Factors impacting the welfare of animals in the wild

Data from rescue centers and animal sanctuaries in Greece

Animal Ethics

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Introduction

To date, the welfare of wild animals living outside direct human control remains gravely understudied. This is at odds with the interest in studying the welfare of domesticated animals, despite the two groups having a similar capacity to experience poor welfare. While it is sometimes considered difficult to study, some of the factors affecting the welfare of wild animals are accessible to examination — in fact, they have often been researched because they are relevant to commonly studied issues such as the behavior or mortality of animals in the wild. Although the primary focus of such studies is not the welfare of the animals, the studies provide information that can help inform policies and programs designed for the sake of the animals themselves.

The majority of studies that have investigated wild animal suffering have largely focused on anthropogenic harms, while little attention has been given to natural harms such as illness and accidents. This paper aims to identify some of the factors negatively affecting the welfare of animals in the wild by looking at the data compiled by wild animal sanctuaries and rescue centers in Greece, particularly with respect to natural harms. The types of animals admitted to these centers and the most commonly reported reasons for admission are analyzed and we discuss how accurately this data may represent wild animal suffering as a whole. This study also examines how natural factors may be an underlying cause of other reasons for admission, such as sick or starving animals being more prone to anthropogenic threats like car accidents. The possible effects of sex, age, and seasonality on wild animal injuries and mortalities are also discussed, and limitations of the current research are identified. The paper concludes with suggestions for future research regarding animal suffering in the wild.

Methods

Rescue centers and sanctuaries

This retrospective study was based on the records of wild animals admitted to rescue centers and animal sanctuaries in Greece. These centers were the Alkyoni Wildlife Hospital in Paros island (Cyclades), which has a vet clinic as well as 13 acres with enclosures for sick and injured birds, reptiles, and small mammals; the Arcturos Environmental Center in Florina, which has a 50 acre sanctuary for bears and a 70 acre sanctuary for wolves; and the MOm (The Hellenic Society for the Study and Protection of the Monk Seal) Monk Seal Rehabilitation Centre in Alonissos (Fig. 1).

Some of the centers did not want to disclose raw data or in some cases, any information at all, and the data presented is based on the best information available from each center and relevant publications from scientists who have worked for these centers. Additionally, some environmental organizations shared literature and reports that didn't include information about natural harms or about natural conditions that might have been contributing factors. One more sanctuary is run on a limited staff and due to the high season of admissions when the research was taking place, there was no personnel to undertake the task of data collection to share with the author, although there was a willingness to disclose information.

Figure 1. Map of wild animal rescue centers and sanctuaries in Greece. Adapted from Google Maps (n.d.).

A total of 4,865 wild animal admission records were used in the present study. The majority of these came from the Alkyoni Wildlife Hospital (n = 4711), based on nine years of records (Fig. 2). Since 1999 they kept records of all animals admitted; however, out of the 20 years recorded, only 9 years of records have been saved due to a hard drive issue which resulted in the loss of the others. The Arcturos Environmental Center provided admission records from the time their sanctuaries were established in 1993 up until 2019 (n = 125). Admission data from the MOm Monk Seal Rehabilitation Centre was based on 28 years of records, dating from the establishment of the Hellenic Rescue and Information Network (RINT) for the Mediterranean monk seal in 1991 up until 2019 (n = 29).

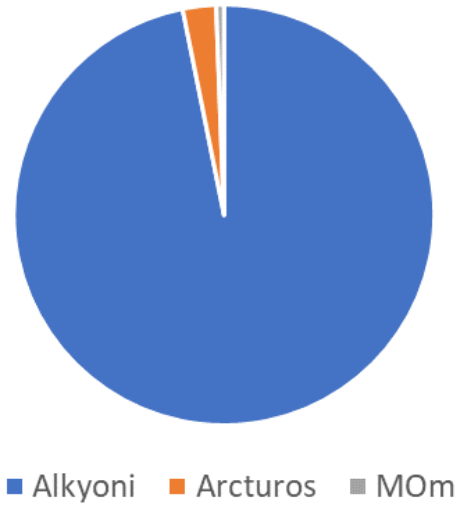

Figure 2. Proportions of wild animal admissions from different rescue centers and sanctuaries in Greece used in the present study

Data compilation

Information from the three rescue centers was compiled into a single database and sorted into categories based on the reasons for admission most frequently recorded by the centers. The data was examined across all cases and compared between three taxonomic groups: birds, reptiles, and mammals.

Reasons for admission were organized into six categories: “natural causes,” “orphaned,” “confiscated,” “hunting,” “hit by car,” and “other reasons.” “Natural causes” included animals affected by diseases, illnesses, parasites, natural disasters such as floods, and birds suffering from migration exhaustion. “Confiscated” referred to animals who were transferred, surrendered, or confiscated from illegal owners and zoos. “Hunting” encompassed injuries sustained from shootings and hunting traps. The category labeled “other reasons” included incidents such as attacks from domestic animals, electrocutions, and reasons either unknown or not recorded. “Other reasons” also encompassed miscellaneous reasons that did not fall under any other category, such as healthy tortoises found in residential areas and bears who entered a sanctuary of their own accord.

Four wolves who were born at the Arcturos center were excluded from the Arcturos dataset. Also excluded were monk seals treated on-site by MOm and members of RINT as these seals were not admitted to the rehabilitation center.

Sex ratios

Sex data was examined based on 148 case records (72 females and 76 males) of grey wolves (*Canis lupus*), eastern timber wolves (*Canis lupus lycaon*), brown bears (*Ursus arctos*) and one black bear (*Ursus americanus*) from Arcturos, and 29 monk seals (*Monachus monachus*) from MOm. No sex data was available for other species. A chi-square analysis was used to determine whether there was a significant difference in reported reasons of admissions between female and male mammals.

