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Enhancing Carcass Removal Trials at Three Wind Energy Facilities in Portugal

J. Bernardino[1,*], R. Bispo[2], P. Torres[1], R. Rebelo[3], M. Mascarenhas[1] & H. Costa[1]

[1] Bio3 Estudos e Projectos em Biologia e Valorização de Recursos Naturais, Lda., Rua D. Francisco Xavier de Noronha, 37B 2800-092 Almada, Portugal.

[2] Grupo de Estatística e Matemática, Instituto Superior de Psicologia Aplicada, Rua Jardim do tabaco, 34, 1149-041 Lisboa, Portugal.

[3] Departamento de Biologia Animal, Faculdade de Ciências da Universidade de Lisboa, Avenida Nª Senhora do Cabo, Nº 939, 2750-374 Cascais, Portugal.

* Corresponding author: e-mail: joana.bernardino@bio3.pt; Phone: +351 212-951-588

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Abstract

During the last years there has been a significant worldwide increase in the number of wind farms. This kind of energy can have negative impacts, such as the direct mortality or lethal injury of birds and bats caused by collision with wind turbines. In order to evaluate bird (or bat) mortality regarding wind power generation facilities, strict monitoring protocols are required which must take into account the possibility of carcass removal by scavenging animals or decomposition before the monitoring session. For this purpose, carcass removal trials with 180 carcasses representing three size classes (small, medium and large) were conducted in two seasons (Spring and Autumn) at three wind farms located in the central region of Portugal. No significant differences were found between removal rates of different wind farms or size classes contrarily to seasons, which presented an average carcass removal time of 3.9 and 4.6 days, respectively for Spring and Autumn. The results of the present study showed the importance of trials to estimate the carcass removal rates, which influences the survey effort management and consequently the monitoring protocols. The experimental design for future trials in the same region should account for season effect and be conducted using daily checks of the carcasses for, at least, 15 days.

Introduction

Nowadays, wind is considered worldwide as one of the most promising energy sources found in nature. Despite the obvious benefits of wind turbines as a clean energy source, the construction of wind farms can be responsible of impacts on flying vertebrates, such as fatality through collision with rotating turbine rotor blades, habitat modification, barrier effect or disturbance in nesting areas [1-4]. These impacts, especially the birds and bats mortality, became a source of major concern among a number of stakeholder groups [5-10]. In fact, results obtained during several monitoring studies indicated that wind farms were responsible for the decrease in some species' populations [11-14] although many other studies revealed that these impacts were not important when compared to those originated by other infrastructures [15-17]. Nevertheless, the potential for wind farms to affect bird or bat populations should not be underestimated [11,18].

During the last two decades, the need to properly assess the impacts on flying vertebrates led to the development of methodologies for evaluating bird and bat fatalities in existing and planned wind facilities developments. Current post-construction monitoring protocols require that carcass estimates under turbines are adjusted taking into consideration the rate at which carcasses decompose or are removed by scavengers [2,19,20]. Therefore, most recent studies include carcass removal trials, although few follow the exact same protocols [21,22]. Furthermore, even fewer studies have been conducted with the specific aim of improving the protocol design for this kind of trials [23,24]. Thus, it is necessary to develop a single and robust methodology in order to validate any results or comparisons between wind farms, allowing at the same time a correct evaluation of the impacts regarding its construction [17].

Over the years protocols have tended to become more strict and demanding [19,20,25-27]. However, they often increase the monitoring costs, which is a problem due to the limited budgets of many monitoring studies. Hence, it is crucial to develop efficient methodologies that consider cost/benefit relationships [28], maximizing effort reduction without compromising the quality of the results. To achieve this goal, it is necessary to clarify the influence of effort reduction in monitoring and consequently in a correct assessment of the results.

The aim of this study was to evaluate the importance of conducting carcass removal trials in order to achieve a correct evaluation of bird mortality regarding wind power generation facilities, and to optimize the survey effort employed in monitoring protocols. It was conducted with data collected during monitoring studies of bird mortality at three Portuguese wind farms.

Methods

Study area

The studied wind farms are located at the central region of Portugal (Fig. 1), each comprising a series of mountain ridges.

