The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
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Avian cognition and the implications for captive parrot welfare

HS Starenchak Baukhagen and MD Engell*

North Carolina State University, Department of Biological Sciences, David Clark Labs 150, Box 7617, Raleigh, NC 27695, USA
* Contact for correspondence: hsstaren@ncsu.edu

Abstract

Previously assumed to be unintelligent animals, many species of birds display high levels of cognition and may even possess conscious awareness. In particular, both corvids and parrots have been the focus of cognitive research including studies on problem-solving, social intelligence, and sentience. Despite their similar neural architecture and cognitive abilities, the laws regarding these two families of birds differ greatly. In the United States, it is illegal to keep corvids as pets. Parrots, however, are one of the most commonly kept pets in America, although their care in captivity remains largely unregulated. Captive parrots suffer from a number of medical and psychological issues and experience high rates of neglect and abandonment. At the same time, wild parrot populations are dwindling due both to habitat loss and capture for the pet trade. This review examines the novel findings on avian cognition and applies them to the potential ethical implications of keeping parrots in captivity. In addition, suggestions for future directions are presented, including the development of legislation to protect captive and wild parrots.

Keywords: *animal ethics, animal welfare, avian cognition, captive parrots, parrot welfare, psittacines*

Introduction

Parrots are one of the most popular companion animals in the United States, with an estimated 7.5 million individuals housed in 3.5 million households (American Veterinary Medical Association [AVMA] 2018). Despite their popularity, captive parrots experience high rates of rehoming, neglect, and abandonment (Engebretson 2006; Tweti 2008). There are dozens of parrot-only rescue and rehoming organisations within the US, which house relinquished, abandoned, and abused parrots. The total number of captive parrots in the US is likely closer to 50 million birds when those in rescues are considered (Tweti 2008). The overwhelming number of parrots in foster organisations demonstrates the need most bird owners have of eventually finding their avian companions a new home. While the long lifespan of parrots contributes to the necessity of multiple homes, frustration and lack of sustained interest are also significant factors. Parrots are loud, messy, and expensive. The most commonly reported reason for their abuse and relinquishment is excessive screaming (Meehan *et al* 2003; van Zeeland *et al* 2016). Parrots require regular social interaction and mental stimulation and can become aggressive and excessively loud if ignored or neglected (Kelly *et al* 2007). Lack of enclosure complexity, minimal opportunities to forage, and the reduction of the ability to engage in natural behaviours are all linked to the development of stereotypic behaviours which are difficult to curtail (Paul-Murphy 2016). These challenging requirements for extensive stimulation, enrichment, and social interaction stem from their high levels of intelligence (Engebretson 2006). By presenting the current research findings on captive parrot cognition and veterinary medicine, this review aims to demonstrate the causes behind these abnormal and damaging behaviours as well as highlight the negative welfare implications associated with keeping intelligent birds in unsuitable captive environments.

Wild parrots are flock animals that spend the majority of their day foraging and interacting with conspecifics (Engebretson 2006; Kelly *et al* 2007). Captive parrots, with social needs identical to that of their wild counterparts, typically spend the majority of their time alone in relatively small cages, presented with minimal or no chances to forage, fly, or interact with other members of their own species (Lumeij & Hommers 2007; Grant *et al* 2017). While human interaction is important for pet parrots, it is not a suitable replacement for contact with parrots of the same species. Additionally, much of the information commonly presented to parrot owners on husbandry is outdated and does not account for modern research into parrot behaviour, cognition, and physiology (Tweti 2008; Grant *et al* 2017). As such, this review seeks to use the modern findings on avian cognition to show that these long-lived, highly intelligent animals would benefit from welfare laws regarding their care in captivity. Based on the research presented herein, these laws should cover several

aspects of captive parrot care and husbandry, including but not limited to: preventing sale before weaning, discouraging or eliminating human hand-rearing of young birds, describing minimum cage size and nutritional requirements, and implementing mandatory housing with conspecifics for parrots of certain species. With these laws in place, the sale of juvenile birds could be significantly reduced. Proper education of all potential parrot owners should be a necessity and would be easier to implement if welfare laws were established. Prospective bird owners should be encouraged, if not required, to foster or adopt parrots from established parrot rehoming organisations. Not only would these guidelines improve the welfare of captive parrots and decrease the number of neglected and rehomed parrots, it would also diminish the need to capture wild parrots for the pet trade, many of which are endangered (Engebretson 2006; Kelly *et al* 2007; Tamungang *et al* 2016). Furthermore, this review highlights the gaps remaining in the modern understanding of avian cognition and medicine, both of which directly impact captive parrot welfare. This demonstrates the need for greater research to be conducted on parrots, both in the wild and in captivity. With these welfare implications in mind, future research should focus on parrots kept in homes, sanctuaries, and zoos as opposed to lab-rearing birds specifically for scientific inquiry.