Results

Animals admitted to rescue centers

The majority of wild animal admissions were birds, making up 91.3% (n = 4,442) of cases, while mammals accounted for 5.43% (n = 264) of admissions and 3.27% (n = 159) were reptiles (Fig. 3).

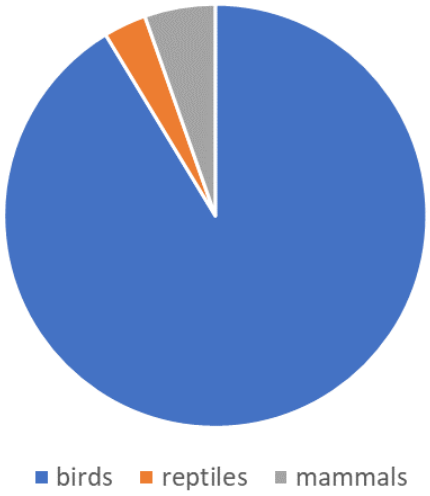

Figure 3. Proportion of taxonomic groups admitted to rescue centers and sanctuaries in Greece

Reported reasons for admissions

The most commonly attributed reason for wild animal rescue center admissions was "hunting" (34.82%, n = 1694), followed by "other reasons" (21.09%, n = 1026), "orphaned" (18.34%, n = 892), "natural causes" (13.44%, n = 654), "hit by a car" (7.73%, n = 376), and "confiscated" (4.67%, n = 227) (Fig. 4).

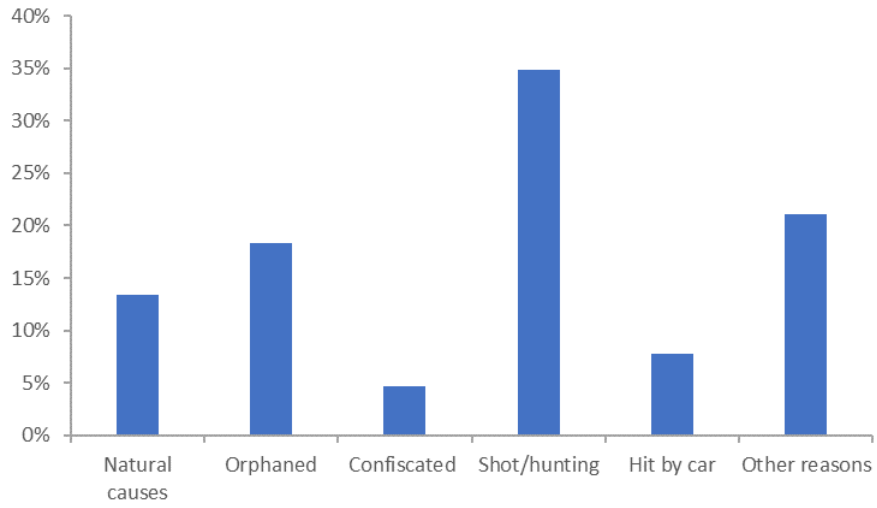

Figure 4. Reported reasons for wild animal admissions to rescue centers and sanctuaries in Greece (%)

The frequency of reported reasons for admission varied across taxonomic groups (Fig. 5). "Hunting" was the most commonly recorded reason for birds (37.91%, n = 1684), followed by "other reasons" (20.37%, n = 905). "Orphaned" (32.58%, n = 86) and "confiscated" (28.03%, n = 74) animals made up the majority of mammal admissions. The leading categories for reptiles were recorded as "other reasons" (54.09%, n = 86) and "hit by a car" (36.48%, n = 58).

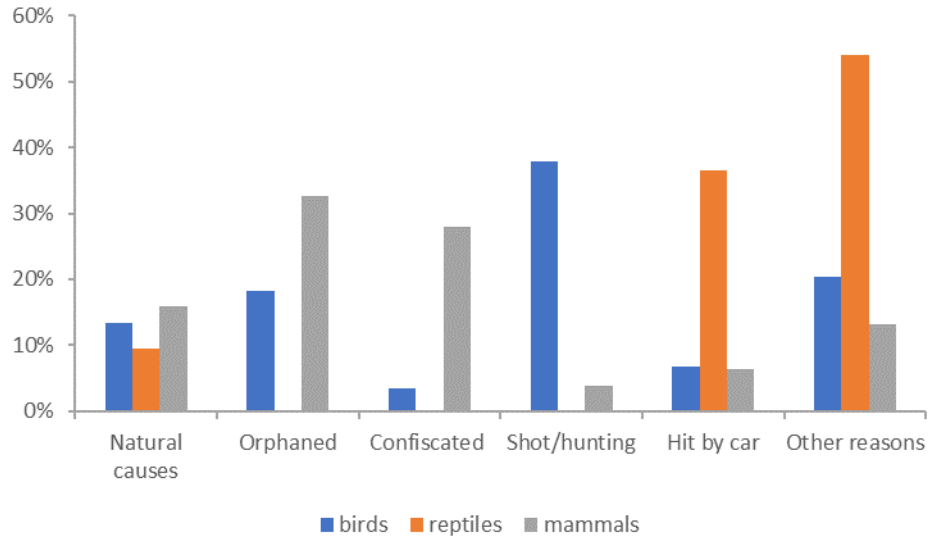

Figure 5. Reported reasons for wild animal admissions between different taxonomic groups (%)

Sex ratios

Female and male mammals showed similar trends with orphans and confiscated animals making up the most frequently reported reasons of admission for both sexes (Fig. 6). A higher number of females were categorized as confiscated compared to males, while more males were reported as orphaned compared to females. However, a statistical analysis showed that these differences were not significant (X^2 = 4.86, p > 0.05), indicating that reported reasons of admissions were not affected by sex.