Caramulo wind farm is situated at Serra do Caramulo (maximum altitude of 1076.57 m a.s.l.) and comprises 45 wind turbines subdivided along five smaller units, each turbine with a power of 2.0 MW. The vegetation consists mainly in shrubs and scattered trees (*Quercus robur* and *Quercus pyrenaica*) on the mountain ridges, and cereal fields in some areas. Average annual temperature and rainfall vary between 10-12.5ºC and 2000-2400 mm, respectively. This facility is supported by Generg Ventos do Caramulo, Lda. (Portuguese Promoter GENERG Group).

Pinhal Interior wind farm also comprises several smaller units along Serra de Alvelos (1084 m), Cabeço da Rainha (1080 m), Moradal (885 m) and Perdigão (566 m), consisting in 58 wind turbines, each with a power of 2 MW, with the exception of Alvelos, which

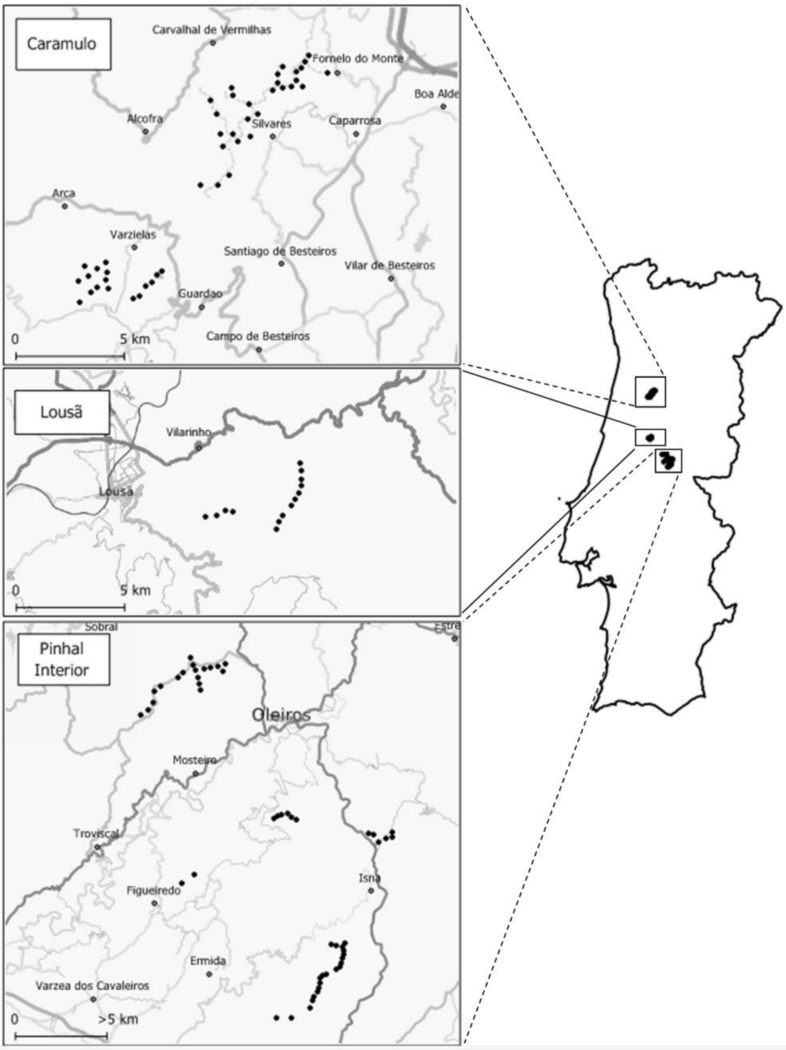

Fig. 1. Location of each wind farm in Portugal. Black dots represent single wind turbines.

presents each turbine with a power of 3 MW. In the last decades the autochthonous vegetation has been replaced by pine (*Pinus pinaster*) and eucalyptus (*Eucalyptus globulus*) trees, however due to forest fires most of the area is now occupied by low-growing shrubs of the genus Erica and related genera. Average annual temperature ranges from 7.5 to16ºC and rainfall from 800 to1600 mm. This wind farm is supported by GENERVENTOS do Pinhal Interior – (company also included in Generg Group).