Materials and methods

To conduct this review, approximately one dozen search terms were used across multiple search platforms. Phrases included, 'parrot intelligence', 'avian cognition', 'captive avian welfare', 'African Grey', 'parrot evolution', 'parrot welfare', 'comparative cognition', 'avian neuroscience', 'corvid intelligence', 'animal welfare', and 'animal cognition.' Searches took place from January 1, 2020 until January 26, 2021. There were no restrictions placed on search terms; all relevant information was referenced, regardless of date, country, research institution, or author, however preference was given to research that specifically examined captive parrots. Several databases were searched, including EBSCOhost: APA PsychInfo, Google Scholar, PsychArticles, and PUBMED. All databases were accessed through North Carolina State University Libraries.

Additionally, information was gathered from six conferences attended by the primary author from 2014 until 2020, with three of the conferences taking place in 2020. These include the biennial conference of the parrot welfare and education organisation, Phoenix Landing (2014, 2016, 2018, 2020), the annual conference of the American Federation of Aviculture (2020), and the Seventh International Conference on Animal-Computer Interaction (2020). During these conferences, detailed notes were taken by the author. In 2014, 2016, and 2018, the Phoenix Landing Conference was held in Asheville, North Carolina, USA. In 2020, all conferences took place virtually, with lectures recorded and posted online for attendees to reference after the live presentation. Lectures were included if they added substantial knowledge on captive parrot care, cognition, or veterinary medicine beyond what could be found in the literature.

Criteria for inclusion included relevance, timeliness, application, and species studied. If reference articles were considered important, they were directly related to the search terms. Papers were selected based on their focal species, research techniques, and overall findings. Those that highlighted intelligence or cognitive processes in captive parrots were considered important for aspects of welfare. Specifically, research that explored parrot sociality, abnormal behaviours, or wild behaviours missing from captivity, such as foraging, highlighted the direct impacts on captive parrot welfare. A few secondary sources were referenced, as some knowledge about pet parrots has not yet been presented in peer-reviewed literature, but rather comes from parrot owners and rescue organisations. Since this review covers topics related to captive parrot welfare with a focus on parrots kept in homes, these aspects were considered important. Several print books were also referenced, which have been read over time by the primary author but were revisited during 2020 for the purpose of writing this review.

Avian cognition research

Avian intelligence is a swiftly growing area of animal behaviour research, with novel understandings of corvid and psittacine intelligence rapidly arising (Gunturkun & Bugnyar 2016; Auersperg & von Bayern 2019; Picard *et al* 2019). This research provides substantial evidence that birds are intelligent animals capable of suffering in understimulating, unnatural captive environments. Research with crows not only demonstrates their large brain-to-body ratio and extensive neocortical regions, but also highlights the adaptability and flexibility of the avian mind (Olkowicz *et al* 2016). Notably, carrion crows (*Corvus corone*) display the neural functioning underlying sensory consciousness and are thus likely able to experience sentience in a manner similar to humans (Nieder *et al* 2020). The amount of research conducted on the intelligence of birds in the order Psittaciformes has also increased in the last few decades. Among the findings are those that indicate significant levels of cognition (Kaufman *et al* 2013; Colbert-White *et al* 2015), sociality (Diamond & Bond 2003; Picard *et al* 2019; Hobson *et al* 2020), and intelligence (Pepperberg 2006; Clements *et al* 2018). Understanding the evolutionary pressures that have shaped such high levels of intelligence allows researchers to develop insights into the development of cognition in these animals. For example, being exposed to variations in their natural climate is believed to be a prerequisite for parrots to evolve larger, more developed brains (Shuck-Paim *et al* 2008). Both New Caledonian crows (*Corvus moneduloides*) (Hunt 1996) and Goffin's cockatoos (*Cacatua goffiniana*) (Auersperg *et al* 2012) have been shown to create tools, one of the hallmarks of traditional intelligence. Unstable environments require flexibility in behaviour, which highlights the importance of learning and the large, complex parrot brain.

Developing a complex neural structure is thought to be a prerequisite to experiencing higher levels of intelligence. As extant descendants of dinosaurs, modern-day birds have been evolving in their niches for millions of years and some are

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particularly well endowed neurologically (Butler & Cotterill 2006). Crows and parrots have ratios of brain-to-body mass comparable to whales and primates, in addition to complex social structures. These characteristics are often associated with animals that possess high levels of cognition and mental ability (Gunturkun & Bugnyar 2016). Hyacinth macaws (*Anodorhynchus hyacinthinus*) have been reported to possess the largest brain-to-body mass of any avian species (Diamond & Bond 2020). Additionally, parrots have many neurons compacted into dense brain areas, surpassing neuronal numbers in primate brains of similar mass (Olkowicz *et al* 2016). Substantial numbers of densely packed neurons enable corvids and psittacine birds to experience the higher levels of cognition once thought only possible with the sulci and gyri of mammalian species (Gunturkun & Bugnyar 2016). Since birds are adapted for flight, natural selection in parrots likely led to a brain structure able to deal with the demands of flight while still maintaining highly complex neural circuitry (Butler & Cotterill 2006).