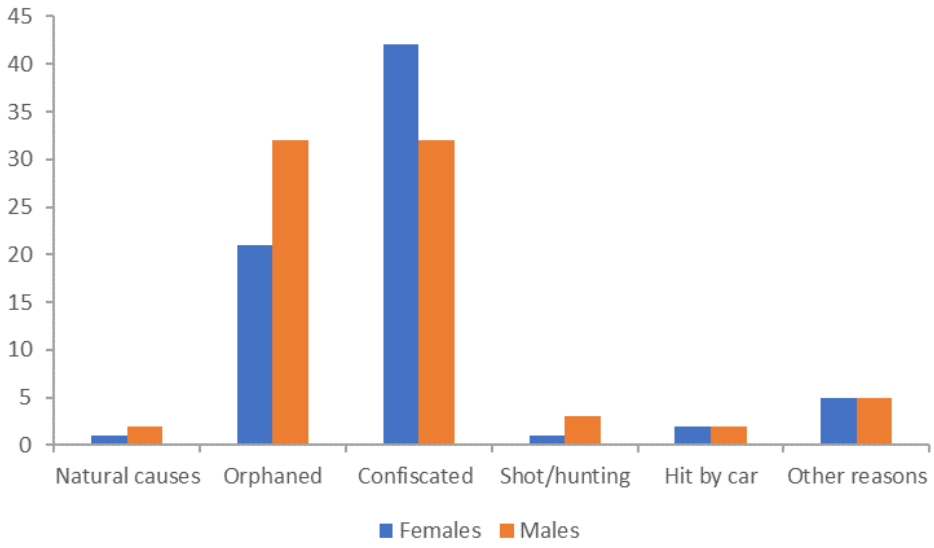

Figure 6. Differences in reported reasons for admission between female and male mammals

Discussion

Animals admitted to rescue centers and sanctuaries

Birds made up the vast majority of admissions used in the present study (91.3%). This is similar to the ratios of over 30,000 animals treated by the ANIMA Wildlife Conservation Society in Athens, where 84.6% of admissions were birds (Tzali et al. 2018). Admissions in other parts of the world also show similar patterns, with birds accounting for 89% of animal intakes to the Wildlife Rehabilitation Center of Torreferrussa in Catalonia, Spain (Molina-López et al. 2017), 86% of admissions to five rehabilitation centers in Chile (Romero et al. 2019) and 83% of admissions to 41 centers in South Africa (Wimberger et al. 2010). In contrast, mammals made up the majority of admissions (51.1%) to a wild animal hospital in Queensland, Australia, with birds the second most commonly admitted taxa (35.2%) (Taylor-Brown et al. 2019).

While these admission numbers provide insight to the types of animals that are brought to rescue centers, they do not reflect the actual ratios of different animals found in the wild. It is estimated that there are more individual wild mammals and reptiles on Earth compared to the number of wild birds, although estimations of these numbers vary (Bar-On et al. 2018; Tomasik 2009; Venkateshan 2019). Even more abundant are worms, arthropods, amphibians, molluscs, and fishes, with individual numbers for each of these taxa estimated to be in the trillions (Bar-On et al. 2018; Tomasik 2009), but there are no recorded instances of any of these types of animals being treated by rescue centers in the present study or scientific literature.

The high ratio of bird admissions compared to other types of animals may be due to a number of factors. Many animals are brought to rescue centers by members of the public, who may value certain types of animals, such as birds, over others, such as insects and reptiles. Negative perceptions or fear of certain types of

animals, such as spiders and snakes, may also make people less inclined to help them (Kellert 1993; Taylor-Brown et al. 2019). It is possible that birds are easier to find, capture, and transport compared to mammals, reptiles or smaller animals like insects and fishes. It is also likely that rescue centers and workers are not equipped to help smaller animals, such as butterflies with broken wings, so even if these animals are rescued from the wild, there is nowhere for them to receive treatment. Although mammal admissions in the present study made up a much smaller ratio compared to birds (5.43%), they still represented the second most commonly admitted taxa, most likely influenced by the fact that two out of the three centers who provided data are facilities devoted to specific types of mammals. This again may be a reflection of the higher regard and interest given to certain types of animals over others.

Reported reasons for admissions

Of all animals admitted to centers used in the present study, "hunting," "other reasons," and "orphaned" animals were the leading reasons reported for admissions. Orphaned animals and anthropogenic reasons such as car accidents and confiscated animals were also among the most commonly reported admission reasons for centers in Athens (Tzali et al. 2018), Spain (Molina-López et al. 2017), and Australia (Taylor-Brown et al. 2019). Reasons categorized as other, undetermined and unspecified also made up a large proportion of admissions to centers in Spain (Molina-López et al. 2017), and Chile (Romero et al. 2019).

Like the ratios of animal taxa admissions, the ratios of animals admitted to rescue centers for anthropogenic harms may not be reflective of actual ratios in the wild. While animals are brought to these sanctuaries from around the country, animals in human-populated areas have a higher chance of being affected by human activities, and of being taken to a rescue center, compared to animals in more remote areas. This means that cases of animals suffering from anthropogenic harms are more likely to be reported, a bias that has been noted in other studies of wild animal admissions (Brown & Sleeman 2002; Deem et al. 1998; Taylor-Brown et al. 2019; Wendell et al. 2002). Public attitudes are also likely to influence these ratios, as people may be less inclined to help an animal suffering from natural causes due to a belief that they should not intervene with natural processes

(Kirkwood & Sainsbury 1996). It is also possible that cases of anthropogenic harms are exacerbated by underlying natural causes that are more difficult to detect.

