Innovative behaviours and personality traits in captive kea (*Nestor notabilis*) as a model for the emergence of kea strike in wild populations

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Abstract

The personality traits of seven captive kea (*Nestor notabilis*) were investigated in terms of neophobia, problem solving ability, and innovation. The first objective was to compare the personalities of the birds and assess these in relation to demographic factors including age and sex, as well as looking at the effect of isolated versus group housing. Kea are known to require high standards of enrichment and sociality, so this information can be used to determine the effect their captive housing may have on important wild traits. The second objective was to observe whether particular personalities or demographic factors made a kea more innovative, or in this case more likely to attack a sheep. Kea strike is a phenomenon whereby kea attack sheep, which often die as a result. This conflict has led to approximately 100,000 kea being shot by farmers in retaliation, and as a consequence there has been a dramatic decline in the wild kea population.

In order to assess each individual's relative neophobia or neophilia, novel objects were presented to the kea and their reactions observed. Problem solving ability was measured by using a Multi-Access Box, which required the birds to use one of four different access routes to retrieve a food reward. To observe levels of innovation and the likelihood of kea strike emerging, a mechanical sheep analogue was used. This was made to resemble a sheep, and contained a food reward for the kea to find. The juveniles in this study were much more neophilic and adept at problem solving than the adults, and this is thought to be because juveniles are still learning about their environment and these traits are therefore highly beneficial to them. Only one juvenile successfully completed the sheep analogue task, and she was the most neophilic and adept at problem solving. This suggests that highly neophilic and explorative kea are more likely to develop innovative behaviours such as kea strike. Understanding the drivers behind kea strike is important if tools are to be developed to minimise the conflict in the future.

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Chapter 1: Introduction and literature review

1.1 Introduction

This thesis will investigate whether past housing and social conditions affects personality traits in kea (*Nestor notabilis*). The data obtained from this study will be used to look at the effect captivity and current enrichment programmes have on intelligence, but also whether this intelligence is related to personality (in regards to neophobia). It will also investigate the underlying factors of kea strike (kea's habit of attacking sheep) in order to help understand this issue and provide information that may help to minimise this conflict.

Kea are a species of parrot endemic to the South Island of New Zealand. They belong to the family *Nestoridae*, of which only two species are still extant, the other being the New Zealand kaka (*Nestor meridionalis*). The closest relative to *Nestoridae* is the kakapo (*Strigops habroptilus*), which is the only other member of the superfamily *Strigopoidea* (Joseph et al., 2012). Under the IUCN Red List, kea are classified as 'Vulnerable' with a decreasing population (Birdlife International, 2016). However under the New Zealand Threat Classification System, kea are classified as Nationally Endangered (category C 1/1, qualifier RR), which means there are a predicted 1,000 – 5,000 mature birds remaining, with a decline rate of 50-70%, and the species is Range Restricted (Robertson et al., 2017). The kea is therefore a New Zealand conservation concern, and there are actions in place to try and halt this decline and boost population numbers.

Kea are known as the only alpine parrot in the world, as their main habitat is within the Southern Alps of the South Island. However they are also known to breed in the temperate forests around Okarito, and these populations experience different environmental challenges and are exposed to different food sources (Greer et al., 2015). The kea was once a thriving species, and evidence suggests it was historically found throughout the entire country. Bones have been found in the Waitomo caves, indicating that 10,000 years ago kea inhabited the North Island (Holdaway & Worthy, 1993). This was during the last glacial period, at which time most of the island was covered in sub-alpine habitat and could therefore have supported the species (Holdaway & Worthy, 1993). A more recent study found three fossil records that suggest kea inhabited the North Island during the Holocene period, and it may therefore have been the appearance of humans that led to the extinction of this population rather than the changing climate (Tennyson, 2014). With the arrival of the first Maori settlers came overhunting and habitat destruction, but it was not until the European settlers came that numbers truly began to drop. Habitat loss became extreme as forests along the Southern Alps were burned down to make room for buildings and farms. As well as this, the introduction of new mammals meant competition for food and predators to which the birds were naïve (Temple, 1996).

A major setback for the kea came with the development of a phenomenon known as kea strike. This was first observed in 1867, when shepherds on the Lake Wanaka station noticed wounds on their sheep (*Ovis aries*) made from an unidentified animal (Temple, 1996). It was soon discovered that kea were responsible for this, something that was witnessed firsthand by James MacDonald in 1868. The birds were seen riding on the back of sheep, tearing flesh from their pelvis, and ripping intestines out through the holes. They also transmitted a bacterium (*Clostridium spp.*), which causes blood poisoning, and often led to the death of the infected sheep (Temple, 1996). This became such a problem for the farmers that the government placed a bounty on killing kea. It is thought that 120,000 birds were killed over 100 years until partial protection was provided (C. Reid, pers. comm. 2017). This meant farmers could still kill kea if they were caught attacking sheep, and it was not until 1986 that the species was given full protection under the Wildlife Act (Department of Conservation, 1996). Despite this, farmers today are still able to apply for a DOC permit to kill nuisance kea (Miskelly, 2014). Kea strike is one subject that there is very little research on. There are few resources that give any mention to it, and those that do exist are descriptive reports rather than research into why it occurs. While kea strike is less of an issue today, it is still something that affects farmers, and actions need to be put into place to minimise this human-wildlife conflict so we can focus on boosting population numbers.

Kea have been kept in captivity for many years, and captive breeding has historically been uncontrolled. In 1991 a coordinated management programme was produced in an attempt to use the current captive population for conservation purposes (Collen, 2011). The 1996 Captive Management Plan set a moratorium on breeding to try and reduce the number of captive individuals to a manageable size (Department of Conservation, 1996). The purpose of maintaining a captive population despite not having a captive breeding programme is for conservation advocacy, as well as research purposes (Department of Conservation, 1996).

The idea of a introducing a captive breeding programme is something that has undergone great debate amongst stakeholders, however it has been agreed upon that this would not currently be of benefit to the wild population (Collen, 2011). Threats to kea are uncontrolled in the wild, which means population numbers may not actually increase despite being supplemented from captive bred birds. It has been suggested that efforts would be better focussed on predator eradication, as this is the main reason population numbers are currently declining. Kea are also a slow reproducing species, particularly in captivity, which means it is likely that more chicks will be born in the wild than through a captive breeding plan (Collen, 2011). This stance may appear to be slightly conflicting given the fact that other New Zealand species do have captive breeding programmes, despite their threats also remaining in the wild. Some species can be placed on predator-free islands (e.g. saddleback (*Philesturnus carunculatus*) and hihi (*Notiomystis cincta*). However given their alpine environment, this is not a practical solution for the kea. The blue duck/whio (*Hymenolaimus malacorhynchos*) lives in fast-flowing rivers, another environment that is not found on predator-free islands (Glaser, 2010). Their main threats include human alteration of these rivers, as well as predation by stoats (*Mustela erminea*). These threats are still ongoing, but despite this, captive breeding still takes place. Even less endangered species such as the brown kiwi (*Apteryx mantelli*) are involved in captive breeding programmes. Operation Nest Egg involves the collection of kiwi eggs from the wild, which are then hatched and raised in captivity before being released back into the wild (Colbourne, 2005). It is apparent from these examples that that captive management programmes are successful in New Zealand, and despite the setbacks there may be the opportunity for this to be carried out on kea in the future.

