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Identification of Novel Can Manipulation Behaviour in the Common Raven (*Corvus corax*)

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Simple Summary: Corvid behaviour is an area of interest for behavioural ecologists and conservationists alike. This explanatory study reports a novel behaviour, aluminium can perforation, presented by the common raven (*Corvus corax*) captured using camera trap technology and behavioural scoring. This study considers the ontogeny and motivation for this behaviour to begin to elucidate its purpose. The results suggest that camera trap technology is useful for capturing behaviour that may not be recorded via human observation, which, in this study, was predominantly can manipulation. However, human observation captured a significantly greater number of maintenance behaviours compared to camera trap collection methods. Can manipulation observations were clustered in human-inhabited areas, potentially due to the abundance of cans in these areas, with the suggested motivations for this behaviour including the olfactory properties of the cans and the performance of can manipulation to extract prey from the cans. This research contributes to our knowledge of corvid behavioural repertoires and paves the way for further research into corvid behaviour on the island of Lanzarote.

Abstract: This study examines the common raven (*Corvus corax*) population on Lanzarote, Spain, at a previously unstudied site. The study aimed to compare the use of camera trap technology and human observation in capturing a wide repertoire of raven behaviour and pay close attention to the perforation of aluminium cans, a behaviour that has not been described in the scientific literature previously but has been reported anecdotally through human observation. Five cameras were sited over a period of 6 months, with three aluminium cans placed at each location. One of the three cans was baited with meat and eggs, mimicking wild feeding substrate. Human observations took place over the same period of time in the same locations. Raven sightings were highly correlated in human-inhabited areas as well as agricultural areas, seemingly linked to food acquisition. Camera trap technology identified a greater number of can-orientated behaviours (interaction, manipulation, peeking inside, and pecking) compared to the human observation method. Conversely, human observation yielded a greater number of non-can-orientated behaviours (analysed as a group) when compared to that of camera trap observation. Overall, there was a significantly greater number of ravens observed via human observation when compared to that of camera trap observation. Initial evidence suggests that ravens only perforate cans they deem salient in terms of food acquisition, with beer cans being the most common focus of the behaviours observed, possibly linked to olfactory stimuli, the movement of the can or learned behaviour relating to reward acquisition. This study presents new data regarding object interaction in ravens, adding to the current body of knowledge.

Keywords: camera trapping; human observation; raven behaviour; aluminium cans; Lanzarote; Spanish Canary Islands; Desert Watch; can piercing

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1. Introduction

The common raven (*Corvus corax*) is a member of the corvid family, classified as a territorial species but also highly social. They have a long period of socio-cognitive development, and it is thought that their highly social nature and complex social relationships aid the development of social and individual learning, novel object exploration and attentional aspects [1].

The common raven has an extensive range and is native to most countries within the Northern hemisphere, owing to the species being a habitat generalist; it can be found across mountain ranges, open coasts, woodlands, steppe and arid areas but is also urbanised in some areas [2,3]. In places where there is a human presence, the species inhabit areas they would not have thrived in before, including desert areas where artificial water stations allow them to survive in the otherwise arid habitat [4]. As habitat generalists, ravens engage in high levels of foraging innovation to exploit novel food sources and invent new foraging techniques [5].

Studies exploring the cognitive abilities of corvids have focused on their social tasks, speed and flexibility and levels of skill sophistication [6]. Although there is a plethora of research on captive raven populations, wild raven data are sparse. Siverio et al. [7] observed breeding raven populations in the central-western islands of the Canarian archipelago (La Palma, Tenerife, Gran Canaria and La Gomera) where they found threats to the species including reduced food sources, poaching, habitat loss and injury related to power lines.

Camera traps (also referred to as trail cameras or wildlife cameras) are one of the technologies that is becoming increasingly available and popularised for surveying animals and populations in a range of different study designs to enhance existing observational strategies [8]. The first recorded study that used a camera trap for data collection was used to identify predator species visiting bird nest sites [9]. Santangeli et al. [10] compared camera trap evidence and a campaign to generate public involvement in the conservation project (citizen science) through citizen observations largely completed by tourists, park rangers and farmers, involving a count of 762 Lappet-faced vultures (*Torgos tracheliotos*) in Namibia, a methodology similar to the one used in the current study of ravens on Lanzarote, Spain. The results of this study identified that the camera trap data contributed far greater levels of information regarding sightings and resighting compared with citizen data, which only made up 0.01% of the data [10]. This method of comparing human observation to camera trap technology can be applied to the current study. The Santangeli study concluded that whilst most data can be captured using camera traps, factors such as vulture deaths could only be determined through human observation, highlighting the limitations of the technology with the potential for important data to remain uncaptured [10].