Anthropogenic harms such as hunting and car collisions are often found to be major reported causes of wild animal admissions, but it is unknown how often natural conditions are a contributing factor. Animals who are sick or injured due to natural reasons may be less alert and move more slowly compared to healthy animals, making them more susceptible to certain anthropogenic harms. An animal suffering from poor eyesight or hearing, for example, is much less likely to detect a hunter or oncoming car and have time to escape. In a study of Florida Key deer (*Odocoileus virginianus clavium*) by Nettles et al. (2002), necropsies revealed that 5.5% of deer killed by vehicles also had debilitating neurologic diseases or parasites that the researchers believed made them predisposed to vehicle collisions. Another 7.1% of these deer were found to be suffering from subclinical health problems including heart and bone diseases, and a further 15.7% had a physical condition rated fair to poor by the researchers based on their muscle mass and body fat. It is likely that other admission categories, such as "orphaned" and "other reasons." also include cases where the underlying cause is an animal suffering from poor health conditions.

The category "other reasons" is used for a variety of admission reasons that do not fall under the other categories, but it is also used when the cause of harm to the animal is unknown. Many natural harms such as diseases and internal injuries may not always show obvious external signs, and may not be detected by rescue centers due to lack of equipment, funding, or experienced staff. A study of Australian wild animal admissions suggested that disease was possibly under-represented in their dataset, noting that a lack of funding means that diagnostic testing is sometimes unable to be performed, and certain diseases go undetected (Taylor-Brown et al. 2019).

Orphans are one of the most frequently used admission categories in the present study and in rescue centers around the world (Molina–López & Darwich 2011; Molina-López et al. 2017; Romero et al. 2019; Taylor-Brown et al. 2019; Tzali et al. 2018; Wimberger & Downs 2010), but in most cases, there is no information given regarding the reasons why young animals become orphaned. The present study included admissions of 3 bear cubs who became separated from their mother due to a flood, which were categorized under "natural causes," but in

the other 892 cases of orphan admissions, the cause of parental separation is unknown. All 29 cases of monk seals admitted to the MOm rehabilitation center were orphaned pups that were weak, dehydrated, malnourished, with many suffering from anemia, parasites, and infections, and who were often found after extreme weather events (Koemtzopoulos K. pers comm., MOm, 2019).

Severe weather conditions have also been linked to orphaned animals in other countries, with an Australian animal center observing an increase in orphan admissions during a period of heavy rainfall, thunderstorms, and flooding (Taylor-Brown et al. 2019). Other centers and researchers have speculated that many instances of orphaned animals may be attributed to young birds falling from their nests, unnecessary intervention by humans, young animals being abandoned by their parents or the death of a parent (Ganoti M. pers comm. 2019; Komnenou et al. 2005; Molina-López et al. 2017; Tzali et al. 2018). Poor health in animals is also likely to be a contributing factor, because a parent suffering from an illness or injury is at risk of dying or becoming more susceptible to other threats.

Birds

"Hunting" was the primary reason given for bird admissions, followed by "other reasons." These findings are consistent with the results of a study of raptors admitted to a veterinary teaching hospital in Greece by Komnenou et al. (2005), who found that the majority of admissions were related to hunting (51.1%). The next leading reasons were undetermined (12.7%) and starvation (9.4%) related to heavy winter and migration. The study also noted that most of the admitted raptors were displaying signs of starvation, dehydration, weight loss, and hypothermia. In addition, Pyrovetsi and Papazahariadou (1995) attributed the weakened conditions and eventual deaths of a number of Dalmatian Pelicans (*Pelecanus crispus*) found in northern Greece to the combined effects of cold weather conditions, starvation, and high parasitic burdens. Another four Pelicans from the same area were found dead with gunshot wounds, but shooting could not be confirmed as the cause of death in one individual due to the superficiality of the wounds, suggesting that natural harms may have also been impacting the Pelicans who were shot. It is possible that natural harms such as starvation also contributed to cases of hunting in the present study but were not recorded or not detected by the centers. There is no information in the scientific literature regarding what

percentage of birds with injuries related to hunting are also suffering from natural harms.

In other studies of birds admitted to rescue centers, a substantial number of cases are recorded as unknown or listed under "other reasons" (Molina–López & Darwich 2011; Romero et al. 2019; Wimberger & Downs 2010). It is possible that these individuals are suffering from viruses and parasites but go undiagnosed due to the limited resources available in these centers. A study of seabird admissions to a center in Spain observed that diagnostic tests could not always be performed due to a lack of funding, and as a result, the influence of diseases and parasites in seabirds were underestimated (Montesdeoca et al. 2017). The prevalence of viruses in raptors admitted to a veterinary teaching hospital in Florida could not be determined due to a lack of necropsies and diagnostic techniques (Deem et al. 1998). Detecting these kinds of natural harms is difficult but essential to the welfare of wild animals, as most free-ranging birds carry parasites which under certain conditions can be very pathogenic and even cause death (Cram 1926; Papazahariadou et al. 1994; Pyrovetsi & Papazahariadou 1995).

The majority of birds admitted to the Alkyoni Wildlife Hospital for natural causes were Eurasian Collared Doves, most of whom were carrying viruses or parasites such as the Newcastle Disease Virus or the protozoan *Trichomonas gallinae* (Fournaris M. pers comm. 2019). Many doves and other birds living in or close to urban areas are often infected by trichomonosis, a disease caused by *T. gallinae* that typically affects the digestive and respiratory systems, and can result in tissue degeneration, organ failure, and death (Kocan & Herman 1971, in Forrester & Foster 2009; Krone et al. 2005). A study by Quillfeldt et al. (2018) found that trichomonosis was present in 42% of wild birds admitted to a veterinary clinic in Germany. Although the birds were mostly admitted for traffic injuries, traumas, or other diseases, the researchers suggested that trichomonosis may have predisposed the birds to other harms due to their weakened conditions. It is likely that the high prevalence of trichomonosis around urban areas is intensified by large populations of urban bird species, which allows the transmission of diseases to occur more easily (Ganoti M. pers comm. 2019).