Kea are a popular study species due to their high levels of intelligence and unique personalities. Studies therefore tend to focus on intelligence and behaviour, in an attempt to understand more about animal cognition and how this has evolved. A number of these studies have been undertaken overseas, and are therefore not aimed at conservation. A highly appraised example is the work of Auersperg, von Bayern et al. (2011), which part of this thesis is based on. They used a puzzle box to compare the cognitive abilities of kea and New Caledonian crows (*Corvus moneduloides*), and found out that although both species are very intelligent, this intelligence differs in tool using and non-tool using species. Such studies are important in learning more about the species as a whole.

This literature review will focus on intelligence in birds and how this is measured; the effect of housing conditions on behaviour; and conflict between humans and wildlife. This will then lead into my research question and methodologies.

1.2 Avian intelligence

Typically, studies of non-human intelligence are focused on primates, with research on birds focusing on behaviour and ecology. Recently however, it has been suggested that some birds (in particular the Order Psittaciformes (parrots) and Family Corvidae (crows, ravens, magpies etc.)) may have equivalent intelligence to primates (Emery, 2006). Comparing the intelligence of different species is a difficult task for a number of reasons. Firstly, designing a test that meets the cognitive demands of a range of species is near impossible. For example, a task which involves the use of tools will be better achieved by a tool-using species, which means it cannot necessarily be concluded that intelligence is higher in that species than in a non-tool using species (Auersperg, von Bayern, et al., 2011). There are also differences in brain physiology and function between mammals and birds, which mean comparisons of the intelligence of the two may need to take this into consideration. Secondly, defining what the word ‘intelligence’ encapsulates is controversial. There have therefore been numerous techniques used in attempt to define and measure intelligence in birds, and the rest of this section will look at some of these methods in more detail.

A concept that needs to be taken into account when researching animal intelligence is that of umwelt. The term was first described by a German biologist in the early 1900s, and refers to the idea of how an animal perceives the world through its sensory system

(Jordan & Ryan, 2015). The umwelt of an organism will affect how it reacts to its environment, and this may be different depending on the species. For example, birds can see UV light, which means the way a bird perceives an environment may be very different to how a human perceives the same environment (Lahti, 2015). Consequently, when we undertake research on animals, we undertake an 'umwelt gamble' – that is, we assume that the way we perceive the experimental task is how the animal will also perceive it (Lahti, 2015). Therefore, in regards to testing cognition, we must be careful to choose tasks indicative of that species' intelligence, rather than a task that we as humans perceive to require intelligence.

1.2.1 Brain size

For reasons still debated, some species have evolved much larger brains (relative to their body size) than others. The brain is a costly organ, using relatively 8-10 times as much energy as skeletal muscle, for example (Aiello & Wheeler, 1995). It is therefore puzzling as to why certain mammalian and avian species have evolved such a costly organ when other phylogenetic groups survive perfectly well with a normal-sized brain. However with cost comes benefit, and therefore there must be an advantage to having a larger than expected brain (Dunbar & Shultz, 2007). In regards to primates in particular, there are two popular proposals as to what these advantages may be and why this trait evolved (Byrne & Whiten, 1988, as cited in Holekamp, 2007). The first is that a challenging physical environment led to the evolution of traits such as tool-use, the recollection of where food sources are, or visual navigation. The second is the 'social intelligence hypothesis', which proposes that the need to interact with other individuals and develop a social environment led to a larger brain. While the social intelligence hypothesis is perhaps the most popular, Holekamp (2007) argues that there are too many exceptions in other species for a social environment to be the only driver. According to this hypothesis we would expect more gregarious species to have higher intelligence than solitary species. Bears possess relatively larger brain sizes than any other family, however they are solitary animals, and pinyon jays (*Gymnorhinus cyanocephalus,* a social species) are less adept at completing different learning tasks than Clark's nutcrackers (*Nucifraga columbiana*, a more solitary species) (Holekamp, 2007). These provide just two examples of the limitations of the social intelligence hypothesis. It is therefore likely that multiple selection factors have been involved in the evolution of brain size, and sociality may therefore not be a prerequisite to intelligence (Holekamp, 2007).

A common way in which intelligence has often been determined is by comparing the relative brain size of different species. Absolute brain size may simply be related to the size of the animal, rather than being an indication of their intelligence, which means body size needs to be taken into account as well. As a way to control the effect of body size, Jerison (1973) created a model known as the encephalization quotient. This compares the actual brain size of a species to the expected brain size based on its body size. According to this method, species with a bigger brain size than expected are considered to have greater cognitive abilities. This idea led to some interesting findings. For example crows (*Corvus spp.*) and chimpanzees (*Pan troglodytes*) both have the same relative brain size, and this is a lot larger than would normally be expected for their body size (Emery, 2006). This is then backed up by the idea that crows are considered to be just as intelligent as chimpanzees. The encephalization quotient does however come with a number of issues. For example it does not take into account differing environments (which may result in different cognitive abilities) and the whole brain size is used rather than those areas used specifically for cognition (Emery, 2006).

It is often proposed that intelligent birds (such as the Order Psittaciformes) have larger brains than other birds. However studies that have previously made these claims have used small sample sizes and few statistics to back up their claims (Iwaniuk et al., 2005). Iwaniuk et al. (2005) tested this theory using 180 different parrot species. This was done by measuring the brain volume and body mass of each species and making comparisons. Kea have a brain volume/body weight of 14.4mL/956g, or 0.015 (Iwaniuk et al., 2005; O'Hara et al., 2016). This is comparable to the family Corvidae, for example the common raven (*Corvus corax*) has a brain volume/body weight of 15.31mL/1405g, or 0.011 (O'Hara et al., 2016; Sol et al., 2010). This large brain to body size ratio may therefore reflect the higher cognitive abilities of the kea (and the whole parrot order). Iwaniuk et al. (2005) has provided experimental evidence that psittaciforms do have relatively large brains compared to non-passerine birds, and also relatively similar sized brains to primates.

As can be seen by looking at these examples, brain size comparisons are a difficult way to accurately measure and assess levels of cognition and intelligence. Other ways of measuring intelligence tend to focus on behavioural aspects, i.e. how a species interacts with its environment to survive, and these studies combined with brain studies may provide a broader knowledge of animal intelligence.

1.2.2 Specialisations of avian cognition

Cognitive abilities may evolve due to environmental problems that a species faces that require specialised abilities to be overcome. There are a number of these problems that have been identified, and a number of species that demonstrate cognitive skills used to conquer them. Three of these specialisations have been identified by Emery (2006) and are discussed below.

1.2.2.1 Spatial memory and food caching

The ability to cache food to consume at a later time is something that is found among many bird species. This allows the collection of a large amount of food at once, which is then stored and used at a later time – a skill that can be used to overcome food shortages due to changing seasons and environments. In order for these caches to be successful, different types of information must be processed. The type of food and how quickly it will perish will determine how long before it must be retrieved (De Kort et al., 2006). It is also necessary for the birds to understand the environmental conditions and how this will affect the degradation of a perishable food item – for example the temperature and humidity of the cache site (De Kort et al., 2006). Most importantly of all however, it is vital that the location of the cache is known, so that food can be successfully retrieved when needed (De Kort et al., 2006). There are two suggestions to how this is done, the first being that the storer takes a snapshot of each location, and the second that visual cues are used to point them in the right direction (Emery, 2006). Either way, this has required the evolution of specialisations in the cognition of these species, and can be considered a progression towards higher intelligence.