Lousã wind farm, located at Serra da Lousã (maximum altitude 1205 m a.s.l.), comprises 14 wind turbines, each with a power of 2.5 MW. The vegetation consists in low shrubs (*Erica* sp. or *Calluna vulgaris*), herbaceous vegetation, oak forests and plantations of coniferous and mixed woods [29]. In this area, average annual temperature ranges 9-22ºC and rainfall 1000-1800 mm. Parque Eólico do Trevim, Lda (Iberwind Group) manages this facility.

Field methods and analytical approach

The carcass removal trials were conducted in two seasons (Spring - May/June; Autumn – September/October) since, according to the monitoring protocol design for all three wind farms, carcass searches are restricted to these periods [30-32]. Specifically, Spring trials were performed from the 7th until 27th of May, 14th of May until 8th of June and from 6th until 30th of June for Lousã, Pinhal Interior and Caramulo wind farms, respectively. During the second season (Autumn), the trials were conducted between day 3 and 23 of October, in all sites.

Complete and fresh carcasses of parakeets (*Melopsittacus undulates*), quails (*Coturnix coturnix*) and partridges (*Alectoris rufa*) were used to represent birds of three size classes (small – ≤15 cm and ≤50g, medium – 15-25 cm and 50-200g; large – ≥25 cm and ≥200g) and more accurately reflect realistic removal rates [33]. Carcasses were obtained in avian breeding facilities. Handling was always performed with lab gloves to prevent human odour contamination.

In each farm, 10 carcasses of each size class were placed per season, comprising a total of 180 corpses. The carcasses were placed near the turbines or associated infrastructures (range 8- 42 m distance), randomly, independently of the size class, and at a minimum distance of 500 m from each other. After its placing, all carcasses were checked daily, every morning, until their removal for a maximum period of 20 days.

Statistical approach

Carcass removal trials involve measuring the time until carcass removal. The obtained data were examined using Survival Analysis [34]. Standard statistical approaches were discarded based on the positively skewed removal time distribution [35] and on the presence of censored observations (carcasses with removal times beyond 20 days).

The survivor function, that in this context describes the probability of a carcass being removed beyond a time *t* (or persist until *t*), was estimated using the Kaplan-Meier estimator. The Log-Rank test was used to test the existence of significant differences between survival curves of different farms, seasons and size classes [36].

Also, according to the variety of survey effort methodologies used in the last decade in monitoring studies, some reduction effort scenarios were selected to evaluate its influence in the results obtained, by comparing it to the used field effort methodology (daily checks through 20 days). The resulting survivor distributions were compared using the Wilcoxon test. Four inspection scenarios were tested against the used methodology, in all wind farms:

- Daily checks for 14 days [37];
- Daily checks for 7 days [38];
- Checks every other day for 20 days;
- Daily checks in the first 4 days and then in the 7th, 10th, 14th and 20th days [39].

Statistical analysis was performed using *R* software [40]. Data were analysed under a 0.05 level of significance.

Results

The majority (>80%) of the 180 carcasses used was removed in the first week after its placement (Fig. 2). After the 15th day, none of the carcasses were removed until the end of the sampling period, disappearing eventually by decomposition (n=13).

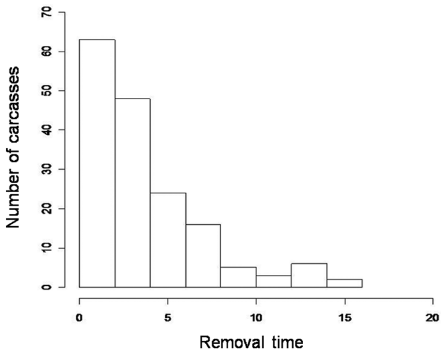

Fig. 2. Histogram of the removal times of non censored carcasses.

The Log-Rank test (Fig. 3) showed no significant differences for the carcass removal times between farms (χ^2= 4.5; d.f. = 2; p = 0.107) or size classes (χ^2= 1.9; d.f. = 2; p = 0.384). However, removal times differed significantly between seasons (χ^2= 5.3;

