban areas) and at coastal islands (eg individuals that suffered relatively mild injuries and were able to fly to seek refuge at their usual roosting/breeding sites). Moreover, because a proportion of frigatebirds injured by kite strings could have drowned and never washed ashore, this study may have underestimated the total number or the geographical distribution of kite-string injured individuals.

Kite flying is a popular sport during the winter holidays in Rio de Janeiro state, whereas beach activities tend to be more popular during summer holidays (D Goldberg, personal observation 2020). This might explain why an increase in kite-injured frigatebirds is usually noted during and shortly after the school winter holidays. From February to June 2020, however, the number of kite-string injuries increased acutely (*circa* 1,200% compared to the same period in previous years). With the suspension of school activities on 16 March and the closure of commerce on 24 March due to the COVID-19 pandemic, many children and adults had plenty of free time to fly kites from their roof-tops, as this was one of the few leisure activities that was still safe during quarantine, especially in economically deprived communities. This was reflected in the number of internet searches using kite-related terms and, unfortunately, in the number of frigatebirds with kite-string injuries. The increase in the number of injured frigatebirds during the peak of the breeding season (May to August; Cunha 2018) at Redonda Island may represent an even more dramatic situation, as the injured adults will not return to the nest to protect or feed the chick, potentially resulting in increased chick mortality.

This study therefore illustrates how epidemic/pandemic events can have unforeseen consequences and aggravate pre-existing human-wildlife conflicts. This is not dissimilar to the impacts of wars and civil strife, which may amplify and create new direct and indirect impacts on wildlife through a multitude of mechanisms (Dudley *et al* 2002; Gaynor *et al* 2016). Since COVID-19 is the largest fast-spreading pandemic in the contemporary era, we still have limited understanding as to how such global events (and the measures employed to mitigate them) can lead to changes to institutional and socioeconomic factors that ultimately affect wildlife and nature conservation. Understanding these mechanisms at the regional level, taking into account wildlife communities, cultural and socioeconomic factors, will be critical in order to adequately prepare for and mitigate their impacts. Past experience has shown that strong and flexible partnerships between local communities, non-governmental organisations and international institutions are critical to mitigate the impacts of violent conflicts on wildlife (Dudley *et al* 2002; Gaynor *et al* 2016), and a similar approach might be necessary to deal with epidemic/pandemic events.

In the case of kite-string injuries in Brazil, in addition to a stricter enforcement of the prohibition of abrasive threads (especially for 'linha chilena', which cannot be easily home-made and is commercialised locally), other approaches beyond law enforcement are also clearly necessary. The development of a regional campaign that embraces kite flying as a positive leisure activity during quarantine, acknowledging its strong cultural roots in Brazilian culture and its role in promoting bonding between parents and their children, could be instrumental in raising awareness about the negative effects of abrasive threads to both humans and wildlife.

Since social isolation and quarantining can cause significant psychological stress (Reynolds *et al* 2008; Brooks *et al*

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2020), the preparedness plans for epidemic/pandemic events would also benefit from planning on providing the population with safe leisure options. In the Rio de Janeiro context, for example, the distribution of kites with non-abrasive strings and other toys (eg action figures, spinning tops, marble balls, etc), perhaps with themes related to frigatebirds and other native species and accompanied by educational booklets and brochures, could help mitigate the social anxiety in ways that are not harmful to wildlife.

Furthermore, while frigatebirds are not the only birds affected by kite-string injuries in Rio de Janeiro, the fact that they are easily recognisable in flight and have several interesting characteristics (eg colourful gular pouch in males, ability to soar with great efficiency) makes them good candidates to become a flagship species. Awareness campaigns could therefore benefit from highlighting the beauty and value of this species, appealing to the public's empathy by showing the suffering experienced by injured frigatebirds and sharing uplifting stories of individuals that were successfully rehabilitated.

The relatively strong correlation between internet searches for kite-related terms and the occurrence of kite-string injuries in frigatebirds suggests that the internet might also be a potential vehicle for educational and enforcement activities. Where possible, the publication of information on how to manufacture 'cerol' or promoting the use of 'linha chilena' should be discouraged (eg demonetised or banned), and websites and online communities promoting kite flying must actively discourage the use of abrasive threads. Additionally, social media campaigns promoting safe kite-flying practices during strategic periods (eg school winter holidays and during quarantine periods) could also help.

Although magnificent frigatebirds are not currently considered threatened with extinction, the relatively high frequency of kite-string injuries documented in this study (244 individuals from October 2016 to August 2020) may be considered a significant threat at the regional level (breeding population = *circa* 3,400 pairs; Moraes-Ornellas & Ornellas 2012; Cunha *et al* 2013). Furthermore, it is worth noting that other species of frigatebirds are critically threatened, such as the Christmas frigatebird (*Fregata andrewsi*), which has a total population of *circa* 4,800 pairs (Birdlife International 2018) and the Atlantic lesser frigatebird (*Fregata trinitatis*), which has an estimated population of *circa* 50 individuals (Olson 2017). Considering the anatomical and behavioural similarities between these species, it seems likely that they would also be highly vulnerable to kite-string injury.

Animal welfare implications

Although the kite-string injuries are usually relatively small and do not damage vital organs, they have a critical impact on the frigatebirds' ability to fly and will ultimately cause their death due to drowning or starvation. The sudden increase in the number of magnificent frigatebirds with kite-string injury in Rio de Janeiro during the period of commerce closure due to quarantining in response to the COVID-19 pandemic illustrates how epidemic events may aggravate existing human-wildlife conflicts. This highlights how pandemic events can have unexpected and far-reaching impacts on animal welfare, even when the pathogen does not infect animals. Pre-identifying human-wildlife conflicts will be valuable to inform preparedness plans for epidemic/pandemic events, so that these plans can incorporate measures to help communities cope with boredom and isolation during quarantine in ways that do not negatively impact the welfare and conservation of wildlife.

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