Kea are not known to cache food (Gajdon et al., 2014), however there is no mention in the literature of kea and spatial memory. The orange-winged Amazon parrot (*Amazona amazonica*) has been shown to use spatial memory in trials of object permanence (Cussen & Mench, 2014). This suggests that parrots do have the cognitive ability to possess this trait, and therefore remember where food sources are found. The alpine habitat of the kea provides food sources that are few and far between, which means they would likely benefit from having a good spatial memory, and this is perhaps an area that should be researched in the future.

1.2.2.2 Social learning

A detailed review of the literature on social learning is beyond the scope of this thesis, however a brief overview is provided in this section. Sociality is often suggested as being a prerequisite for higher intelligence (e.g. Humphrey, 1976). Humphrey (1976) asks the question of why species such as higher primates need to be as intelligent as they are, when the majority of cognitive tasks they complete in laboratories are of no use in their wild habitat. This is thought to come back to sociality. A social environment provides the benefits of social learning and protection from a group, however it also requires cooperation and the ability to be calculating of one's own actions as well as the behaviour of others. This requires a lot of intellect, and can explain where all this "unnecessary" intelligence comes from. Whilst these complex social environments are often attributed to primates, birds too are highly social creatures. In fact all bird species that have been researched in regards to social learning have shown successful outcomes.

A study by Huber et al. (2001) looked at social learning in regards to problem solving in kea. A box containing a food reward was presented to the birds, however there were several locking mechanisms that had to be undone before success. Two adult birds were trained to successfully open the box, and the remaining ten birds were not. Five of these kea were allowed to watch the trained adults open the box before investigating it themselves, while the other five were not. The results showed that the birds allowed to observe a successful opening were faster to approach, spent more time interacting with the box, and were more successful at opening the locks than the non-observer group. This sort of behaviour is important for wild birds, as younger individuals can observe older ones in order to get food or learn other important life skills. The idea of social learning can brought back to the topic of kea strike. Young kea learn how to find food from other kea, which means it is possible they could also learn how to attack sheep (a new food source) from innovative individuals. Whilst multiple kea may benefit from a sheep kill, not all kea actually attack them (Temple, 1996). This suggests it is not an innate behaviour, and could be something that is learned.

1.2.2.3 Tool use

The use of tools has again been well described in primates, however it has also been demonstrated in many bird species. Tool use refers to 'the use of physical objects other than the animal's own body or appendages as a means to extend the physical influence realised by the animal' (Jones & Kamil, 1973, p. 1076). The question then emerges as to whether or not a species understands how the tools they are using actually work and that the action they perform is a direct consequence of the tool use (Emery, 2006). New Caledonian crows are perhaps the most well known tool-using species, and have demonstrated this ability in many studies. One of the more remarkable trials involved a crow that was able to bend a straight piece of wire into a hook in order to retrieve a bucket of food that had been placed down a pipe (Weir et al., 2002). This act suggests that the crow did realise the consequence of her tool use, and in fact understood that the properties of the wire would allow her to manipulate it in order to successfully retrieve the food (Emery, 2006).

Kea, despite not being a tool-using species in the wild, have demonstrated successful tool use in research experiments. Auersperg, von Bayern, et al. (2011) compared the cognitive abilities of New Caledonian crows and kea using a 'multi-access box'. This box allows a food reward to be obtained in four different ways. Two of these options involved tools – either a ball must be inserted into a tube to knock the reward off the platform, or a stick must be used to directly push the reward off the platform. All the kea that were tested successfully used the ball to obtain the reward, and one individual also successfully used the stick. The stick task in particular proved difficult due to the curvature of kea's beaks. They are not able to hold tools such as sticks in a way that they have much control over them. Despite this, tool use is apparently something they are capable of given the outcome of these trials. Kea have also anecdotally been described as using tools in the wild. Birds have been caught on camera using sticks to set off stoat traps to get the eggs used as bait (Price, 2014). The fact that kea have been observed using tools both experimentally and anecdotally, despite not being natural tool-users, suggests that these birds still have the cognitive capacity to do so.

1.2.3 Exploration-avoidance and neophobia

Animal innovations are key to species survival and evolution. Ramsey et al. (2007) define innovation as 'the process that generates in an individual a novel learned behaviour that is not simply a consequence of social learning or environmental induction' (p. 395). Such behaviours then allow an animal to utilise new resources, and therefore make better use of their environment (Biondi et al., 2010). Innovative behaviours tend to arise from individuals that are very explorative and have low levels of neophobia, and are especially important for species that live in a constantly changing environment or have an opportunistic feeding style (Biondi et al., 2010). This becomes even more important given the impact humans are having on the environment and the changes we make to a species natural habitat.

Neophobia and exploration are well-studied areas of ornithology, as a large number of bird species tend to be very explorative given the changes that humans have caused in their environments. One example is our study species, the kea. It is well known how inquisitive (and infuriating) kea can be towards humans and human equipment on the ski slopes of the Southern Alps. The birds will eat human food left out on tables, and chew on the rubber parts of cars left in the parking lots. They have also been observed opening the lids of rubbish bins outside a local hotel to obtain food scraps (Gajdon et al., 2006). The rubbish bins are a very recent addition to the kea's environment on an evolutionary scale, which means this behaviour is a new innovation, and has most likely been made possible by their neophilic nature. In this case it is thought that a behaviour performed in the kea's natural environment (i.e. turning over heavy stones to obtain insect larvae) has been transferred to a novel situation (Biondi et al., 2010). In addition to this, the sporadic nature of kea strike has led to the hypothesis that it is a recurrent innovative behaviour of the birds rather than an innate predatory behaviour.

Neophobia and exploration are thought to be related to problem solving ability, and they are therefore well studied in regards to intelligence. In a broad sense, research is undertaken by presenting subjects with novel objects and recording their reactions. Heinrich (1995) used juvenile common ravens to look at the effect of age on neophilia. The young ravens in this study were very curious, and at first made contact with nearly every new object introduced to their enclosure. After several trials they learned to distinguish food items from everything else, and eventually ignored any non-food items. These trials were repeated as the birds aged, and they became less interested in all the novel objects (food included). This relationship between age and neophilia has been reported time and time again, for example in the chimango caracara (*Milvago chimango*) (Biondi et al., 2010), the Gouldian finch (*Erythura gouldiae*) (Mettke-Hofmann & Fusani, 2012), and carrion crows (*Corvus ccorone*) (Miller et al., 2015). Young birds learning to forage need to learn what is acceptable eating material through trial and error, and a more exploratory nature may allow them to do this (Heinrich, 1995). As they age, they become less curious as they have learned which foods they should consume and have become familiar with their environment. In a separate trial, Heinrich (1995) used wild caught adult birds to test the effect of hunger on neophobia. The birds were split into two groups – one of which was fed ad libitum, the other of which was left hungry. The hungry birds approached and interacted with more of the novel objects (some of which were food) than the well-fed birds. These results suggest that in the event of hunger, an individual may become more neophilic in order to explore more food options and prevent themselves from starving.