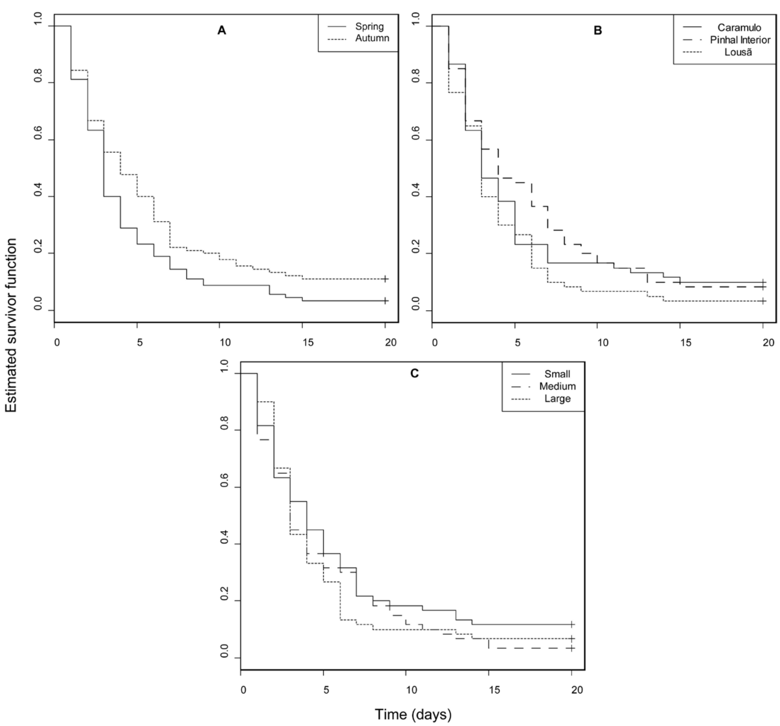

Fig. 3. Survival functions determined with the Kaplan-Meier estimator. A - between seasons; B - between wind farms; C - between carcass sizes.

d.f. = 1; p = 0.021). The data analysis showed that in Spring the carcasses were removed faster, with almost 80% disappearing in the first 5 days (Fig. 4). In Autumn, within the same period, only 60% of carcasses were removed, reflecting a lower carcass removing probability throughout the sampling period (20 days). Mean carcass removal time (standard deviation in brackets) in the wind farms was 3.9 (0.34) and 4.4 (0.37), respectively in Spring and Autumn.

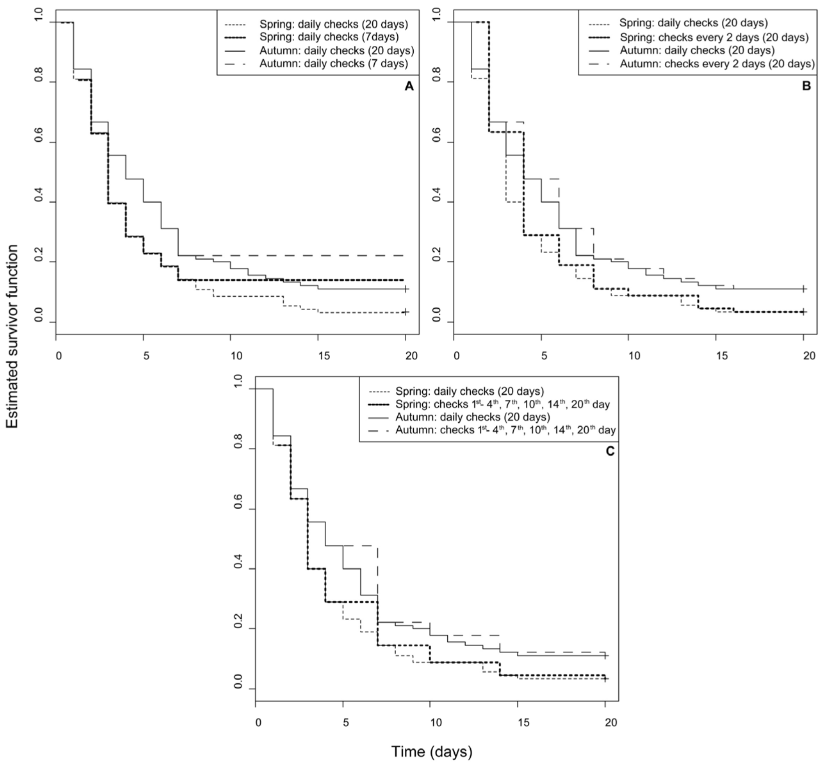

Fig. 4. Survival functions determined with the Kaplan-Meier estimator according to the survey effort performed. A - comparison between daily checks for 20 and 7 days, for both seasons; B - comparison between daily checks and every 2 days, for a period of 20 days, for both seasons; C - comparison between daily checks and checks every day until the 4th day and then only in the 7th, 10th, 14th and 20th days, for a period of 20 days, for both seasons.