Will et al. [11] researched digital technologies and their applications in nature conservation, reporting that mass-produced high-tech sensors provide a cost-efficient and effective method to capture data on the natural world compared to conventional solely human-recorded data collection techniques that are more time-consuming. In addition to cost and efficiency considerations, human observer differences, including sensory perception differences [12], can affect the reliability of data collected solely in real-time human observation [13]. Technology, such as the use of camera traps, is designed to enhance the reliability of the data collected using human observation, allowing for the consideration of the reliability and repeatability of measures [12]. It has been recognised that camera traps are a non-invasive method of wildlife monitoring, causing minimal disturbance to wildlife; they can record for 24 h a day and can be left unattended for days, in some cases weeks, giving them the capacity to detect rare and elusive species and behaviours [14,15] and gather large quantities of data without the need for a human presence or additional resources [16].

However, as mentioned by Santangeli et al. [10], technology use can lead to missing data. Additionally, one's choice of equipment and study design can significantly impact its functionality and reliability as a methodology, as some equipment models are more technically difficult to utilise than others, potentially presenting issues such as insufficient data collection and a reduction in the ecological value of the study [16]. A study by Palencia et al. [17] found that there was insufficient evidence within the literature regarding the testing of camera trap performance, especially in the field, and by testing 45 individual camera traps from five commonly used brands, the study found that the trigger speed was significantly affected by the species under study and the distance between the animal and camera. This suggests that the type of camera should be taken into consideration during the interpretation of results, as animal interactions have the potential to be missed due to the slower trigger speeds of some models. A study carried out by Wearn et al. [18] concluded that when comparing camera trap technology to other methods, generally most studies support camera traps as a highly effective tool for surveying wildlife. Camera trap monitoring captures a larger range of species and behaviours compared to human observers that monitor the same areas [19] and has the potential to reduce observer bias, with camera traps allowing for the verification of behavioural scoring and ensuring the consistency of data recordings, provided that the technology is adequately installed [15]. Nevertheless, this technology has limitations. There have been times when animals have passed through but did not trigger the cameras; however, trackers found evidence of this the next day and recorded the data. In addition, there are reports of camera traps being stolen or destroyed, potentially by hunters who are suspicious of their use [19].

This study examines the behaviour of the common raven population in a little-known area, El Jable, Lanzarote, Spain [20]. Particularly, the observation of ravens piercing open aluminium cans, a behaviour that has not been described in the scientific literature previously but has been reported anecdotally, is explored. Here we report the use of camera trapping technology and human observation to record and analyse behaviour. We hypothesized that there would be a significant difference in raven behaviours identified through the use of camera traps versus human observation and that the ravens may have an identifiable preference for different types of cans within their interactions.

2. Materials and Methods

2.1. Study Area

Lanzarote is one of the Spanish Canary Islands, situated off the west coast of Africa. The island was declared a biosphere reserve by UNESCO in 1992 [21]. The global human population has undergone a significant increase in recent years [22] with the population density of Lanzarote rising to 187.7/km^2 in 2023 [23]. El Jable is the desert that runs through the centre of the island and has a diverse ecosystem with a range of animal species, including vulnerable bird species. This area fluctuates between arid and humid climate, and the sands in the region are used to grow cereals, yams and watermelons. Even though the island is a biosphere reserve, very little is known about its ecosystems and the wildlife within them [20].

This project partners with Desert Watch to collect data in Lanzarote and provide much needed information about the El Jable area. Desert Watch is a non-profit organisation that was set up to conduct research on and protect this area [20]. The use of citizen science, through civilian data collection, has previously enabled research that would not have otherwise taken place [24]. It is due to this method that the unique aluminium can behaviour in the raven population of Lanzarote was first observed anecdotally throughout 2020–2021, paving the way for this study.

The island of Lanzarote (Figure 1) is shaped by a desert-like climate with little rainfall. Trade winds pass over the area, causing it to be dry [25]. Though the island is sparse in vegetation, it is still a major site for bird populations and has proven to be a perfect destination for birdwatching due to its uniqueness [26].

Figure 1. (**A**)The island of Lanzarote pinpointed on a European scale; and (**B**) the area of El Jable shown circled within Lanzarote (Google Maps, 2024).

The study area this project focuses on is El Jable (Figure 2), as this is one of the areas where the common raven is found [27]. Through the volunteers at Desert Watch, ravens were observed opening aluminium cans to extract small animal species found sheltering inside. This can manipulation behaviour has, to our knowledge, not previously been described in the scientific literature on ravens.

Figure 2. The agricultural area of El Jable on the island of Lanzarote showing the landscape towards the coast (**a**,**b**) and the landscape inland (**c**,**d**).

2.2. Study Species

This study focusses solely on the common raven, a generalist bird species weighing ~800–1000 g, which was abundant in the Canaries for at least 2000 years with around 600 breeding pairs [28]. More recently, the increased use of pesticides, vehicle collisions and other human factors have led to an observed decrease in the raven population in this area with the IUCN Red List highlighting the negative effects of intensified farming, human disturbances and the removal of woodland on raven populations in this area [2,7].