Behavioural research on captive and wild parrots indicates the cognitive abilities of these birds. One of the most well-known and long-running parrot research endeavours was conducted with Alex, a male Congo African Grey parrot (*Psittacus erithacus*). Dr Irene Pepperberg worked with Alex for nearly 30 years, until his death in 2007 (Pepperberg 2009). When training Alex and other Grey parrots, Arthur, Athena, and Griffin, Pepperberg used a technique called the 'model-rival method' (Pepperberg 1999). Pepperberg would present an object to another human lab member in front of the birds, ask the person what the object was, and if they correctly identified it, they would receive the object. Alex was encouraged to interrupt the lab member if he knew the correct answer and would be rewarded with the object if he answered correctly. Through this method, Alex learned numerous concepts, including colours, numbers, shapes, and English labels for over one hundred objects (Pepperberg 1999, 2006). Alex demonstrated object permanence and created novel labels for unknown objects, spontaneously calling cake 'yummy bread' and a grape 'bannery', a previously untaught combination of the words 'banana' and 'berry' (Pepperberg 2009).

Beyond the Alex studies, research with other parrot species provides evidence of higher levels of intelligence, including playfulness and musicality. Play is a form of explorative learning in which animals gain novel understandings of the objects in their environment. Playful behaviours have been correlated with the development of problem-solving abilities (Auersperg *et al* 2015). Playful behaviours are typically observed in young animals but may continue throughout the lifespan in more slowly developing species (Fagen 1977). Social play has been primarily reported in cognitively advanced species such as humans, primates, and cetaceans (Lewis & Barton 2004; Auersperg *et al* 2015). Numerous species of parrots and corvids have been documented engaging in playful behaviours at all ages and social play is common in numerous bird species including ravens, cockatoos, and keas (*Nestor notablis*) (Diamond & Bond 2003; Auersperg & von Bayern 2019; Kaplan 2020). A study examining play behaviour in multiple parrot and corvid species found that Goffin's cockatoos were more likely than New Caledonian crows to combine multiple play objects together, and were the only species examined to spontaneously engage in ring-stacking (Auersperg *et al* 2015). In addition to social play, the kea has also been observed engaging in 'contagious laughter' a behaviour previously observed only in mammals, such as humans, rats, and chimpanzees (Schwing *et al* 2017). Palm cockatoos (*Probosciger aterrimus*) have been reported creating tools which they use to produce rhythmic beats, highlighting a close relationship to drumming in humans (Heinsohn *et al* 2017). Another study found that an African Grey parrot exhibited spontaneous movement to music, with head bobbing correlated to the beat of the music (Schachner *et al* 2009). Birds are highly vocal animals. In the wild, parrots communicate with loud songs and calls, which travel easily through dense rainforests in which many species evolved. For this reason, music has been recommended as a form of enrichment for captive birds (Robbins & Margulis 2016; Williams *et al* 2017). Parrots are adept at recreating sounds in their environment using their syrinx, a sound-producing organ in their throat which moves in all directions, enabling them to imitate most sounds they hear. Additionally, some researchers postulate that certain species of parrots demonstrate effective use of human language to communicate, although this remains a controversial topic among linguists (Pepperberg 1999, 2007; Kaufman *et al* 2013).

Studies into the communicative abilities of parrots highlight fascinating parallels between human and avian communication. A Congo African Grey parrot has been shown to be more likely to use English words as opposed to non-verbal sounds after having a verbal request rejected or ignored by her owner (Colbert-White *et al* 2015). Analysis of the vocalisations, using a hyperspace analogue to language model, found that the parrot's verbal communication was highly contextual and appropriate to the situations in which they were given (Kaufman *et al* 2013). English word utterances from the bird were unlikely to occur without context, which suggests an awareness of what the words meant and the appropriate times to use them. African Grey parrots, considered by some to be the most verbally expressive species of parrot, likewise tend to behave differently depending on whether their verbal requests are accepted or denied by the human they are interacting with (Pepperberg 2009; Colbert-White *et al* 2015).

Other research has found that footedness — which foot is favoured when manipulating objects — is correlated to both lexicon size and cognitive ability in parrots (Snyder & Harris 1996; Magat & Brown 2009). Snyder and Harris showed that right-footed birds had larger vocabularies than parrots who favoured their left foot. This suggests that the left and right hemispheres of parrot brains may be lateralised, highlighting another potential parallel between humans and parrots. While other birds, such as chickens and pigeons, have been shown to possess brain lateralisation, the extent to which this phenomenon affects cognitive

ability is not fully understood (Rogers 2021). Magat and Brown (2009) went on to demonstrate that parrots that preferred either their right or left side performed significantly better on cognitive tasks than those that had no preference. Additionally, these results were more pronounced when the task was more difficult. Considering both vocal ability and intelligence are reasons parrot owners may desire a particular species of bird, understanding the communicative and cognitive abilities of parrots is important for their overall welfare in captivity (van Zeeland *et al* 2016). Furthermore, this research provides evidence of the substantial cognitive abilities in parrots and demonstrates the underlying neural architecture that is often neglected in captive environments.