The present study included migration exhaustion, a harm that is unique to birds, under the category "natural causes," and it accounted for 7.99% of all bird

admissions. According to BirdLife International, over 60% of bird species in Greece are migratory (2020a). Migration journeys are long, often traversing continents, and such large distances require stopover sites for birds to rest, eat, and drink before continuing their journeys (BirdLife International 2020b). Migration exhaustion occurs when a bird becomes too tired or weak to fly, often due to a lack of stopover sites and wintering grounds (BirdLife International 2020b; Wilcove & Wikelski 2008). The threat of hunting is also linked to migration, as some regions in the Mediterranean view the poaching of migratory birds as traditional, with an average of 704,000 birds poached or taken every year in Greece alone (Karris et al. 2018). Migration also carries a high risk of disease transmission, as birds travel in large flocks and interact with other bird populations at stopover sites (Becker et al. 2020; Hubálek 2004).

Mammals

"Orphaned" animals was the most commonly reported reason of admission for mammals in the present study. Some mammal species are dependent on their parents for long periods of time, so young mammals are particularly vulnerable when their parents become ill, injured, or separated from them (Goldenberg et al. 2018; MOm 2020a; Stewart 1988). As previously mentioned, the reason why animals become orphaned is usually not recorded, but was attributed to a flood for 3 bear cubs, and associated with extreme weather events in many cases of orphaned seal pups. Natural causes were reported in 15.92% of mammal admissions, and it is possible that this number would be larger if it were possible to separate natural causes of orphaning from anthropogenic ones.

No cases of adult seals were included in the present study, as orphaned pups were the only seals admitted to the MOm Monk Seal Rehabilitation Centre, although MOm and members of RINT have treated adult monk seals in the field. These include cases of injuries sustained during extreme weather events or fighting with other seals, as well as illnesses, infections, and disease (Dasarxeio 2014; Iliopoulou 2012, 2016). A study based on RINT reports and necropsies of monk seals stranded in Greece by Androulaki et al. (2006) found that 45% of mortalities were due to natural reasons, and in 27% of cases the cause of death could not be diagnosed. Full necropsies were only conducted for 84 of the 203 reported strandings, due to the state of the bodies. More research is needed to

understand the causes of mortality in monk seals, and provide insight into the reasons why seal pups become orphaned.

The second highest reported category for mammals was “confiscated,” and like orphans, there is usually little information available about these animals prior to their admission to rescue centers. Because mammals were found to be frequently orphaned in the present study and in other studies (Kelly & Sleeman 2003; Molina-López et al. 2017; Taylor-Brown et al. 2019), it is possible that many mammals who are confiscated from illegal owners were initially taken from the wild as orphans when they were at their most vulnerable (Freund et al. 2017). It is also likely that wild adult mammals with injuries or illnesses would be easier to trap and transport compared to healthy animals, but it would be very difficult to determine what percentage of confiscated animals were suffering from pre-existing natural harms that may have predisposed them to being taken from the wild.

The majority of mammals admitted to the Alkyoni Wildlife Hospital for "natural causes" were hedgehogs who often carry ticks or are infected by other parasites (Fournaris M. pers comm. 2019). Mange, caused by parasitic mites, was found in the majority of adult hedgehogs admitted to ANIMA (Ganoti M. pers comm. 2019). In cases of heavy parasitism, hedgehogs have been known to display severe clinical signs such as diarrhea and abdominal swelling, which may result in death (Skuballa et al. 2010). A study of mortality in hedgehogs admitted to rescue centers in the UK and Netherlands found that 59% of deaths likely resulted from natural causes such as parasites and infections (Reeve & Huijser 1999).

Reptiles

The leading reason reported for admissions for reptiles was listed as “other reasons.” Many of these cases were tortoises found in residential areas who were not ill or injured but it was deemed necessary to relocate them. The reasons why tortoises were found in these areas were not given, but tortoise movements and activity are often related to food availability, reproduction, and weather conditions (Hailey 1989). Tortoises do not typically travel far, with Hermann's tortoise (*Testudo hermanni*) having an average home range between one and two hectares, but they may extend this range when searching for resources (Bertolero et al.

2011; Hailey 1989). Home ranges of tortoises usually remain stable throughout their lives, and individuals have been known to return to these ranges following relocations (Chelazzi & Francisci 1980). This suggests that relocating tortoises may not always be ideal, as they may attempt to return to the same area where they were initially found and encounter different threats along the way. However, more information such as sex, age, and species would be needed to determine the best ways to help tortoises who are encountered in these areas.

The majority of reptiles admitted to the Alkyoni Wildlife Hospital for "natural causes" were tortoises, with many carrying ticks or other parasites. Based on research made by Siroký et al. (2006), *Hyalomma aegyptium* were the most frequent tick species found on both Hermann's tortoise and the marginated tortoise (*Testudo marginata*) in Greek localities. Ticks are carriers and transmitters of a variety of pathogens, and infected hosts may suffer from bacterial illnesses such as ehrlichiosis (Fournaris M. pers comm. 2019; Pastiu et al. 2012). Tick infestations have also been known to cause anemia and ulcerous skin legions in reptiles (Jacobson 2007), as well as reducing energy resources and increasing their host's susceptibility to other harms (Pough et al. 2004).

Marine turtles are also prone to parasites but face different types of threats due to their aquatic environment, while tortoises are terrestrial (Holroyd & Parham 2003). In Brazil, the parasite *P.Cymbiformis* has been associated with chronic cystitis in a loggerhead turtle (Werneck et al. 2018). A total of 34 parasites have been reported in two marine turtle species in Costa Rica (Santoro & Mattiucci 2009) and three species of trematodes were collected from a leatherback turtle in Italy (Manfredi et al. 1996). However, these studies make no mention of the suffering inflicted on turtles as a result of these parasites. To the best of the author's knowledge, there is no information in the current scientific literature regarding parasitic burdens in marine turtles in Greece.