2.3. Data Collection and Field Methods

2.3.1. Pilot Study

A pilot study was conducted within the UK in May 2021, prior to the project's commencement, to trial the planned methodology in full, including the use of camera traps and assessment of the feasibility of the planned human observations. The pilot study included the setting up of baited cans, testing of the recording equipment (including testing of the camera traps' field of view, recording capacity in hours, optimal camera resolution and camera placement) to ensure maximum amount of data could be collected. Furthermore, an ethogram of the ravens' behaviours and data recording sheets were used to trial the planned human observation method. Following this pilot study, additional behaviours were added to the ethogram when observed.

2.3.2. Field Methods

This exploratory study focused on verifying, quantifying and analysing the reported novel can interaction behaviour of the common raven in the El Jable region. Regular reports of opened cans, particularly tropical beer cans, were recorded during previous desert clear ups, leading to an interest in how these cans were being perforated and by what. As this was an initial study of this behaviour, it was important to understand the areas that the majority of the perforated cans were located in, as this indicated where the ravens predominantly spent their time and would form the basis for study point locations. Data were recorded during desert clear ups to count the frequency of ripped cans within each clear-up session.

Camera trap technology and human observations, in the same discrete locations, were compared during monitoring of raven behaviour over a 6-month period between August 2021 and February 2022. Five camera traps were set up at previously identified (via Desert Watch clear ups) areas throughout the desert. The equipment used included three different makes and models of camera traps: Campark digital trail camera (Campark, Hong Kong), Browning BTC-5HDPX (Browning Trail Cameras, Birmingham, AL, USA), and Victure H200 (Victure, Shenzhen, China). Three green, empty 0.33l aluminium beer cans were cleaned and placed at each camera site (Figure 3). One of the three cans was baited, initially with cashew nuts as this is a popular treat for captive ravens [29]; however, further preference testing identified that meat and eggs were more ethologically relevant to the ravens as this resembled their natural diet [30,31]. The cans were positioned in a line 2 m apart under either flora or with rocks acting as wedges to prevent them from rolling outside of the camera's field of view. The flora that is readily available in the location is aulaga (*Genista scorpius*), meaning that the camera traps could only be placed within these bushes. The cameras were placed at a distance of at least 6 m (range of 6–50 m) from the roads so that they were hidden from view of cars and to ensure that individuals were not identified in any footage. The locations chosen ensured that they were close enough to be accessible for maintenance with little disturbance to the wildlife. The camera traps were then set to take videos in sequences of 15 s. The batteries and SD cards were alternated every two to three days to prevent missing data. If a can was perforated, a new can was substituted for it in subsequent trials. An overview of the data collection process can be seen in Figure 3.

Figure 3. An overview of the data collection process.

In conjunction with the camera traps collecting data on how the ravens were opening the aluminium cans (Video S1a–d), human observations recorded data on the perforated cans (frequency and type of perforation) found in the areas of El Jable. Camera trap data were subsequently scored by one human observer to identify behaviours expressed in terms of their form and frequency. In addition, cans that were previously pierced by the ravens were collected, with time and date logged. An observational record of each can's condition, how it was opened and its GPS location was also detailed (Figure 4).