Another way in which neophilia is thought to have evolved is in response to the feeding technique of a species. A generalist or opportunistic species will utilise many more foods than a specialist species, which means they are more likely to encounter novel food sources (Sandra & Lefebvre, 2000). Sandra and Lefebvre (2000) tested this theory with the Lesser-Antillean bullfinch (*Loxigilla noctis*) (a generalist species) and the bananaquit (*Coereba flaveola*) (a nectarivorous specialist). Wild birds were provided with a dish of sucrose solution at a number of different sites. Once a bird approached the dish and started feeding, an experimenter moved towards the dish and placed a novel object next to it. The latency to reapproach the dish was then recorded. Overall the more generalist bullfinch approached significantly more quickly than the bananaquit (who often did not return at all), supporting the theory that neophobia is closely related to feeding specialisation.

Neophobia not only differs between species, but between individuals of the same species. These differences in behaviour are referred to as 'personality', and are thought to be consistent throughout an individual's lifetime (Cole & Quinn, 2014). There is a personality continuum from proactive to reactive, with proactive individuals being bolder and more neophilic, and reactive individuals being more neophobic. In regards to conservation and the continuation of a species, being reactive may compromise breeding success. For example, a study on the great tit (*Parus major*) by Cole and Quinn (2014) looked at the link between personality (in particular risk taking behaviour) and the effect on incubating behaviours in the wild. They placed a novel object (in this case a flag) on the nesting boxes of incubating females and measured the latency to resume normal incubation after this object was introduced. The shyer females took significantly longer to return to their nests than the bolder birds, and some did not return until the novel object was removed. This could have an overall effect on reproductive success, as if a female is away from her nest for longer than 10 minutes, hatching success may be compromised. This prioritisation of survival over reproduction is intrinsic in most species, however this study suggests that certain individuals may be more likely to abandon their nests, and in the case of endangered species this could be very detrimental. Conversely, bolder individuals may be more prone to predation and misadventure, which means there are costs and benefits to each strategy. It has been suggested that variation in personality types within a population allows the group to work in a unified fashion, and ultimately improve survival (e.g. as shown in great tits by Aplin et al., 2014).

1.2.4 Problem solving

A common way in which avian intelligence is measured is in regards to problem solving ability. Overcoming environmental challenges is necessary for a species to live in said environment, and we can test the extent to which they are able to do this by providing them with problem solving models of our own. This area has provided many research opportunities, as it tends to be non-invasive and also allows for animal enrichment.

Kea, the subject of this thesis, are particularly renowned for their problem solving ability, a trait that may have arisen from their constantly changing alpine environment (Emery, 2006). Alpine environments present an array of challenges to the species that live there, due to the changing weather conditions and therefore temporary food sources (Temple, 1996). It has been suggested that the seasonal change in food sources is what has led to the opportunistic foraging style of these birds, and the unique way in which they do this (Temple, 1996). This trait, combined with their neophilic nature, has allowed them to exploit human settlements as well. They have been observed opening the lids of rubbish bins to obtain scraps from outside hotel restaurants (Gajdon et al., 2006) and are often found hanging around ski fields snacking on human food. The fact that they are so curious and explorative means they are a popular study species, and many papers looking at problem solving will mention the kea as a well known intelligent species.

Problem solving can be used to compare the cognitive abilities of different species, as well as to look at the overall cognitive capabilities of a singular species. A major study in this subject area was undertaken by Auersperg, von Bayern, et al. (2011) who aimed to compare the cognitive abilities of New Caledonian crows and kea. The crows are natural tool users, whereas kea are not known to make use of tools in the wild. The study therefore consisted of both tool and non-tool using tasks. An apparatus known as the Multi Access Box (MAB) was built. This consisted of a box made of transparent walls with a platform in the middle. A food reward is placed on the platform, and the birds have four different ways in which they can access it: by pulling on a string; opening a door; dropping a ball down a tube; or poking a stick through a hole. The kea had trouble manipulating the stick through the hole, due to the curvature of their beaks and their non-tool using nature. One kea did manage to complete all four tasks however, showing that with enough manipulation the stick task is within their physical capabilities. One crow also completed all four tasks, which suggests that the task could be completed by both species, and therefore was a good way to compare their cognitive abilities. The study showed differences in performance however, with the kea succeeding at different tasks much more quickly than the crows, which tended to stick to one task until it was blocked off. These differences were attributed to the level of neophobia of each species. Kea are renowned for their neophilic behaviour, and completed the tasks by touch and manipulation. New Caledonian crows however are much more neophobic, and used sight to guide them before actually touching the apparatus. This shows that comparing cognitive abilities of different species can involve a number of conflicting factors, and differences in performances may be attributed to different environments and therefore different ways of approaching problems. This reinforces the idea that intelligence and cognition are difficult aspects of physiology and behaviour to measure and compare between species. For the purposes of this thesis, the MAB provides an excellent model system for assessing differences within a species, and allows us to begin investigating drivers of intelligence, cognition, and problem solving in kea.

1.3 Effect of past housing on behaviour

Part of this thesis aims to determine whether past housing conditions affects behaviour and intelligence in kea. In this case, the term ‘past housing’ refers to social context (i.e. isolation or group housing) as well as enrichment (i.e. was the environment stimulating or deprived). Abnormal behaviours (behaviours not seen in the wild) are common in individuals of all species that have had inadequate housing (either past or present). This could be in terms of enrichment or social context, and what this thesis aims to look at is whether these aspects affect intelligence and levels of neophobia. Historically, kea have been kept as pets over long periods of time, and were often isolated and severely under-enriched. Because of their need for high levels of enrichment, it is also possible that birds kept in captive institutes are not adequately enriched either, which may be a problem for captive breeding programmes. Birds that are captive bred may pick up these abnormal behaviours and then take them into the wild when they are released. This section will look at the development of stereotypic behaviours in pet birds and zoo facilities, and will also look at the loss of wild behaviours in these captive birds.

1.3.1 Stereotypic behaviour

Stereotypic behaviours can be defined as behaviours that are abnormal, repetitive, and which have no apparent function (Mason, 1991). Such behaviours are common in animals kept in captive environments, and can be indicative of welfare issues (Mason, 1991). They can arise when the expression of normal behaviours is restricted (for example flight and foraging behaviour) (Rodríguez-López, 2016). The degree to which these behaviours occur depends on the species and the adequacy of their environment (social and physical).

1.3.1.1 Birds kept in captive facilities

A study by Cussen and Mench (2015) looked at the effect of personality on the frequency of abnormal behaviours in orange-winged Amazon parrots. These birds were raised in an enriched environment, which became unenriched and then re-enriched throughout the study. It was found that once enrichment had been taken away, stereotypical behaviours increased, as did the proportion of time spent preening (which in turn led to feather plucking). The amount of time spent engaging in stereotypical behaviours was positively associated with personality type. The more extroverted individuals spent less time engaging in such behaviours than the introverted birds. This supports the theory that some animals are more likely to engage in abnormal behaviours than others. More importantly, once enrichment was reintroduced to the population, while stereotypies did decrease, they did not return to baseline levels. This finding has not yet been confirmed by any other research, however it does suggest that even a short period of time in an unsuitable environment can have significant effects on an individual’s behaviour.

A similar study, also on stereotypical behaviour in orange-winged Amazon parrots, was undertaken by Meehan et al. (2004). They observed the development of stereotypies in birds that had not yet reached sexual maturity. For 48 weeks, the individuals of one group were provided with a constant physical and foraging enrichment, while the others were kept in a barren environment. The unenriched group was then provided with 16 weeks of enrichment. While both groups developed stereotypical behaviour, the unenriched group spent a larger proportion of their time engaged in such behaviours. After re-enrichment, the proportion of stereotypical behaviours decreased dramatically, which provides further support for the idea that enrichment is important in minimising these abnormal behaviours. For my purposes, this raises the question as to whether kea that have been deprived will be more likely to show abnormal behaviours in captivity.