There were no marine turtle admissions found in the records of rescue centers used in the present study; however, previous research has examined threats faced by marine turtles in the wild. A report by Kopsida et al. (2000) investigated marine turtle strandings in Greece based on data collected by ARCHELON's Sea Turtle Rescue Network (STRN), and found that in the majority of cases the causes of turtle strandings are unknown (36%). Cases belonging to the unknown category included turtles with no obvious signs of injuries and dead turtles where decomposition had set in. Stranded turtles who were observed to be weak,

lethargic, cold-stunned, suffering from buoyancy problems or pathogenic infections were listed as "other." However, the report did not state the percentage of turtles belonging to this category. The authors suggested inexperienced personnel and a lack of necropsies were obstacles in determining causes of strandings and may have produced inaccuracies in the data. This may have also resulted in natural harms such as disease being under-reported by the STRN and receiving little attention in the report.

Sex Ratios

In the present study, ratios of admission records were approximately equal between the sexes, with a total of 72 females and 76 males recorded. This is consistent with the findings of a survey of 30 mammal rehabilitation centers around the world, where the majority of centers received even numbers of females and males, with only 10% of centers reporting more admissions of male animals (Guy et al. 2013). Instances of increased male admissions may be partly attributed to tendencies in certain male mammals, particularly carnivores, to disperse more than females (Bekoff et al. 1984).

No significant differences were found in the reasons for admissions between females and males in the present study. However, sex was only specified in 3.04% of total admission records, and all of these belonged to large mammals. As a result, the analysis of sex ratios was skewed by the lack of available data, and it is unknown whether sex had an effect on reported admission reasons in birds, reptiles and small mammals. Sex was also undetermined in the majority of admissions from centers in other studies (Komnenou et al. 2005; Molina-López et al. 2017; Molina–López & Darwich 2011; Montesdeoca et al. 2017; Romero et al. 2019).

In rescue centers, the sex of animals may be determined by visual inspection, blood analysis, or examination during necropsies (Molina-López et al. 2017; Molina–López & Darwich 2011; Montesdeoca et al. 2017). Determining sex can be very difficult in certain species, particularly in birds and reptiles where the sexes often show few external differences, so a lack of experienced staff and funding for

diagnostic tests and necropsies are likely reasons for the lack of sex data in admission records (Montesdeoca et al. 2017; Romero et al. 2019).

Age

There was little information available in the present study regarding the age of wild animals admitted to rescue centers apart from instances of orphaned animals, who accounted for 18.34% of all admissions, but other research can provide insight into age patterns of animals harmed in the wild.

In cases of stranded monk seals reported through RINT, mortalities attributed to natural harms were found to be higher in younger animals, affecting 93% of seal pups, 33% of sub-adults and 18% of adult seals (Androulaki et al. 2006). As discussed earlier, this may be due in part to the young seals' high dependency on their parents, which makes them vulnerable to threats such as predation and starvation when they are left alone (MOm 2020a).

A study by Calzada et al. (1994) found that a morbillivirus outbreak in the Mediterranean Sea caused the deaths of large numbers of striped dolphins from 1990 to 1992, with the highest mortalities recorded in sexually mature individuals. While juveniles were less affected, calves also suffered high mortality rates, which may have been influenced by their dependency on their mothers who were the most susceptible to the disease. The schooling behavior of dolphins within different age groups may have influenced transmission rates, and age-specific susceptibility to viruses and geographical distributions have also been suggested as possible reasons for these differences in mortality rates.

Certain diseases carry a higher rate of juvenile susceptibility. Several studies have found that avian influenza viruses are more prevalent in juvenile birds compared to adults (Hoye et al. 2011; Kleijn et al. 2010; Van Dijk et al. 2014), with adult birds more likely to carry antibodies against the viruses (Hoye et al. 2011; Kistler et al. 2012; Lambrecht et al. 2016; Van Dijk et al. 2014). Juvenile birds and mammals also typically experience higher intensities of parasites compared to adults (Allander & Bennett 1994; Ferreira, et al. 2019; Gregory et al. 1992; Sol et al. 2003), which may be due to an acquired immunity in older animals (Sol et al. 2003; Wakelin 1996).

Other studies have investigated age group ratios in relation to wild reptiles. From 1997-1999, the proportions of stranded marine turtles reported to the STRN in Greece were 47.2% adult and sub adult, 26.5% babies and 26.3% juveniles. It was also noted that when incidents of strandings increased, these group percentages remained constant (Kopsida et al. 2000). Adults were found to be more affected in a study of stranded loggerhead turtles by Komnenou et al. (2018), where 65.7% were adults and 34.3% were juveniles, although in cases of depressed turtles (25% of all cases) 52.6% of these were juveniles. Survival rates in juvenile reptiles are estimated to be higher in species with larger offspring, and higher in reptiles who give birth compared to egg laying species (Pike et al. 2008).

A lack of recorded age data found in the present study is likely due to the difficulty in determining the age of animals, apart from very young individuals, by observation alone. The condition of teeth, skin and muscle tone may be used to estimate the age of a mammal (Kramer 2013), while feather color and molt patterns can be indicators of a bird's age (Swick 2017). Growth marks on the shell surface of turtles (Cagle 1946) and body size in lizards (Patnaik & Behera 1981) have been shown to correlate with age, although these features only provide approximate age estimations and vary widely between different species (Castanet 1994).

Rescue center workers and volunteers may not have the level of training or knowledge required to accurately identify an animal's age, so the information goes unrecorded on admission forms. However, as illustrated by high instances of orphaned and affected juvenile animals in the present study and other research (Molina–López & Darwich 2011; Molina-López et al. 2017; Romero et al. 2019; Taylor-Brown et al. 2019; Tzali et al. 2018; Wendell et al. 2002; Wimberger & Downs 2010), age data would be valuable in determining which age groups are most vulnerable to particular threats in the wild.