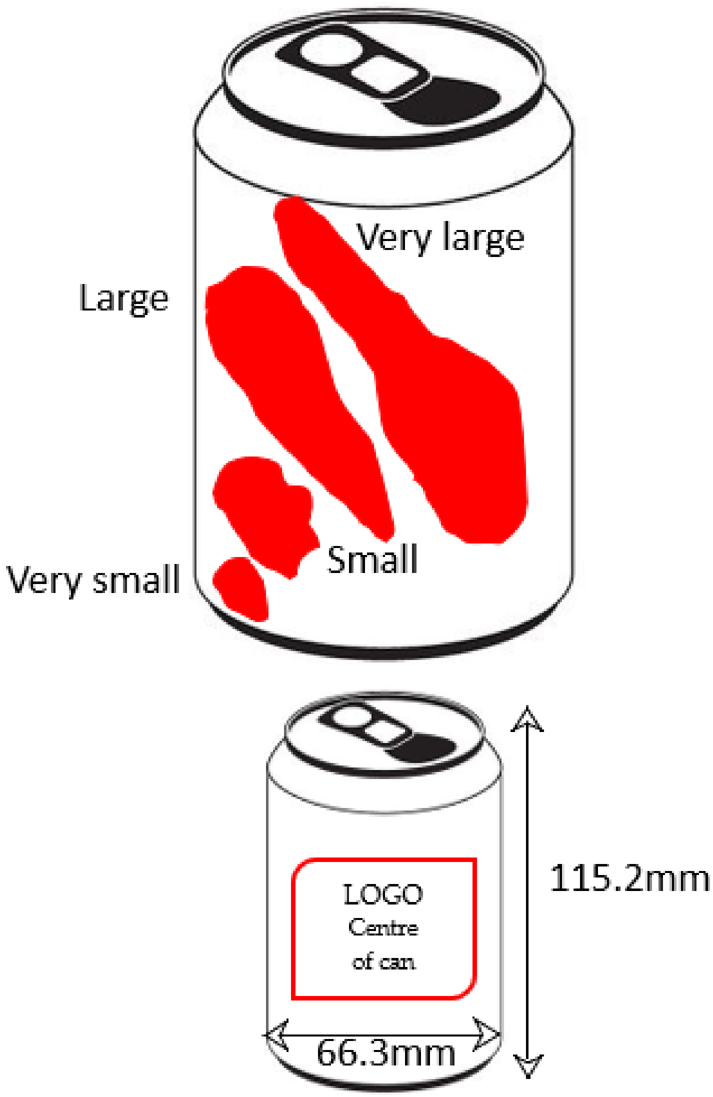

Figure 4. Diagrammatic representation of the categorisation of beer can perforation denoted by the red shapes increasing in size from those categorized as very small to those categorised as very large.

Human observational data are often limited and restricted to after sunrise and before sunset [32]. Due to this, the manual bird surveys were performed between the hours of 8 am and 1 pm and 4 and 8 pm (Daylight Saving Time depending—GMT). The timeframe between 1 and 4 pm was avoided to prevent the observer suffering from any form of heat exhaustion. Observers remained in their vehicle on road to ensure there was little to no wildlife disturbance and binoculars were used to observe animals from a minimum distance of 6 m (range of 6–50 m). The data collected included date, time, GPS location, number of individuals and the behaviour observed, paying close attention to any interaction with aluminium cans.

Human observations were conducted in one of two ways: through pre-planned observation of the camera traps at baited sites around 50 m away and using binoculars 30–60 min post baiting to identify raven interest and activity; or through an opportunistic sample, whereby when a raven was seen, an observation on that individual began. The vehicle was stopped, GPS data were recorded to show where the raven was seen and its first identified behaviour was noted. The GPS data were taken to identify clustering of raven observations. This opportunistic method unavoidably resulted in some ravens being seen at a close range of 6 m, as the observations occurred throughout the desert; however, the high cluster rate in agricultural areas was often recorded in locations closer to roads. The observation would continue with all behaviours recorded until the raven was out of sight. Both human observation and camera trap technology were used to identify behaviours at the baited can sites.

The behaviour of the ravens that was interesting, such as their interactions with the cans, as well as other previously reported maintenance behaviours [33,34], were included in the measurements taken using a specific ethogram descriptor list of behaviours which was developed a priori (Table S1). This led to further investigation into the can-directed behaviour of the ravens, which considered their selectivity in the choice of cans and extrapolated motivations for their selections. Using the five camera traps, data were opportunistically collected on the raven species present.

Both human observations and camera trap videos were analysed via an all-occurrence strategy, facilitating accurate frequency recording of all behavioural events observed via each recording method. Data recorded during both human and camera trap observations included site number (out of the five camera trap sites), latitude and longitude, date, start time, end time, temperature (°C), weather conditions, raven developmental stage (fledgling, juvenile or adult) and the behaviour observed.

2.4. Data Analysis

Behavioural data from both the camera trap footage and human observation were reviewed, cleaned and coded. Data for human observation did not follow normal distribution, and due to the relatively low sample size, non-parametric tests were utilised for these data. The data were analysed in R 4.1.3 (R Project) using multiple regression, Mann–Whitney and Chi-square tests [35,36]. Chi-square tests were used to compare frequency data of the categorical variables to identify differences in the frequency of performance of the range of raven behaviours compared across the human and camera observation groups, which had equal variance (Levene's test, F = 0.46, $p = 0.504$), and to identify differences in the types of behaviours seen within each observation group. Chi-square tests were also used to ascertain differences in the types of cans being perforated by ravens and the types of perforation seen. Mann–Whitney analysis was utilised when parametric assumptions were not met in order to compare continuous date-paired camera trap and human observation data at the same site to identify if there were differences between the data captured by human observation and camera trap technology. With the assumptions of the test met, multiple linear regression was used to identify whether the weather conditions (sun, cloud, still, windy), temperature or time of day (independent variables) had an effect on the types of raven behaviours (dependent variable) observed.

3. Results

3.1. Observation Locations and Recording

Raven observations were frequent between 29.0367° N, 13.5946° W and 29.0503° N, 13.6023° W, including agricultural areas (Figure S1), such as those shown in Figure 2. In total, there were 146 h of human observation over 28 observation sessions, and 229 h of camera trap data were recorded over 23 sessions. The proportion of the total raven behaviours identified was relatively equally spread between the human (51.1%) and camera trap (48.9%) observation methods; however, differences were identified in the types of behaviours recorded via each method (Figure 5). The weather, temperature and time of day had no significant effect on raven behaviour (multiple linear regression, F = 1.27, df = 8, $p = 0.268$).