Considering the survey effort comparisons, once no carcasses were removed after the 15th day, there were no changes in the survivor curves of any wind farm when the trial length was reduced from 20 to 14 days. However, when the survey effort was reduced to 7 days (Fig. 4A) the resulting survivor curves differ significantly for both seasons (p=0.0346 and p=0.0143, for Spring and Autumn, respectively). Also, when the survey effort reduced to one check every other day (Fig. 4B) the curves differed significantly for both seasons (p=0.022 and p=0.014, for Spring and Autumn respectively). Considering the last scenario, the survey effort consisted in daily checks in the first 4 days followed by surveys conducted only on the 7th, 10th, 14th and 20th days (Fig. 4C), again the survivor curves differed significantly for both seasons (p=0.005 and p=0.002, for Spring and Autumn respectively).

Discussion

In our study we did not found a significant effect of bird size on carcass removal times. This may be related with specific biophysical characteristics of the mountain ridges, since the same result has been observed in other regions of Portugal [41]. In contrast, studies performed for instance in the north of Portugal, with exactly the same species, detected significant differences in removal rates between class sizes [42]. Nevertheless, in this study significant differences were detected between seasons, with the corpses disappearing faster in spring/early summer than in autumn. This result is similar to those described in several other studies performed at Portuguese wind farms [43-45] possibly due to different scavengers activity between seasons [22].

Although the differences between seasons seem relatively small and some times negligible, they must be taken into account, since it can produce significant bias in the mortality estimates (Table 1). To exemplify the importance of even slightly different removal rates, let's consider that the mortality rate (number of corpses per period of time) can be simply estimated by:

$$\mathrm{M} = \sum_{i=1}^{n} C_i / (p \times r_i)$$

where C_i, is the total number of carcass found at the *i*-th search; r_i the removal correction factor (proportion of carcasses that persist unscavenged at the *i*-th search); and p the detection rate (in this case, we assume 0.25)[46]. Considering that, during one of the Spring searches, the carcass of 1 bird, which died 5 days before, is found, the removal correction factor is 0.23, which would result in a mortality estimate of, approximately, 17 birds (*i.e.* M= 1/(0.25×0.23)), for that period of time. However, if the same situation occurred during Autumn, the mortality estimate would be considerably lower, 10 birds (*i.e.* M=1/(0.25×0.40)). Naturally, the estimates differ even more as the number of observed mortality and the time between the bird´s death and the i-th search increases (*e.g.* C=5, found 7 days after death; M=143 and M=91, respectively, during Spring and Autumn).

Table 1. Mortality estimate (estimated by estimator presented in [46]), considering different removal rates (r) and a detection rate (p) of 0.25. C- Number of carcass found at the *i*-th search.

Days since death	Spring				Autunm			
	Removal rate (r)	Mortality estimate (M)			Removal rate (r)	Mortality estimate (M)		
		C=1	C=2	C=5		C=1	C=2	C=5
1	0.81	4.9	9.9	24.7	0.84	4.8	9.5	23.8
2	0.63	6.3	12.7	31.7	0.67	6.0	11.9	29.9
3	0.40	10.0	20.0	50.0	0.56	7.1	14.3	35.7
4	0.29	13.8	27.6	69.0	0.48	8.3	16.7	41.7
5	0.23	17.4	34.8	87.0	0.40	10.0	20.0	50.0
6	0.19	21.1	42.1	105.3	0.31	12.9	25.8	64.5
7	0.14	28.6	57.1	142.9	0.22	18.2	36.4	90.9

Despite the differences between seasons, the high rate at which the carcasses were removed in the three wind farms was similar to that reported for other studies developed at North America and Europe, in similar mountain ridges [9,47-51], with more than 80%

of the carcasses removed until the end of the first week. Strickland *et al.* [52] reported the mean carcass removal time between six and seven days for birds and about 10 days for bats at Buffalo Ridge, Minnesota. Also at this site, Higgins, Dieter, and Usgaard [9] reported scavenging of 12 from 15 carcasses (80%) after one week (two trials). At Vansycle wind farm located primarily in wheat fields, small carcasses lasted on average 15 days [39]. At the Buffalo Ridge Wind farm, small carcasses persisted on average 4.7 days, whereas small birds at Foote Creek Rim persisted 12.2 days [48]. Also, Wobeser & Wobeser [53] reported that nearly 80% (79.2) of the chicks placed in a mixed grazed pasture were removed within 24 hours. In France, Pain [54] estimated duck carcasses lasted an average of 1.5 days in open vegetations, whereas those concealed by vegetation or those in water lasted 3.3–7.6 days. At Tehachapi Pass (EUA) small and large carcasses endured an average of 3.1 and 2.12 days, respectively [48].