Seasonality

Instances of orphaned animals are often linked to breeding seasons. The orphaned seal pups admitted to MOm's Monk Seal Rehabilitation Center were encountered over the period October to December (Koemtzopoulos K. pers comm., MOm, 2019).

This coincides with the birthing season for monk seals in Greece, which occurs from August to December with the majority of pups born in October (MOm 2020a).

Other research has also shown a pattern of increased admissions in orphaned animals during breeding seasons. Orphans accounted for 7.7% of bird admissions to the Veterinary Medical Teaching Hospital at the University of Thessaloniki, which were all presented during the breeding season (Komnenou et al. 2005). The majority of admissions to ANIMA of young birds recently separated from their parents take place from April to August and peak in June, which is the reproduction period for the majority of the bird species (Tzali et al. 2018). Studies of wild animals in Chile and Australia have noted that instances of orphaned animals from all taxa increase during the spring and summer, which is also the time when many young animals begin to disperse to find their own territories (Basso 2014, in Romero et al. 2019; Taylor-Brown et al. 2019).

Several studies have reported an increase in overall admissions, not just juveniles, to rescue centers during breeding seasons (Mullineaux & Kidner 2011; Taylor-Brown et al. 2019; Tzali et al. 2018; Wendell et al. 2002). This may be associated with an increase in adult activity during this time, such as courtship and mating, which may sometimes involve males fighting each other for territories and mates (Mullineaux & Kidner 2011; Taylor-Brown et al. 2019).

According to the STRN, approximately 50% of all stranded turtles encountered between 1997-1999 were found during summer, with 72% of green turtle strandings occurring between May and September (Kopsida et al. 2000). A study of leatherback turtles by Margaritoulis (1986) found that the majority of strandings occurred in the summer and autumn, and while the reason for this seasonal pattern is unknown, the authors speculated that it may be associated with the turtles' migratory movements or their feeding habits, as they will often move into temperate zones in search of jellyfish.

Certain illnesses and disorders may also be related to particular times of the year. Komnenou et al. (2018) reported that 42.1% of loggerhead turtles admitted to Aristotle University's Veterinary Hospital were found during winter. Among depressed individuals, 52.6% were juveniles who suffered from severe hypothermia and cold stunning accompanied by malnutrition during early winter. Most also showed clinical signs of respiratory problems (lethargy, anorexia, dyspnea, abnormal respiratory sounds, and buoyancy issues), and radiographic findings revealed severe pneumonia.

Underestimation of natural harms

While "natural causes" were recorded for 13.44% of all admissions in the present study, it is possible that many other natural harms such as diseases, parasites, starvation, and internal injuries sustained in the wild are not diagnosed when animals are admitted to rescue centers. As previously discussed, necropsies of wild animals that have died from anthropogenic harms have revealed underlying health issues that may have predisposed them to these threats (Nettles et al. 2002). Other studies of wild birds, mammals, and reptiles have speculated that many animals may be suffering from undetected natural disorders in conjunction with anthropogenic injuries (Brown & Sleeman 2002; Chaloupka et al. 2008; Deem et al. 1998; Kelly & Sleeman 2003; Wendell at al. 2002), which likely contributed to the underreporting of natural harms in the research.

It is also possible that wild animal mortalities due to natural harms are sometimes misdiagnosed as anthropogenically induced. A study of mortalities in Californian fishers (*Pekania pennanti*) by Gabriel et al. (2015) found that a number of fisher deaths were incorrectly attributed to predation and vehicle strikes, while necropsies revealed that these animals had died from diseases. This was due to field observations, such as finding the animal near a road, being used as evidence of cause of death, compounded with the difficulty in identifying diseases from observations alone. Natural harms are also difficult to detect when an animal's body has undergone too much tissue loss or decomposition, and this may also be a factor in the underestimation of naturally caused wild animal mortalities (Androulaki et al. 2006; Gabriel et al. 2015; Kopsida et al. 2000; Newton et al., in Molina-López & Darwich 2011).

Methods of data collection and categorization in wild animal studies often show a bias towards anthropogenic threats, and this may contribute to the underreporting of natural harms. The present study included six categories of reported admission reasons based on the data provided by rescue centers, with only one category, "natural causes," encompassing all of the natural harms, while three of the categories were devoted to specific anthropogenic harms. If more detailed information on natural harms was available, for example the specific number of cases related to disease, this could have been included as a separate category and provided a more accurate representation of wild animal harms.

Studies of wild animals in the field also demonstrate a bias towards anthropogenic threats. On the reporting sheet for stranded turtles in Greece, three of the five categories provided are for specific human-induced causes; bycatch, boat and propeller strike, and intentional injuries (Kopsida et al. 2000). There are no categories relating specifically to natural causes of strandings, only the general categories of unknown or other reasons. This makes it more likely that people collecting stranding data, particularly inexperienced workers, will attribute visible wounds and injuries to anthropogenic categories rather than considering possible natural causes. This has likely resulted in natural harms being underestimated, as researchers have determined natural harms to be one of the primary causes of marine turtle strandings in other parts of the world (Chaloupka et al. 2008; Flint et al. 2010; Murakawa et al. 1999; Shaver et al. 2017).

There was difficulty in compiling and comparing data in the present study, as each rescue center has their own method of classifying and grouping harms together. For example, “trauma” and “accidents” were categories used by some centers that encompassed many different kinds of harms, and sometimes the causes of trauma were not specified. Consequently, injuries from natural harms may have been underreported in these studies. Admission records should be as specific as possible, and ideally, standardized across all rescue centers and uploaded to a centralized database, to improve the accuracy of data and allow comparisons of datasets (Romero et al. 2019; Wimberger & Downs 2010).

Limitations

During the process of compiling data for the present study, a discrepancy was found (n = 4) in the recorded reasons of admission compared to the overall number of wild animal admissions. This discrepancy was unable to be rectified, leaving an error rate of 0.08% in the reported reasons of admission categories. We can infer that the overall admission numbers were correct, as they corresponded with the total number of reported case outcomes.