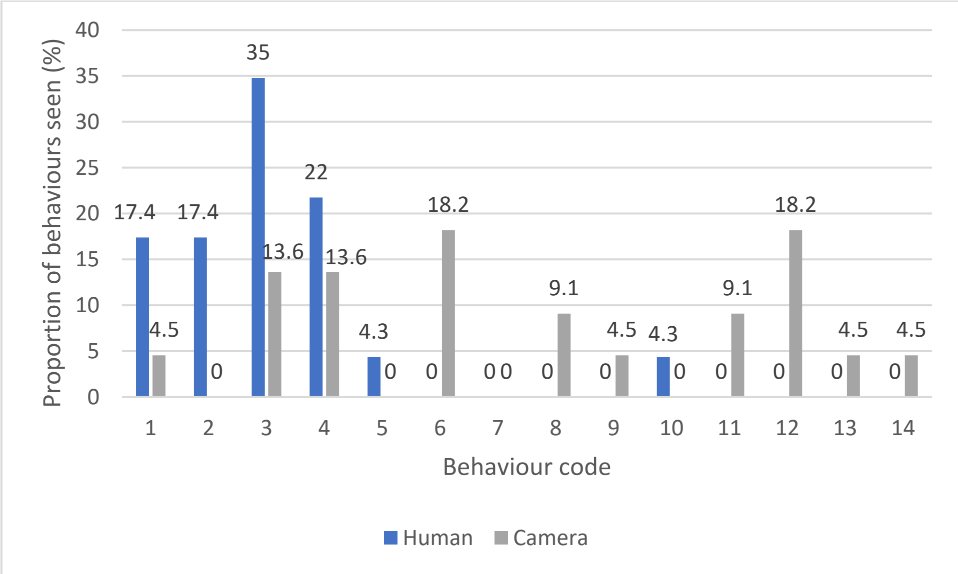

Figure 5. Proportion of behaviours identified by human and camera observation methods. Behaviour code: 1: Walking, 2: Flying overhead, 3: Landing, 4: Pecking ground, 5: Manipulation of an item, 6: Vigilance, 7: Vocalisation, 8: Perched, 9: Fly away, 10: Eating, 11: Can interaction: Walking, 12: Can interaction: Manipulation, 13: Can interaction: Peeking inside and 14: Can interaction: Pecking.

3.2. Camera Trap Observation

Ten discrete behaviours were identified in ravens over 23 observation sessions using camera trap technology (Figure 5); however, there was no statistically significant difference in the frequency of behaviours seen within this observation method, albeit this was approaching significance; (X^2 = 18.19, df = 10, p = 0.052). The modal behaviours presented were 'vigilance' (behaviour code 6) and 'can interaction: manipulation' (behaviour code 12).

3.3. Human Observation

Six discrete behaviours were identified over 28 human observations of ravens (Figure 4) with a statistically significant difference in the frequency of behaviours identified (X^2 = 12.63, df = 6, p = 0.049). The behaviour 'landing' (code 3) was the modal behaviour identified in the presence of humans, followed by 'pecking ground' (code 4), 'walking' (code 1) and 'flying overhead' (code 2). Ravens were not observed interacting with cans of any type during the human observations.

3.4. Comparing Camera Trap and Human Observational Data

There was no significant difference in the individual behaviour type frequency between the human and camera trap observations when paired by date and site of observation (Mann–Whitney, W = 187.00, p = 0.455, n = 28,). However, overall, there was a significantly greater number of ravens observed via human observation when compared to that with the camera traps (X^2 = 26.04, df = 1, p < 0.001). The camera traps identified significantly more can-orientated behaviours (interaction, manipulation, peeking inside and pecking) compared to the human observation method (X^2 = 5.44, df = 1, p = 0.020). Conversely, the human observations yielded a greater number of non-can-orientated behaviours (analysed as a group) when compared to that of the camera traps (X^2 = 33.84, df = 1, p < 0.001). Overall, non-can-orientated behaviours were seen significantly more often than can-orientated behaviours across both groups (X^2 = 30.48, df = 1, p < 0.001).

3.5. Can Piercing Behaviour Identified in Desert Clear Ups

Evidence of novel can-piercing behaviour by ravens was seen predominantly throughout the sand belt region of the island. Beer cans were significantly more likely to be found with perforations made by ravens compared to other types of cans (X^2 = 254.88, df = 4, $p < 0.001$). The cans were perforated in a number of ways by the ravens (see Figures 4, 6 and S2).

Figure 6. Example of a perforated can.

The majority of the cans collected had one large hole in the side of the can (code 6), while one small rip on one side (code 4) and one large rip in the centre (designated as the logo placement site, code 5) were also frequently seen (Figure 7) with significant differences in the frequency of the can rip type identified (X^2 = 75.66, df = 14, $p < 0.001$).