1.3.1.2 Birds kept as pets

Birds are becoming an increasingly popular pet. Surveys have been undertaken by the NZCAC to report on the companion animal population within New Zealand (New Zealand Companion Animal Council Inc., 2016). The 2015 survey had only 1,013 respondents, however it still provides an overview of the pet population in New Zealand. In 2015, birds were the fourth most popular pet in New Zealand, following cats, dogs, and fish. 7% of the households surveyed had at least one bird (the most popular being chickens). New Zealand follows very similar trends to both Australia and the USA (where birds are also the fourth most popular pet). Besides chickens, it is well known that Psittaciformes (parrots) are popular pets (e.g. budgerigars (*Melopsittacus undulatus*), cockatiels (*Nymphicus hollandicus*), and the sulphur-crested cockatoo (*Cacatua galerita*)). This trend raises concerns due to the intelligence and long life spans of most parrot species (Rodríguez-López, 2016). Parrots exhibit a number of stereotypic behaviours, perhaps the most common one being feather plucking (where a bird removes its own feathers). A study in the United Kingdom looked at the occurrence of feather plucking in African grey parrots (*Psittacus erithacus*) and cockatoos (*Cacatua spp.*) registered with 9 veterinary clinics (Jayson et al., 2014). Of the surveys completed, 39% of African grey parrots, and 42.4% of cockatoos had shown signs of feather plucking during their lifetime. This raises welfare concerns, as it suggests pet parrot environments are not stimulating or enriching enough. While this study is aimed specifically at investigating kea, the results will have implications for the welfare of pet birds, and of parrots in particular. Current trends are to remove kea from unsuitable environments, however some of the individuals in my study were previously housed in such conditions, and two were housed in isolation while my research was being undertaken.

1.3.2 Loss of wild behaviours

Another question that arises is how captive housing conditions may affect wild behaviours, and therefore survival rates and reproductive success if an individual were to be released. The behaviours of captive and wild black-and-white ruffed lemurs (*Varecia variegate*) were compared to determine the extent to which captive individuals had lost natural behaviours, and to establish ways to enhance them (Kerridge, 2005). The aim of this study was to figure out ways to alter the captive environment to increase the prevalence of wild behaviours before they were released into the wild. They found that wild lemurs spent more time feeding, less time grooming, and less time engaged in social activities than their captive counterparts. An enrichment device was constructed to encourage feeding behaviour in the captive lemurs, and this was successful in increasing time spent feeding. It may therefore be beneficial to target enrichment devices to encourage certain wild behaviours, rather than adding enrichment simply for welfare reasons (Kerridge, 2005).

Furthermore, a genetic model was created by Ford (2002), which suggested that if a supplementary breeding programme is put into place with no gene flow from wild populations, the captive bred individuals that are released cause a shift in the wild phenotype towards the captive phenotype. This may reduce the wild populations fitness and therefore survival, as they will be optimally suited to the captive environment, which may be completely different to the wild environment. There are limitations to this model, such as the amount of gene flow between the two populations, and the simplification of the phenotypes used in the study. However it raises an issue that needs to be considered when implementing captive breeding programmes, as released individuals need to retain their wild traits as much as possible to increase survival rates.

There is currently no captive breeding programme in place for kea, however it is possible that one may be needed in the future. A review of the captive management plan was undertaken in 2011 (Collen, 2011), and it was noted that if kea were to be released in the future, genetic diversity in captivity would need to be maximised. However there was no mention of also maximising retention of wild behaviours. The need for kea to forage in unpredictable conditions and find new food sources is a vital trait for these birds to survive in the wild. Social interactions including play and social learning will also be important. If these traits are not maintained through captive enrichment programmes, it is possible that survival rates in released birds would be low.

1.4 Human-wildlife conflict

Human-wildlife conflict is one of the major issues within conservation today. It can be defined as 'situations occurring when an action by either humans or wildlife has an adverse effect on the other' (Conover, 2002, as cited in Redpath et al., 2014). This definition has led to some confusion, as some "human-wildlife" conflict is actually human-human conflict. For example orangutans (*Pongo pygmaeus*) and palm oil plantations are not in direct conflict with each other, it is two groups of humans (one that wants to protect the orangutans, and the other that wants to make money from palm oil) that are actually in conflict (Redpath et al., 2014). It has therefore been suggested that the term be split into two separate components: the first focusing on the impact of wildlife on human activities (and vice versa), and the second focusing on the conflict between humans in regards to conservation and biodiversity concerns (Young et al., 2010). For the purposes of this thesis I will concentrate solely on direct conflict between animals and humans, and how this relates to conservation.

Human-wildlife conflict can become a major issue when either species begins to kill the other. This is especially a concern when humans start killing an endangered species, or kill to the extent where a species may become endangered. African elephants (*Loxodonta africana*) are known to enter human villages where they raid food and water supplies, destroy crops, and have even been known to injure or kill people in their way (Hoare, 2000). In turn, the elephants are deterred, injured, or even killed by the villagers. African elephants are classified as vulnerable under the IUCN Red List, and if human populations continue to expand, it is likely that this conflict will only get worse, and so will their endangered status (Blanc, 2008).

Conflict between humans and wildlife can lead to a lower tolerance towards a species, and can even result in policy changes around how that species is managed. This has been demonstrated in the grey wolf (*Canis lupus*) in Wisconsin, where the species was listed and relisted under the Endangered Species Act on multiple occasions (Olson et al., 2015). This inconsistency led to changing public views, and more illegal killings of the species. Wolves have been known to kill livestock, pets, and even people (Olson et al., 2015), which is why it is so important to have a consistent management plan to minimise the conflict between the wolves and humans.

The literature appears to focus on conflict between humans and large mammals, usually because these species are a direct threat to human livelihood (as is the case with the African elephant discussed above). However there are also many examples of conflict between humans and avian species. The Bonelli's eagle (*Aquila fasciata*), for example, is a bird of prey that is known to hunt pigeons (*Columba spp.*) and red-legged partridges (*Alectoris rufa*) (Palma et. al, 2006). In some populations this is a problem, as it leads to persecution from hunters and pigeon fanciers. This has led to a decline in population numbers in certain areas. This, in turn, has severe management implications, as the eagles rely on hunting these species to survive, yet they are also important to the humans in the area (Palma et. al, 2006). These types of conflict are often seen in carnivorous birds, and another example more relevant to New Zealand is that of the sub-Antarctic skua (*Catharacta antarctica*)on the Chatham Islands. There appears to be little published literature on the conflict between this species and humans, however it is known that conflict does exist between the skua and farmers

(Hemmings, 2013). Skua are thought to be a danger to livestock, and so are shot by farmers. Although this is not their main threat, it is a conflict that could be managed in order to prevent skua numbers continuing to decline.

In some cases, it is because of conflict between human and wildlife that a species has become endangered in the first place. One example is our study species, the kea, which are now nationally endangered (Robertson et al., 2017). There are a number of reasons for their population decline, including habitat destruction, human encroachment, and introduced predators. However the main reason kea numbers are so low today is due to the persecution that occurred between 1868 and 1970 after the emergence of the phenomenon known as kea strike (as discussed on page 3). Despite now being fully protected, it is still possible for farmers to seek permits from the Department of Conservation to kill troublesome kea, and there are even illegal shootings and poisonings still occurring (Miskelly, 2014). This means that the conflict between farmers and kea is ongoing, and is still in need of a resolution.