This high decrease of animal corpses in the first days clearly influences the survey effort management and monitoring protocols, mainly regarding the estimation of removal/decomposition rates and consequently the mortality evaluation in wind farms. No significant differences were found in the survivor curves when the trial length was reduced from 20 to 14 days, which is explained by the absence of carcass removal in this last five days. In the scenarios where the survey effort was considerably reduced, the resulting survivor curves changed significantly. For example, during Autumn with daily checks, the carcass persistence probability at the end of 6 days was 30%, while in the last scenario tested (daily checks in the first 4 days and then in the 7th, 10th, 14th and 20th days) this probability increased to 50%, underestimating the wind farm mortality rate. Therefore, in similar mountain ridges it seems advisable to check carcasses daily, for a minimum period of time of 15 days.

Although these results cannot be directly extrapolated to others regions, considering that the majority of studies also presented removal rates specially high during the first days of the trails, is legitimate to assume similar results in other wind farms, which highlights the importance of developing strict monitoring protocols, mainly regarding survey effort. According to Table 2, within 30 monitoring studies performed in the last decade with removal trials, 43.3% carried out daily checks for a minimum of 14 days. Still, the majority of these studies presented monitoring protocols less strict, justified by financial and logistical limitations that must be contested facing these results.

In the three wind farms studied, and since the inspection periods were restricted, the removal trials had to be performed just in two seasons (Spring and Autumn). Thus, further research should be conducted at several other wind farms located in the same region, especially during winter and summer, in order to determine if the differences between the removal times remain. In fact, recent guidelines recommend that removal trials should be performed at least four times a year [20]. As explained above, small differences regarding the removal rates can significantly bias the mortality estimates. So, if no previous studies have been conducted in the vicinity of a new wind farm, we propose that the removal trials should be performed throughout a year (to include seasonal effects), with daily checks. Once these rigorous trails have been conducted (considering different seasons, carcass sizes, etc.) and similar conclusions have been achieved for the region, the team responsible for developing the monitoring program of a new wind farm should be able to evaluate if new removal trails are really needed or if they can be redesign. Nevertheless, it is clear that further studies are required to optimize the trials design and achieve the best cost/benefit relation.

Table 2. Monitoring studies performed in the last decade with removal trials.

References	Monitoring protocol
[46]	Daily checks for 15 days and then weekly
[55]	Daily checks for 15 days
[56]	Daily checks for 20 days
[57]	Daily checks for 20 days
[58]	Daily checks for 14 days
[37]	Daily checks for 8 days and then every other day
[33]	Daily checks for 21 days
[59]	Daily checks for 4 days, the 7th, 14th, 21th, 28th days
[52]	Daily checks for 14 days
[39]	Daily checks for 4 days, the 7th, 10th, 14th, 20th, 28th days
[60]	Daily checks for 4 days, the 30th and 60th days
[61]	Daily checks for 14 days
[62]	Checks in the 7th, 15th, 25th and 31th days
[63]	Checks for 21 days with gaps of 4/5 days
[64]	Daily checks for 4 days, the 7th, 10th, 14th, 18th, 23th, 28th days
[65]	Daily checks for 14 days
[38]	Daily checks for 8 days
[66]	Checks in the 2th, 7th, 10th, 15th and 30th days
[67]	Daily checks for 14 days
[68]	Daily checks until removal of all carcasses
[40,50]	Daily checks for 30 days
[69]	Daily checks until removal of all carcasses
[70]	Daily checks for 15 days then each 3 days
[71]	Checks in the 1th, 7th, 15th and 30th days
[72]	Checks in the 1th and 7th days
[45]	Daily checks for 15 days
[73]	Daily checks for 8 days
[51]	Daily checks for 10 days

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