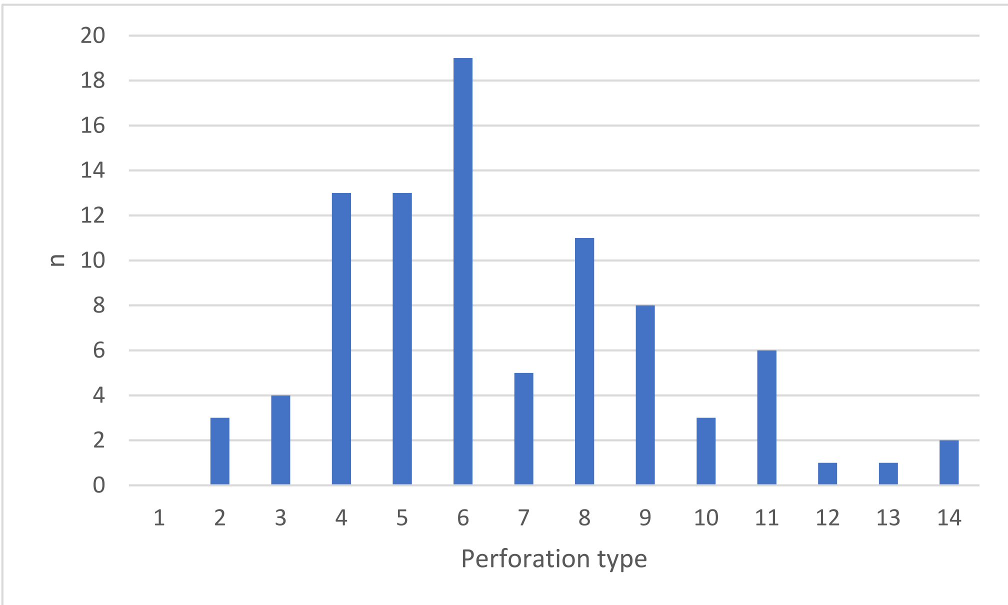

Figure 7. Frequency of perforation types seen in found cans. Perforation code: 1: very small hole in the centre, 2: very small on one side, 3: small hole in the centre, 4: small hole on one side, 5: large centre hole, 6: large hole on one side, 7: very large hole in the centre, 8: very large hole on one side, 9: one small and one large hole, 10: one small hole, 11: one large hole, 12: three small holes, 13: three large holes and 14: more than 3 holes.

The majority of ripped cans (71%) were found between the areas of 29.0381° N, 13.5963° W and 29.0417° N, 13.5998° W (Figure 8); these are the same areas as some of the raven sightings.

Figure 8. Location of the highest concentration of ripped cans (circled in red) found in the agricultural area of El Jable, Lanzarote (Google Maps, 2024).

4. Discussion

This study shows significant differences in the types of behaviours identified through the two different observation methods (camera traps versus human observation), which may be valuable for researchers planning methodologies to measure specific behaviours of common ravens. In addition, our study indicated novel can manipulation behaviours which were, to our knowledge, previously unreported in the corvid literature.

4.1. Camera Trapping Technology vs. Human Observation

The significantly greater number of observations of ravens interacting with cans using camera trap technology compared to that of a manual human survey was anticipated due to the relatively unobtrusive nature of the observation method [37]. Previous research suggests that camera trap technology captures a greater amount of data than human observation methods [38]; however, within this study, human observations generated more data than camera trap technology in terms of both the absolute number of behaviours recorded and the additional human-collected data as part of desert clean ups. This may have been due to the placement of the cameras and their relative fields of view compared with the human visual field. However, conversely, it is expected that the presence of humans would deter the ravens, leading to fewer observations; this may have been the case for some discrete behaviours, such as flying overhead and landing, which are observed at a distance and would not be recorded by a camera trap [39]. The results indicate that both methods of data collection are valid and useful depending on the metrics required, with camera trap technology unable to replace the wide field of view utilised in human observations but proving useful for recording specialised behaviours (such as can interactions) that may be interrupted by the presence of humans [40]. Human observations are generally useful for a wider understanding of a range of maintenance behaviours, especially at a distance [37,38].

4.2. Camera Traps Showing Raven Behaviour

Vigilance and can manipulation were the most frequently identified behaviours seen when utilising this data collection method in this cohort of ravens. Fernandez-Juricic et al. [41] found evidence that corvids can converge their eyes to look closely at an object, then use their beaks to manipulate the item by pecking or probing it. This explanation describes the behavioural repertoire observed during can manipulation. Bugnyar [42] indicated that behaviours demonstrated by ravens include sophisticated social interactions, such as staying vigilant for the safety of the group. The behaviour seen in this study is an indication that, although an individual was manipulating and looking into a can, it was also vigilant to its surroundings, as would be anticipated when in a potentially vulnerable ground-based position. By definition, tool use in animals is when an individual 'uses external objects as a functional extension of mouth or beak, hand or claw, in the attainment of an immediate goal' [43,44]. There is a multiplicity of evidence in terms of tool use in corvids, with prior research focusing specifically on tool use for foraging [45]. This ability provides the species with the potential to adapt to their current environment and situation. Within our study, we consider that the ravens were engaging in opportunistic object interactions rather than tool use per se, as no external objects were used for their manipulation of the cans. The motivation of the ravens in Lanzarote to spend energy to open the cans might be the content of the cans. In this case, the reward is meat and eggs (if the raven selects a can from our study) or insects and reptiles that migrate into non-study cans.