Despite this negative human-kea interaction, there are also positive interactions as well. Kea are known to frequent the ski field of the Southern Alps, where they are a constant source of entertainment for tourists. There is some conflict with the destruction of ski gear and cars, however the curious nature of the kea means they are always remembered.

1.5 Aims of research

The literature I have analysed has provided a brief overview of the current knowledge on animal intelligence, where I have particularly focused on exploration-avoidance and neophobia, as well as problem solving. This study will look at three different aspects of kea intelligence, the methods of which are based on previous research in wild kea. It was hoped that these results would be compared to the wild kea research to determine whether the behaviour of captive kea significantly differs from their wild counterparts, in particular whether different social conditions in captivity have affected their behaviours in terms of learning, innovation, and problem solving in response to enrichment. However the data on the wild kea has not yet been published, and this study will therefore be a standalone, leaving room for possible comparisons in the future.

The main objectives of the study are:

1) To characterise individual birds' personality, in particular their levels of innovation, neophilia and exploration – i.e. are they curious or will they avoid a novel object – and determine whether these personality traits are associated with their past housing and social experiences.

2) To look at problem solving ability – i.e. is the bird able to navigate a multi-access box apparatus to gain access to a food reward – and determine whether this is associated with their past housing and social experiences.

3) To determine whether there are any specific demographic or behavioural characteristics associated with the behavioural drivers of kea strike on sheep that can be identified in captive kea.

Chapter 2: Exploration–avoidance and neophobia

2.1 Introduction

The term neophobia refers to the fear or aversion an animal may show towards an unfamiliar object (Greenberg, 2003). The topic is a popular one amongst animal behaviourists, and research regarding avian species is particularly abundant. Given the ongoing environmental changes occurring in their natural habitats, a species that is more neophilic and explorative may have an advantage. While some species are certainly more neophilic than others, there is also variability within a species. A more neophilic individual is likely to develop innovative behaviours, which can then spread through a population and allow them to exploit new resources (Greenberg, 2003) However, there are benefits to both neophilia and neophobia. Neophilia allows the exploration of new objects, and hence information on whether an object can be approached or not and if it may be a useful resource (Greenberg & Mettke-Hofmann, 2001). On the other hand, a new object may be hazardous, for example poisonous plants, or house unknown predators, and so neophilia may also result in higher mortality rates. In hazardous situations, neophobia has its benefits (Greenberg & Mettke-Hofmann, 2001).

Many studies have assessed the costs and benefits of neophobia versus neophilia in the same species. In the great tit, for example, neophilic individuals in the presence of a novel object returned to their nestlings much faster than neophobic individuals (Cole & Quinn, 2014; Vrublevska et al., 2015). This in turn resulted in a higher reproductive success for the neophilic females. This is something that is particularly important to consider in our study species, the kea, as predators play a large role in their decline. Stoats, and even possums (*Trichosurus vulpecula*), have been recorded killing fledglings, and adult females also have a high risk of predation (Orr-Walker, 2013). This means reduced nest success, or fewer reproducing females, and therefore lower recruitment rates. While there is not necessarily anything that can be done about this in regards to conservation, it is important to note that personality can have an effect on individual survival and reproduction rates.

Another point to take into consideration is how neophilia or a lack of fear fits in with human urbanisation of a species' habitat. Greggor et al. (2016) for example looked at different bird species and the time taken to approach objects made from human litter. Even corvids, a naturally neophobic family, approached these items quickly, suggesting a species may become used to seeing such items in their environment. This becomes an issue if they begin to consume items that are unsuitable as food. For kea this is particularly a problem, as they are found around the ski slopes of the Southern Alps where human presence is inevitable. People who visit the ski slopes are often heard talking about how cheeky the kea are, eating human food of the tables, drinking beer, and chewing the rubber off car windows. One case study found that a kea had died from eating chocolate (Gartrell & Reid, 2007), and lead poisoning is also a big problem (Reid, 2008). This demonstrates the negative effects humans can have directly on individual birds, and this is made worse by the fact that kea are such a neophilic species.

The kea is known to be extremely curious and inquisitive, and birds are often found on the ski slopes of the Southern Alps interacting with humans. They are known to be a very neophilic species, something that may have arisen due to their constantly changing alpine environment and therefore variability in the available food sources. These factors are what make them so interesting to study. Neophobia trials provide information important for wild birds, for example in relation to lead poisoning (Reid, 2008) and kea strike (looked at further in Chapter 4). Kea are also housed in many captive institutes throughout New Zealand. Understanding differences among individuals and the factors underlying this may help us create enrichment programmes more tailored to individual birds. This will be particularly important if captive breeding is ever implemented, as it will be vital to find ways to maintain wild traits.

The most common way in which neophobia is measured is by observing the reaction of individuals to the introduction of novel objects. There is currently one other published study that has used novel objects in kea (Reid, 2008). This involved introducing objects such as dog toys into the environment of wild kea, and observing the exploration response. These results were then compared to blood lead levels, and it was found that more neophilic birds were more prone to lead poisoning. This gives an example of where neophilia may be a disadvantage in the wild environment, and why it is important to undertake more research in this area. Other examples of neophobia trials tend to focus on how long a bird takes to resume feeding once a novel object is placed near its food source. This involves withholding food for a period of time to ensure the birds are motivated to feed, and then placing a novel object near their familiar food source. This has been done in both captive (e.g. Biondi et al., 2010; Mettke-Hofmann and Fusani, 2012) and wild birds (e.g. Brown and Jones, 2016; Sandra and Lefebvre, 2000) to determine neophobia differences between species and among species.

The aim of these trials was to determine the level of neophobia for each individual using novel objects, and determine whether specific demographic factors (e.g. age) or past housing scenarios (i.e. group versus isolation) has any effect on these levels.

2.2 Methodology

This study was undertaken using seven kea housed at Wellington Zoo, each of which differed in sex, age, and housing history (See Table 2.1 and Appendix 1 for a more detailed history). For the sake of these trials, juveniles are considered to be two years of age and under, and adults are considered to be over two years of age. Two of the birds were housed separately away from public display, and behind the tiger (*Panthera tigris*) and sun bear (*Helarctos malayanus*) enclosures, which meant there were a lot of unfamiliar sounds around them. The other five birds are a family, and were housed together on display to the public. The trials for the isolated individuals were therefore undertaken separately, however the family group could not be separated for logistical reasons, and so trials were performed with all five individuals at the same time. I had the assistance of one of the Wellington Zoo staff members, who took the equipment in and out of the enclosures between trials.

Table 2.1 Brief demographic and housing information for each bird.