Behavioural and medical issues of captive parrots

Behavioural issues represent outward displays of internal distress in captive parrots. Common problems include feather-damaging behaviours, route tracing, intentless and repetitive movements, excessive screaming, and aggressive behaviours, such as biting and destruction of the environment (Lumeji & Hommers 2007; Cussen & Mench 2015; De Almedia *et al* 2018). Though relatively little is known about wild parrot behaviour, it is unlikely that these behaviours occur in wild parrots (Mellor *et al* 2018). A number of factors contribute to the development of these behaviours in captive birds. The lack of foraging opportunities for captive parrots can lead to a disproportionate amount of time spent sitting idly in their cage (Meehan *et al* 2003). In the wild, parrots spend up to eight hours a day foraging for food, which requires a great deal of physical and mental effort (Engebretson 2006). Restricted to a cage with little to no opportunity to forage, birds become under-stimulated and bored. Boredom is a mental state shown to increase maladaptive behaviours in captive species (Burn 2017). In recent years, the implementation of enrichment items to reduce boredom and increase overall welfare in zoo animals has become well established (Greco *et al* 2016; Goswami *et al* 2021). Enrichment in the homes of captive wild species is much less commonplace. Unfortunately, the impact stereotypic behaviours can have on parrots and their owners is much more detrimental for birds kept in private homes than it is to those kept in public zoos and aviaries. Zoos and institutions accredited by organisations such as the Association for Zoos and Aquariums (AZA) are bound by their accreditation to create enriching, safe and fulfilling environments for the animals in their care. Pets in homes, as well as birds in non-accredited institutions, are not bound by the same codes and often have major gaps in their care (Engebretson 2006). This is an ethical concern which could be addressed with greater legislative protections for these animals.

The maladaptive and stereotypic behaviours commonly observed in captive parrots can lead to distress in both parrots and their owners. Some researchers consider these behaviours to be analogous to mental illnesses in humans (Garner *et al* 2002). Parrots that have lived through trauma and abuse are described as having a type of post-traumatic stress and exhibit similar levels of fear, avoidance, and hyper-vigilance as humans diagnosed with post-traumatic stress disorder (Siebert 2016). Parallels also exist between feather-mutilating behaviours and both obsessive compulsive disorder and trichotillomania (Bordnick *et al* 1994; Braitman 2014). Such comparisons can be helpful in identifying and drawing attention to these conditions, and the neural mechanisms underlying the behaviours may be similar. However, mammalian and avian anatomy are each unique, and greater insights into the function of the parrot brain are necessary to draw more definite conclusions into how these disorder-like behaviours develop. For example, the neurological basis of some abnormal repetitive behaviours may stem from alterations in the functioning of neurotransmitters such as dopamine and serotonin, but the invasive studies needed to support these claims have not been conducted (Garner *et al* 2002; Mellor *et al* 2018). Due to both their cognitive abilities and dwindling wild populations, euthanasing parrots for research is considered unethical, and thus *in vivo* experiments on parrot neuroanatomy and physiology are practically non-existent. Some parrots with self-mutilating behaviours have been treated with psychotropic drugs, such as haloperidol, an anti-psychotic medication used to treat schizophrenia in humans (van Zeeland 2020). While some successes have been reported with this type of treatment, the side-effects of these medications can be severe, including anorexia, depression and seizures. The use of drugs is not recommended for most birds, as proper husbandry and increased enrichment can often ameliorate behavioural issues without medical intervention.

General health and physiology contribute to the development of abnormal behaviours. Ongoing research with African Grey parrots indicates that a large number of captive Grey parrots suffer from osteoporosis (Echols 2020). This results from a combination of lack of direct sunlight, inadequate amounts of exercise, and improper diet. Some of the self-mutilating and destructive behaviours observed in these birds may be linked to the underlying degree of bone degeneration. Parrots are prey animals that are adept at hiding medical issues, and often do not show symptoms of illness until it is too late to treat them. At the same time, very few parrot owners have ever taken their parrot to a veterinarian, with previous research indicating that only 11.8% of owners take their parrots for a medical exam within their lifetime (Engebretson 2006). While dog owners spend an average of $US410 per year on veterinary care for their pets, that number is an astonishingly low $US40 annually for parrots (AVMA 2018). Regular examinations, blood tests, lab work-ups, and appropriate medical treatments are crucial elements of providing parrots with proper husbandry, and should not be considered optional (Grant *et al* 2017). With modern veterinary research finding many previously unknown medical issues to be common in captive avian species, the prevention and treatment of these underlying conditions should be considered a mandatory element of keeping parrots in captivity. Implementing welfare laws for parrots could help to ensure that parrots kept in captivity receive regular veterinary care, preventing illness and premature death.

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Potential causes of maladaptive behaviours in captive parrots

The abnormal behaviours observed in captive parrots are likely due to a multitude of factors as opposed to being triggered by one single stressor. This means understanding how these behaviours develop is difficult. It also makes finding a simple, one-size-fits-all solution for mollifying such issues unlikely. Parrots with maladaptive behaviours are frequently, but not always, subject to improper husbandry that does not account for their broad range of social, nutritional, environmental and physical needs (Mellor *et al* 2018). A multidimensional approach is necessary when attempting to understand how and why the behaviours in question have developed. Similarly, understanding the behaviours and environmental constructs of wild parrots allows researchers to better comprehend the elements that make up a proper environment for a captive bird. This, in turn, leads to updated husbandry recommendations and practices that improve parrot health and allow parrots and their owners to cohabitate in a more peaceful and engaging environment, increasing overall welfare.