The camera footage reviewed did not provide further insight into external factors that may have caused vigilance in the ravens, though during one video, a group of ravens were startled and flew away from the research site. Due to the technology used, the videos taken were only of the field of view, leading to missing data that may have been explanatory in relation to external stimuli triggers for their behavioural responses [46].

4.3. Human Observations of Raven Behaviour

There were no human observational sightings of the ravens manipulating the cans during this study, a finding supported in a previous work by Caravaggi et al. [15], which showed that key behaviours, especially those for which an animal may be in a vulnerable position whilst undertaking them, may be unidentifiable without camera trap technology.

The behaviours of flying overhead, landing, walking and pecking the ground were seen the majority of the time when ravens were sighted during the human observations. These behaviours are often seen in sequence when ravens have detected an item or area of interest and may also be linked to the time of day (for example, avoiding higher temperatures) or escaping from potential threats, such as approaching and passing cars. Corvids have excellent memories and are likely to recall incidents of threats through one-trial learning, meaning that they may avoid cars if they have previously had a negative experience with one [47].

Within this study, different types of behaviour were identified via the two methods of observation with a greater number of maintenance-type behaviours identified through human observation and more novel behaviours identified through the camera trap technology, indicating that the use of one of these methods alone may lead to a failure to capture a full view of the behavioural repertoire being exhibited, as has also been described by Santangeli et al. [10].

4.4. GPS Location of Ravens

Within this study, raven populations were concentrated in more agricultural areas (Figure S1) in line with previous studies, whereby the density of corvid populations increases as the proportion of the agricultural land increases [48]. The number of ravens seen together were between two and twenty individuals, with the larger groups identified around agricultural land in the vicinity of an inactive vulture-feeding station.

In addition, this study was undertaken during the winter months, a time when farmers grow their crops in Lanzarote. Alhem et al. [49] conducted a study that resulted in findings that showed ravens reduce crop pest populations as they target the insects found on the growing flora. In contrast, when food is sparce for ravens, they do sometimes target crops themselves as sources of food [50], potentially explaining why the ravens grouped around the agricultural areas in El Jable. Lanzarote is a dry, arid landscape; however, during the winter season when rain is a more common occurrence, berries and leaves grow on bushes throughout the desert [4]. This means the ravens may have been less motivated to spend energy locating and perforating the aluminium cans than they were to feed on small prey insects on the growing crops. Despite frequent clean ups of the site, newly perforated cans were constantly identified with either living or dead animals trapped inside or were found pierced with nothing inside [34], indicating that the ravens had attempted to, or had successfully, extracted the prey from inside.

4.5. Ravens' Manipulation of Cans

Beer cans were the modal type of can with raven-induced perforations. Ravens are omnivorous birds who may chronically consume small quantities of ethanol for its high calorific properties via the ingestion of over-ripe fruits, meaning that the alcohol residue in beer cans may have been more salient to them than cans that had held non-alcoholic drinks [51,52]. The scent of the leftover liquid and overall smell of the can may have attracted the ravens, with some evidence detailing odour use in corvids [53]. For example, Harriman et al. [54] found that corvids can detect meat hidden 2.4 m beneath the ground. Similarly, Wascher et al. [53] discussed corvids' use of odours in social and foraging tasks. This suggests that the scent coming from the cans could be a motivating factor in this behaviour.

Alternatively, beer is known to attract insects and as such may have been more appetising to the surrounding insects than other types of drink cans, leading to higher densities of insects (or higher success rates in finding insects in cans) for the ravens showing these can manipulation behaviours. This primary reinforcement of the behaviour over time, highly contingent on the can type, would likely lead to the selection of beer cans by ravens searching for insects [55]. In addition, prior research has identified the interactions of corvids specifically with human-provided alcoholic beverages as well as ethanol from tree sap and ripe berries. Whilst the latter may be consumed due to their high-glucose content, the former may well emanate from the modified barriers between humans and birds described previously due to the expansion of the human population in this area of Lanzarote [52]. Indeed, Garcia-Arroyo et al. [56] recently reported corvid interactions with unintentional food resources (trash bins) in Finland and described the ability, also seen in the present study, of corvids to modify their foraging behaviour according to the features of the landscape they are in.

Another factor linked to insect presence in cans is can movement. Visual perception is highly specialised in corvids to help them detect movement to locate prey [57]. Despite there being no live prey in the cans near the camera traps, the windy desert environment caused the cans to move, which potentially mimicked that which would be seen if they were inhabited by insects. In addition, ravens, especially young and naïve individuals, are known to be attracted to round smooth objects [33], and any movement or other visual cues presented by the smooth round cans may have attracted this type of individual to investigate.