Currently, four wildlife hospitals which accept birds and small mammals are operating in Greece; Alkyoni Wildlife Hospital in Paros island (Cyclades), ANIMA Wildlife Conservation Society in Athens (Southern Greece), Action for wildlife in Thessaloniki (Northern Greece) and KEPPAZ Wild Life Protection and Rehabilitation Center in Messinia (Peloponnese). Another center was operating on the island of Aegina (the EKPAZ Wildlife Care Center), but in 2018 the Environment Ministry suspended its operations due to a failure to provide adequate care for animals, including a lack of electricity and water, insufficient staff and poor hygiene practices (Keep Talking Greece 2018). The small number of wild animal facilities operating in Greece who were willing and able to disclose information, limited the amount of data available for analysis in the present study.

All of the wild animal centers examined in the present study are nonprofit NGOs (non-governmental organizations) which largely rely on donations and volunteers to continue their operations. The ongoing financial crisis in Greece which started in 2008 further reduced the amount of resources available and increased the difficulty in conducting necropsies and diagnostic tests on sick and injured wild animals. As reflected in the present study, this means a substantial number of admission causes, as well as sex and age data, are unknown or not recorded, and this restricts the ability of researchers to accurately determine the reasons why wild animals are harmed in nature.

A major limitation in studies of wild animal suffering is a lack of information on wild amphibians, fishes, and invertebrates. As previously discussed, admission

data from rescue centers is predominantly limited to birds, mammals, and reptiles, which may be due in part to insufficient center resources to care for other types of animals. A lack of public awareness regarding the capacity for certain animals to experience suffering (Animal Ethics 2020) and negative perceptions of some species (Kellert 1993; Taylor-Brown et al. 2019) are also likely to influence which animals receive more care and attention. Biases within the scientific community also contribute to the narrow range of available species data, as larger vertebrate species are more frequently represented in wild animal research compared to amphibians, fishes, and invertebrates (Cox & Merrill 2015; Gratwicke et al. 2012; Grodsky et al. 2015).

Many rescue centers and sanctuaries have a conservationist approach to wild animal rescue and rehabilitation (ANIMA 2020; Arcturos 2020; Guy et al. 2013; MOm 2020b; Romero et al. 2019), which focuses on preserving populations of certain species (Soulé 1985). At times, this approach conflicts with animal welfare concerns, as it prioritizes caring for individuals belonging to species that are considered to have a high ecological value over the welfare of individual animals (Animal Ethics 2020; Kirkwood & Sainsbury 1996; Olsen 1990), and some may deny care to animals who are deemed to be a “nuisance” or “invasive” species (Sleeman 2008). These views are often reflected in studies of wild animals, where non-indigenous or “exotic” animals are regularly excluded from datasets (Molina-López et al. 2017; Romero et al. 2019; Taylor-Brown et al. 2019). Such approaches greatly limit the amount of data available, as the omission of entire species from research prevents us from gaining a complete understanding of the harms faced by animals in the wild. Conservation research is also heavily focused on anthropogenic harms (Soulé 1985), which may contribute to the underestimation of natural harms in rescue centers and scientific publications.

Conclusion

The present study found that wild animals admitted to rescue centers and sanctuaries in Greece suffer from a variety of harms, with many factors contributing to the types of animals that are admitted and the prevalence of different harms that are reported. While birds made up the vast majority of admissions in Greece and in other parts of the world, this does not reflect the actual ratios of different types of animals suffering in the wild, as global estimates of individual amphibians, fishes, and invertebrates are all higher than individual bird numbers. Similarly, while anthropogenic harms tend to be reported more often than natural harms, this is not an accurate representation of the total number of animals suffering from natural harms in the wild.

As observed in previous research of wild animal injuries and mortalities, natural harms often go undetected by rescue centers and sanctuaries, usually due to a lack of funding and inexperienced staff. As a result, many animals are admitted to centers for reasons that are unknown, undetermined, or misdiagnosed, and important information such as age and sex are often unreported. Previous studies have also found that many animals suffer from a combination of harms, and natural harms such as parasites and illnesses can make an animal much more susceptible to other threats like hunting and car accidents. These animals are usually reported to be suffering from anthropogenic harms, as a lack of diagnostic testing and necropsies make it unlikely that the underlying natural causes will be detected.

The welfare of animals would benefit from increased rescue center funding and volunteer training to improve the accuracy of diagnoses and demographic information, and enhance the animals' chances of recovery. The implementation of standardized categories and databases in centers would also help in strengthening the reliability of data collection, and a network of centers working together could provide guidance and assistance to centers with fewer resources. This would also provide more insight into patterns of wild animal admissions regarding age, sex

and species, enabling centers to prepare for these trends accordingly. These advancements would also allow researchers to more accurately determine the prevalence of natural harms in the wild and identify how often they contribute to instances of anthropogenic harms.

The underreporting of natural harms is also common in the scientific literature, with the majority of wild animal studies showing a bias towards anthropogenic causes of suffering in methods of data collection and categorization. As a consequence, the focus of discussions and proposed solutions to wild animal suffering has been on anthropogenic threats, while little attention has been given to natural causes. Future research into wild animal suffering would be advanced by giving greater consideration to natural threats, and including specific categories such as diseases, parasites, internal injuries, and weather events when compiling data. To gain a more accurate representation of the types of animals harmed in nature, extensive research is needed on lesser studied taxa such as invertebrates and fishes, as well as animals living in more remote areas. While these kinds of animals are not typically admitted to rescue centers and sanctuaries, data can be gathered through non-invasive sampling techniques such as camera traps, drones, and eDNA sampling. These approaches would provide researchers with more detailed information on natural harms and assist in developing effective management strategies and policies to reduce wild animal suffering, such as providing resources following natural disasters and vaccinations to combat diseases.

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