In modern aviculture, hand-rearing parrot chicks has been accepted as the standard for decades (van Zeeland *et al* 2016). Unfortunately, this practice may be detrimental to proper development, leading to a lifetime of medical and behavioural anomalies not found in wild or parent-raised counterparts (van Zeeland *et al* 2016). Previous research indicates the pitfalls of preventing parents from raising their own offspring and highlights the need for further studies into how hand-rearing affects captive birds (Aengus & Millam 1999; Collette *et al* 2000). For several decades, most parrot breeders have removed eggs from their parents and incubated them artificially. From hatching onward, the chicks are fed only by the human breeder and have no interaction with their parents (Engebretson 2006). Though commonplace in parrot breeding, it would be considered preposterous if dog or cat breeders did the same. Which begs the question: why is this practice considered necessary for raising captive birds? Because parrots are no more than a generation or two removed from the wild, it was long assumed that hand-rearing would make birds more tame and gentle and thus more likely to bond with humans. To date, no research supports this idea. Instead, removing young parrots from their parents may result in a multitude of health and behavioural problems that severely impact their quality of life (van Zeeland *et al* 2016). Research suggests that hand-reared parrots are more likely to develop stereotypic behaviours and less likely to engage with enrichment than birds that were raised by their parents (Grant *et al* 2017).

Other research has shown that handling neonatal parrots causes chronic stress-like responses as well as decreasing the functioning of both the thymus and cell-mediated immunity (Collette *et al* 2000). Wild parrots spend months weaning their offspring, with some species of larger parrots caring for their young for a year or more post-fledging (van Zeeland *et al* 2016). As with most intelligent species, parrots have an extended developmental period, more similar to apes than to dogs and cats, which allows for both increased brain development and longer periods of learning (van Zeeland *et al* 2016). Other species of intelligent birds, such as corvids, exhibit lifelong relationships with their parents and siblings (Clayton & Emery 2007). Not only does hand-rearing remove the necessary social aspect of the parent-offspring relationship, but it also does not provide the same nutritional profile as would occur with parent birds. As nutritional deficiencies are one of the potential causes for behavioural and medical ailments, this aspect of hand-rearing needs to be examined. Furthermore, premature weaning in other animals can elicit lifelong negative behaviours, such as increased anxiety and aggression in dogs (Hurt *et al* 2015), cats (Ahola *et al* 2017) and mice (Kikusui *et al* 2004). It is logical that with their long lifespans and marked sociality, similar and perhaps more severe effects would be common in prematurely weaned parrots. Hand-rearing parrots is becoming less prevalent in some countries and is banned in The Netherlands, although it remains common in the United States (Grant *et al* 2017). Welfare laws for parrots may address the issue of hand-rearing birds as well as prevent the sale of unweaned parrots.

A major element of captive parrot husbandry lacking in many homes is a proper diet and the opportunity to forage for their food. In the wild, parrots eat a wide variety of foods, including flowers, fruits, nuts, seeds, grasses, insects and other plant material (Crean 2020). This wild diet is variable and changes with the season, providing a broad range of highly nutritious and readily available foods (Burger 2001). Not only does eating this wild diet ensure optimal health, searching for, learning about, and remembering where the plants that have the best-tasting fruits are requires substantial metal effort (Orosz 2014; Crean 2020). This important detail of parrot diet and husbandry is almost entirely overlooked in modern aviculture. While some avian experts are beginning to consider the importance of an 'ancestral diet' for captive parrots, much of the widely available processed food lacks this updated understanding of bird nutrition. While improvements have been made by some food manufacturers in switching from a seed to a pellet-based formula, these foods are still highly processed and offer little variety in texture, colour, flavour, or nutritional value, which is in stark contrast to the food available to wild parrots. Additionally, there is no challenge in feeding from a bowl, which prevents captive parrots from using the cognitive abilities they possess to search for, obtain, and manipulate food items (Meehan *et al* 2003). Without being required to spend the significant amount of time and energy that wild birds must in order to eat, captive parrots spend an unbalanced amount of time sitting idly in their cages, giving abnormal behaviours time to develop. To increase welfare for captive parrots, the types of food and the methods through which they are presented must be considered.

Another important factor of parrot health is exposure to natural sunlight. In humans, UV exposure is linked to proper vitamin D synthesis. Vitamin D is crucial for the development of bones and the absorption of calcium and is associated with an increased mood (Penckofer *et al* 2010). While

there are few studies of vitamin D deficiency in parrots, there likely exists a significant difference in levels between captive and wild birds. Because of the link between vitamin D exposure and mood, it is possible that the welfare of many captive parrots suffers due to lack of direct sunlight and the resulting vitamin D deficiency. Most captive parrots are kept indoors all year round, preventing them from obtaining regular sunlight exposure, and likely resulting in a deficiency of vitamin D and depressed mood. Parrots are unable to use vitamin D2, which is the primary form of vitamin D provided in the diet, indicating UV exposure is necessary for avian health (Orosz 2016). It has been suggested that UV exposure might be more advantageous for species that typically spend greater amounts of time in the sun in the wild, such as African species, although few parrot breeders provide species-specific husbandry requirements to parrot owners (Stanford 2006). In addition, biological markers of stress, such as corticosterone, are reduced with UV exposure (Maddocks *et al* 2002). To mitigate potential negative effects from lack of sunlight and vitamin D production, captive parrots should receive natural sunlight exposure by being taken outside. The ability to experience the sun and interact with all aspects of the natural world in which they have evolved stimulate their brains and may prevent maladaptive behaviours associated with life in captivity.