Bird ID	Sex	Age	Previous housing	Current housing
Isolated1	Female	24 years	Pair (brother), isolated	Isolated
Isolated2	Female	24 years	Pair (sister), isolated	Isolated
Familymale	Male	36 years	Group/pair	Group
Familyfemale	Female	21 years	Group/pair	Group
Familyjuv1	Female	2 years	Group	Group
Familyjuv2	Female	2 years	Group	Group
Familyjuv3	Female	2 years	Group	Group

These trials involved assessing the reaction of kea to the introduction of novel objects into the enclosure in order to determine measures of exploration-avoidance and neophobia for each bird. Previous studies such as Fox and Millam (2007) have similar methodology, however they tend to focus on the latency to approach food in the presence of a novel object, while this study treated the novel objects as an enrichment device. I had a collection of ten random objects, each of which were checked over by zoo staff to ensure the kea had not encountered something similar during their time at the zoo. The objects were a collection of household items and pet toys, and were presented in a random order one at a time. Each object was attached to a wooden board by a short piece of light chain, which was then placed on a flat surface within the enclosure. All trials were video recorded, and the trial time started from when the keeper had placed the object down and had moved approximately one metre away. Each trial lasted ten minutes, with the following aspects being observed: latency to approach within one metre; proportion of the trial spent interacting with the object (including being within one metre of the object); the number of touches, grabs, and chews of the object; and the proportion of time spent chewing the object. Interactions were only recorded in regards to the actual object, and did not include any interactions towards the wooden board or chain. The rate of each interaction type with the novel objects was defined as the total sum of the frequency of the interaction over the number of trials.

Data were extracted from the videos using the programme B.O.R.I.S. and processed in Microsoft Excel to calculate descriptive statistics and to produce graphs. No further statistical analyses were undertaken on the data due to the small sample size, as well as the different housing situations (some birds being in a group, some being housed singularly), which may have confounded the results.

2.3 Results

Nine trials were successfully recorded and analysed for the family group, and ten trials for each of the isolated birds. The frequency of trial involvement can be seen in Table 2.2.

Table 2.2 Frequency of trials during which an approach (considered a success) was made for each bird. Birds are shown in order of descending approach frequency, and this is used as an indicator of increasing neophobia.

Bird ID	Total number of trials	Successful trials	Percentage of approaches
Familyjuv1	9	9	100.0%
Familyjuv2	9	9	100.0%
Isolated2	10	8	80.0%
Familyjuv3	9	7	77.8%
Isolated1	10	6	60.0%
Familymale	9	4	44.4%
Familyfemale	9	1	11.1%

The birds that approached more often did not necessarily have quicker approach times (Figure 2.1). While Familyjuv1 took on average 4.89 seconds to approach the novel objects, Familyjuv2, who also approached in every trial, took a 37.1 seconds. Isolated2, who also approached in the majority of trials, took the longest time of all at 142.5 seconds. Rather than immediately investigating the novel objects, she spent a long time walking around her cage and looking at the objects from above before approaching.

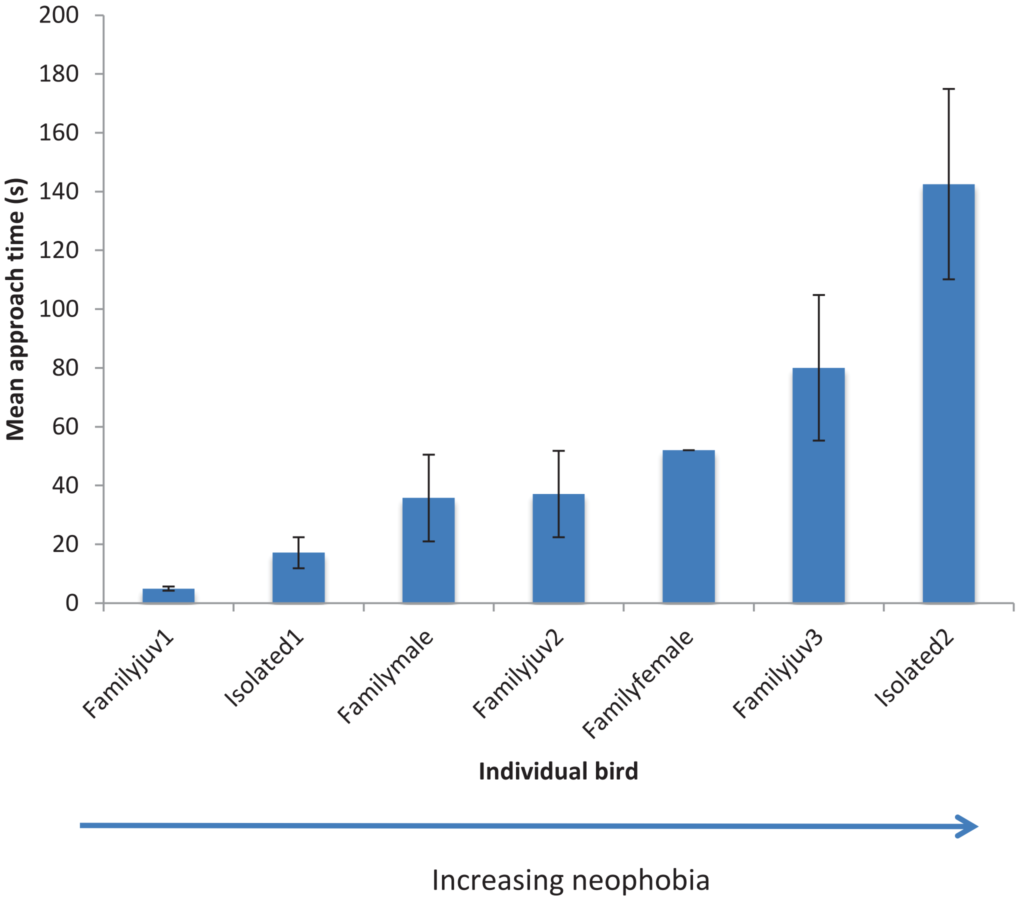

Figure 2.1 The mean time in seconds for each bird to approach the novel objects over all trials. Error bars represent one standard error. The birds have been ordered by increasing latency to approach using this factor as an indicator of increasing neophobia (baseline arrow).

The amount of time each individual spent interacting with each object over the ten minute trial (interaction length) was also recorded (Figure 2.2). There were some associations between this parameter and the approach time data. Familyjuv1 had the quickest mean approach time, and also the longest average interaction length (474.2s), while Isolated2 had the longest mean approach time and the shortest mean interaction length (13.5s). In regards to interaction length alone, there appears to be two groups, with the juveniles interacting for a longer period of time than the adults.