4.6. Can Perforation Strategies

Tool use has previously been described in other corvid species, such as New Caledonian crows (*Corvus moneduloides*), with tools being made for a specific purpose or the features of the landscape used as tools [58]. Within corvid species, social learning has been identified as a factor in the spread of tool use in addition to genetics [59]. Whilst the neural mechanisms for the development of tool use are not yet clearly understood in non-human animals, the use of tools has also been observed in Hawaiian crows (*Corvus hawaiiensis*), rooks (*Corvus frugilegus*), Eurasian jays (*Garrulus glandarius*), Northern blue jays (*Cyanocitta cristata*) and ravens [60] with the corvid family being presented as an ideal species to study the neural mechanisms underlying this behaviour and the potential for its development via convergent evolution with great apes (*Hominidae*) [61].

Presumptive tool use in Northern ravens was reported as early as 1987 [62] and has been described in laboratory-based experiments more recently, in which ravens displayed future planning and tool use at a level of proficiency seen in apes, suggesting an evolutionary cognitive pathway for these behaviours [63]. A recent review of tool use and tooling in ravens by Jacobs and Osvath [64] identified 11 modes of tool use with specific tool use (such as twigs, stones and pinecones) in 10 sub-modes. Other sub-modes identified the use of water to soak foodstuff, the exchange of tokens with conspecifics and placing food within an object, such as a piece of cloth, and folding it over. Only seven of these sub-modes have been observed in wild populations with tool use in these instances relating to instances of threat (dropping stones on other species), courtship (presenting food and objects in courtship displays and appeasement) and hiding caches of food. The can-opening behaviour reported within this study does not appear to constitute tool use; however, it is a behaviour that has not, to our knowledge, been previously reported within the literature for this species. As corvids are known to prey on live animals, carrion and eggs, it is clear that the species can open objects using a hard surface [65]. Similarly to the opening of eggs using their beaks, it appears that ravens have generalised this behaviour to the perforation of aluminium cans in order to retrieve prey or food items within. Further research at this study site will attempt to elucidate whether examples of tool use during can manipulation can be identified as part of the behavioural repertoire of ravens at El Jable and whether the type of can perforation is indicative of the type or size of prey contained with it. This study suggests that the common raven population in Lanzarote is selectively perforating only the cans with a sufficient amount of food inside to be worth the physiological effort, with some evidence of can manipulation to show this, as previously reported by Harel et al. [66].

4.7. Study Limitations

This study's limitations include the very high temperature levels in August 2021, which caused the raven populations to avoid the exposed, shadeless sand belt region and reduced the quantity of data collected via the camera traps. This initial study was limited by its timeframe and could benefit from expansion to collect observational data over a full year to account for seasonal changes in behaviour. Furthermore, the manual observer surveys were limited to morning and evening to prevent heat exhaustion, which restricted the observer data to daylight hours [32]. Despite their limitations, human observations facilitated the collection of rich and numerous data, with the observers able to change their positions to observe the ravens and the cans to ensure that a wide repertoire of behaviours were identified to remediate for aspects that would not be recorded by camera traps alone [27]. In addition to the issue of missing data using the camera trap technology, this methodology is also vulnerable to damage and theft, as was experienced within this study and has been previously reported by Dupuis-Desormeaux et al. [19], who stated that camera traps are vulnerable to theft or destruction by poachers or hunters.

4.8. Further Research

This initial study would benefit from expansion to collect further data on the motivation of ravens pecking and manipulating cans. This may facilitate investigation into the ontogeny of these behaviours in relation to evolutionary mechanisms, cognitive adaptability and social learning [67]. The data from this study are also important as they highlight the effect of human refuse on wildlife behaviour and potentially health [56,68] in addition to significant effects on the raven population. This study also identified reptiles such as lizards attempting to enter the cans, which has been reported by Schulte et al. [69] to be a survival strategy. They use their environment to escape threats by finding shelter. Alternatively, this could potentially indicate that the sensitive olfactory capabilities of lizards with their combined gustation may have attracted them to the cans in a similar way to the ravens [70].

5. Conclusions

The main aim of this study was to explore the use camera trap technology to detect previously anecdotally reported can interaction behaviours and to extrapolate the potential motivations for these behaviours. In doing so, this study has identified an interesting and novel can manipulation behaviour of the raven population in El Jable and considered the potential behavioural motivations for this, highlighting the assessment of cans by ravens and their subsequent decision making process to manipulate the cans to open them and retrieve foodstuffs [69], building on the work of previous authors [41]. Further research into the specific motivations behind this behaviour and any evidence of tool use is warranted.

Additionally, this study has highlighted a disparity in the type and quantity of data collected through camera trap technology compared with human manual observations, providing insight into optimal methodological strategies for future studies.

This study presents valuable information on a novel behaviour in ravens and highlights important methodological considerations when considering studies of this type.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/birds5010011/s1, Video S1a–d: Raven can interactions; Table S1: corvid ethogram; Figure S1: GPS location of Raven observations in El Jable; Figure S2: Can manipulation images.

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