Considering the amount of time captive birds spend in their cages, lack of exercise is a serious concern. Wild parrots spend a significant amount of time each day flying, climbing, and foraging (Kelly *et al* 2007). Not only does free-flight engage their muscles, remembering where to go and how to get there requires significant mental effort. This flight-specific use of their cognitive abilities is all but completely eliminated in captivity. While wing clipping has become less common in recent years, most parrots do not experience free-flight like their wild counterparts. As many parrots self-mutilate their feathers, some captive parrots are unable to fly due to the destruction of flight feathers (Tweti 2008). Regular exercise in humans is linked to reduced rates of anxiety and depression, due in part to the increased availability of neurotransmitters associated with positive mental health and well-being, such as serotonin (Craft & Perna 2004). While research on exercise and well-being in parrots is lacking, if neurotransmitter imbalance is suspected as a potential cause of maladaptive behaviours, it is possible that lack of free-flight and exercise are at least partially responsible. When parrots fly, small feathers known as filoplumes become activated, stimulating the production of serotonin (Orosz 2014). This is believed to affect both mental state and well-being. As animals that experience high levels of cognition, it is likely that parrots are able to suffer from depression. While free-flying may not be recommended for all captive parrots, opportunities for exercise can easily be presented for most captive birds. Even birds who do not have their flight feathers would benefit from increased time outside of the cage, as chances to climb, walk, and explore their environment have positive effects on overall quality of life. Furthermore, cardiovascular disease is so frequent as to potentially be the most common cause of premature death in captive parrots (Echols 2020). As with humans, cardiovascular disease is often related to diet, but lack of exercise also significantly increases the risk of developing atherosclerosis and obesity, both of which are common in captive parrots, highlighting another welfare concern associated with captivity.

As highly social species, parrots in the wild spend their lives in flocks, interacting with their conspecifics on a regular basis (Picard *et al* 2019). Communication with the flock is important in maintaining social bonds as well as avoiding predation (Kelly *et al* 2007). The sociality of parrots is believed to have helped shape their intelligence, with social play often identified as a requisite for developing certain aspects of intelligence, such as insight (Diamond & Bond 2003; Hobson *et al* 2020). Unlike most other common pet species, parrots are not domesticated, and are still driven by their natural tendencies and instincts (van Zeeland *et al* 2016). Thus, it is safe to assume that captive birds have the same strong need to belong in a flock structure. While human companionship may fulfill some of these needs, it is not comparable to interaction with birds of the same species (Kelly *et al* 2007). Although some parrot owners keep more than one bird, they are often of a different species. Many homes do not house multiple parrots which can be extremely stressful for a captive bird, especially if left alone during much of the day (van Zeeland *et al* 2016). When the lack of social interaction is combined with other aspects of life in captivity such as poor diet, confinement to a small cage, and lack of mental stimulation, parrots are at an increased risk of developing self-mutilating behaviours that can be difficult to eliminate (Grant *et al* 2017). Laws requiring social birds to be kept in conspecific groups are non-existent, but there is some precedent for mandating social animals be housed with their own kind. In Switzerland, it is illegal to keep a guinea pig singly housed due to the negative effects being alone can have on a social species (Andrei 2021). Conducting research on how interaction with conspecifics affects behaviour and physiology would benefit captive parrots, and potentially lead to similar regulations for their captivity.

Finally, it is worth noting the near complete lack of choice that captive parrots experience in their daily routine. Wild parrots make many decisions each day, such as when to leave the roosting site, where to forage for food, and with whom to interact. These decisions engage their minds and require significant mental effort (Meehan *et al* 2003). As animals with substantial cognitive facilities, the diverse number of activities decided upon each day by parrots in the wild are necessary for both welfare and proper cognitive functioning. While similar research with parrots has not been conducted, a study examining brain alterations in captured songbirds found that wild black-capped chickadees (*Poecile atricapillus*) lose up to 23% of their hippocampal volume after being in captivity for six weeks (Tarr *et al* 2009). It is possible that eliminating the freedom to make choices diminishes captive parrots' cognitive abilities and changes their neuroanatomy. For the most part, captive parrots are kept in small cages with wooden, non-interactive toys, presented with open food bowls, and left home alone

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most of the day. While this is not true for all captive parrot homes, it is likely that the majority of parrot owners have not considered how little freedom their birds have to make choices throughout their day. Auersperg and her team (2015) found that when given a choice of which objects to manipulate, some of the birds examined had specific preferences unique to the species. Goffin's cockatoos chose to interact with a yellow object more frequently than red or blue ones while New Caledonian crows preferred to play with balls as opposed to rings or cubes. Other research has shown that individual differences in Grey parrots impact their playful behaviours, and these differences determine whether or not they are likely to engage in contrafreeloading (Smith *et al* 2021). When given a choice of which toys to play with, when to come out, or which foods to eat, captive parrots experience a small amount of the freedom wild parrots have on a daily basis. This lack of choice in most captive parrots not only prevents birds from using their substantial cognitive facilities, it may also lead to a sense of boredom and helplessness, both of which increase the likelihood of maladaptive behaviours (Garner *et al* 2002; Burn 2017; Brando & Buchanan-Smith 2018; Meagher 2019). Little formal research has been published on the impact choice, or lack thereof, has on animal welfare. To create updated husbandry guidelines that improve captive avian welfare, it will be crucial to consider all of the natural behaviours that parrots in captivity are unable to display.

Ethical considerations of keeping parrots in captivity

While many parrot owners, and pet owners in general, consider the animals in their homes to be an important part of their family, not all homes are suitable environments for captive birds (Grant *et al* 2017). The overwhelming number of parrots in rehoming and rescue organisations, as well as the high level of maladaptive and stereotypic behaviours seen in captive parrots, supports this unfortunate fact. Therefore, the ethical considerations of keeping such highly intelligent species in captivity must be discussed. Research on the cognitive abilities of parrots suggests that they likely possess both sentience and consciousness (Butler & Cotterill 2006; Nieder *et al* 2020). It has been argued that animals exist for their own intrinsic purpose and that, because a life devoid of pain is preferable to one full of suffering, it is unethical to cause undue suffering to animals (Korsgaard 2018). While many scientists and philosophers postulate that most, if not all, non-human animals kept in captivity deserve a life free of discomfort and pain, those that have longer lifespans and greater cognitive abilities are more likely to remember their suffering, indicating a greater need for protections. This makes captive parrots a strong candidate for extensive legal protections. Even if a direct comparison between human and parrot emotionality and sentience cannot be made, the research presented provides substantial evidence of the parrot's ability to think, feel, and thus suffer in a manner that is comparable to at least a medium-sized primate (Braitman 2014; Gunturkun & Bugnyar 2016; Nieder *et al* 2020). However, despite this large body of evidence, the legislation protecting birds is severely lacking in most countries, including the US. Even birds used in research labs in the US are not protected from unnecessary suffering, as birds are not currently covered under the Animal Welfare Act, which was created to ensure minimum care stands for animals used in research, bred for commercial sale, or presented to the public. The US Department of Agriculture (USDA) is currently considering adopting minimum care standards for captive birds not used in research, but these regulations have not yet been finalised and are being argued against by some parrot breeders and owners (USDA 2020). With outdated husbandry information being disseminated by a large number of parrot breeders and pet retail chains, and avian protection laws practically non-existent, a notable moral dilemma arises: is keeping parrots in captivity ethically acceptable knowing they are likely to suffer some amount of distress during their lifetime? Can parrot owners present ample enrichment opportunities that, in turn, increase welfare enough to balance out the potential suffering of their animals?

Avian cognition research is generating large amounts of data regarding intelligent species of birds. This review presents numerous examples of higher-level cognitive functioning previously thought to exist only in humans, non-human primates, and a select number of highly intelligent mammals, such as elephants and whales. This newly discovered information brings a greater understanding of how keeping such intelligent species in captivity can be detrimental to their health, well-being, and overall quality of life. Preventing social species from interacting with conspecifics should be a moral consideration, given that loneliness creates suffering in social species and singly housed parrots are more likely to develop stereotypic behaviours (Williams *et al* 2017; Brando & Buchanan-Smith 2018). Like social bond formation, most wild behaviours are severely limited in captive parrots, leading to a decreased quality of life and the development of maladaptive behaviours lacking in the wild. If parrot owners are unable to introduce elements critical for maintaining a healthy, well-adjusted bird, then it may be best to eventually eliminate the keeping of parrots as pets. This is likely to be contested by parrot owners, many of whom spend their entire lives and share a deep emotional bond with a particular bird (van Zeeland *et al* 2016; Grant *et al* 2017). Thus, instead of eliminating captive parrot ownership, steps should be taken to mitigate maladaptive behaviours and increase the overall quality of life of all parrot species in captivity. In order to treat these birds in a manner that is ethical according to novel understandings of parrot behaviour, significant changes must be made to the ways in which captive parrots are obtained, raised, and kept in homes.

An issue parrot owners face that owners of most other pet types do not is the fact that a parrot is likely to outlive its owner (Engebretson 2006). As such, considerations must be made for what will happen to the bird after its owner passes away or is no longer able to care for the animal. Some owners will their birds to their next of kin. This can result in an individual feeling forced to take care of a parrot that they do not want or do not know how to care for. In addition, the parrot itself may be suffering the loss of its owner, as parrots

have been reported to mourn the loss of both human and avian companions, expressing grief, sadness, loss, and depression (Tweti 2008). This trauma and stress may result in maladaptive behaviours such as aggression, screaming, and biting, all of which can make the new owner even less willing or able to properly care for it (Siebert 2016).

There are a few changes to the way parrots are kept and acquired that can help mitigate this issue. Instead of purchasing a young bird, which can live upwards of 100 years depending on the species, prospective parrot owners should be encouraged, if not required, to foster or adopt an older parrot. Due to their high levels of intelligence, parrots are highly adaptable (Schuck-Paim *et al* 2008). If a proper environment, adequate diet, ample enrichment, and significant social interaction are provided, most, if not all, parrots will be able to adapt to a new home. Other means of addressing the long lifespan of parrots include increasing the number of parrot welfare organisations that retain ownership of the parrot across its lifespan. One such example is parrot welfare and education organisation, Phoenix Landing. All parrots relinquished to Phoenix Landing have a home for life. That is, if at any time a fostered or adopted parrot is no longer cared for by its owner, Phoenix Landing, has legal ownership over the bird and will reacquire the animal. While not necessary for other pet species, this succession of homes needs to be considered for most parrots. Ensuring that more organisations like Phoenix Landing exist and are funded will decrease the number of parrots in poorly suited homes, as well as alleviate some of the ethical concerns associated with keeping a bird that is likely to outlive its owner.

The treatment of captive birds by breeders and pet stores, who often sell birds without providing proper husbandry or life history information to the owners, is another ethical concern. Since parrots are at significant risk of being rehomed, breeders and pet stores should not be able to sell pet birds to everyone who wants one. While no pet should ever be purchased as an impulse item or a gift, parrots in particular are wild animals that do not make ideal pets (Engebretson 2006). They are loud, messy, expensive, experience a wide range of emotions, and possess strong beaks, capable of inflicting potentially significant wounds. No one should be able to purchase a parrot of any size without demonstrating they have conducted research into the care, lifespan, and personality of said parrot. Laws regarding the proper husbandry of parrots are necessary to the implementation of such a regulation. Breeders and pet stores should be required to provide substantial, up-to-date husbandry and medical information for all parrots sold. Prospective parrot owners should be denied the right to purchase a species of bird if it is unlikely that they will be able to provide the proper level of care for the animal. While these suggestions may seem overbearing, the overwhelming number of parrots that display self-mutilating behaviours, as well as the thousands of birds in rescues, demands that strong efforts be made to ensure that all parrots are taken into homes willing and able to provide them a proper quality of life (Grant *et al* 2017). While no such federal law exists in the United States, California has a law mandating that all dogs, cats, and rabbits sold in pet stores be from adoption agencies (California Legislative Counsel 2017). It is a logical next step to include parrots in this legislature. In order to obtain a parrot, certain rehoming organisations like Phoenix Landing require an application, a home visit, an adoption fee, and attendance at no less than one class regarding the health, welfare, and keeping of captive parrots. Additionally, all birds are placed into their new homes as a foster situation. The home may adopt the parrot after two months if they decide that the parrot is a good fit. If the bird is not the right match for the family, the parrot is returned to Phoenix Landing or placed in another foster home. While supporting and funding such organisations may ameliorate some of the welfare concerns related to keeping parrots in captivity, captive parrot welfare regulations are necessary to ensure these animals are provided sufficient protections.

Animal welfare implications

Modern research into avian cognition repeatedly demonstrates the advanced mental abilities of parrots. As one of the most common pet species in the United States, with essentially no laws protecting them, the application of cognition research to welfare guidelines is of the utmost importance. Improving welfare for parrots will require research efforts from many different fields, ranging from comparative cognition and behavioural ecology to animal behaviour and veterinary medicine. Consideration of wild behaviour and increased understanding of avian cognition in captive settings can lead to improvements in the practice of parrot-keeping and aviculture. Additionally, by increasing the monitoring of wild parrots, it may be possible to reduce the numbers of birds taken from the wild for the pet trade. Working together, researchers across many disciplines can develop new understandings of parrot health and behaviour, ultimately leading to improvements in quality of life for these unique birds.

The findings in this paper present an obvious ethical dilemma for keeping pet parrots, as it highlights the ways they suffer in captivity. By offering opportunities for parrots to engage in natural species-specific behaviours, several of these behavioural and medical afflictions can be reduced, improving overall welfare. Greater opportunity to exercise choice may reduce the downtime in which maladaptive behaviours manifest. More time out of the cage increases the opportunity for exercise and social interaction. Eliminating wing clipping and encouraging regular flight and exercise increases wellness and mood and decreases risk of atherosclerosis. Offering a more nutrient-rich, whole plant-based diet fulfills nutritional needs and increases foraging behaviours, drawing again on the natural elements missing from a captive parrot's life. It is also crucial to replace outdated ideas on hand-rearing parrots and instead encourage co-parenting or parent-raised chicks.

Unlike the domesticated animals commonly kept as pets, parrots are still very much in touch with their wild nature. Their behaviours reflect the need for complex social groups, challenging environments, and a variable nutritious diet.

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Novel enrichment has the potential to ameliorate many of the issues associated with keeping parrots in captivity, including nutrition-related illnesses, premature death due to lack of exercise, stereotypic behaviours resulting from lack of choice and under-stimulation, and frequent rehoming due to maladaptive behaviours that cause owners to relinquish them. With their long lifespans, significant cognitive abilities, and propensity for physical and behavioural abnormalities in captivity, parrots require legislation in order to protect them. Though there is much work and research needing to be done, it is surely work worth doing in order to safeguard wild populations and improve the lives of captive parrots and their owners.

Declaration of interest

None.

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