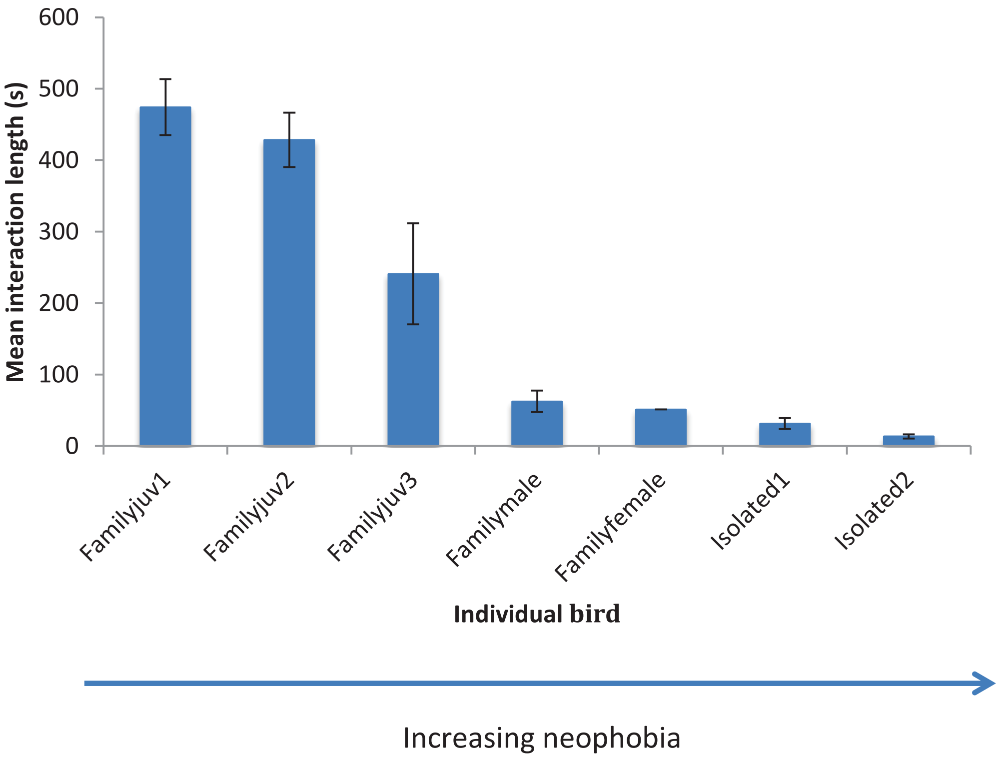

Figure 2.2 The mean time in seconds each bird spent interacting with the novel objects over a ten minute period for all trials. Error bars represent one standard error. The birds have been ordered by decreasing interaction length using this factor as an indicator of increasing neophobia (baseline arrow).

The rate and type of interactions with the novel object varied between individuals (Figure 2.3). Familyjuv1 and Familyjuv2 had the largest rates, in particular in chewing and grabbing. The others had fewer interactions, suggesting more of their interaction time was involved in approach or observation of the object. For all three juveniles, grabbing and chewing occurred more frequently than touching. These may be considered more invasive actions, and therefore indicative of more neophilic tendencies. While Familyfemale did approach during one trial, she did not interact with the object in terms of touching, chewing, or grabbing, hence why her interaction rate is zero in this graph.

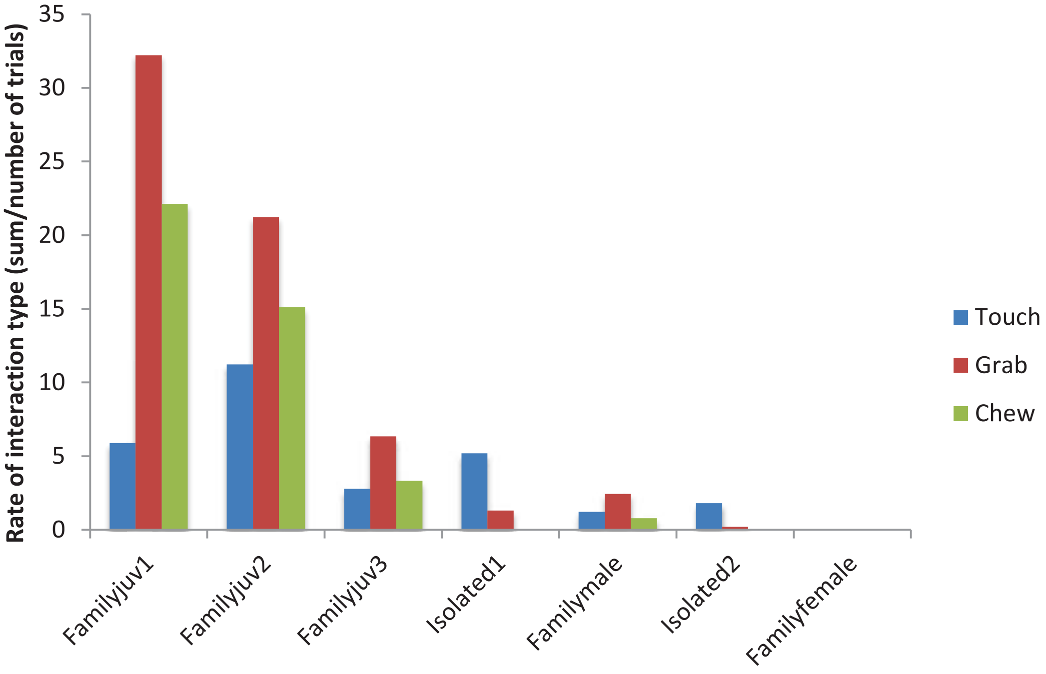

Figure 2.3 The rate of different interaction types (touch, grab, chew) over all trials for each bird. Rate is defined as the total sum of the frequency of interaction over the number of trials.

The final aspect that was recorded in regards to novel objects was the amount of time spent engaged in chewing (Figure 2.4). Only four of the seven birds engaged in chewing behaviour: the three juveniles and Familymale. The order of neophilia remains similar to what is shown in the previous graphs, with Familyjuv1 spending more time engaged in chewing than the others, and Familymale spending the least amount of time chewing.

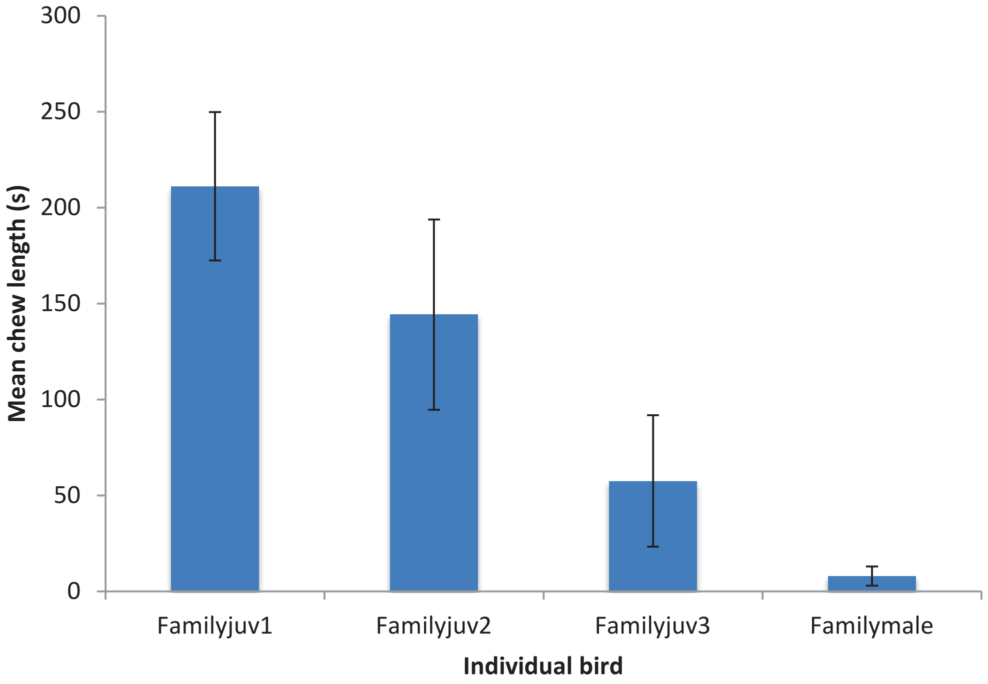

Figure 2.4 The mean time in seconds each bird spent chewing the novel objects across trials.

Observations were made on interactions within the family group to assess how social interactions may have affected the data. Based on my own impressions, there appeared to be a hierarchy among the group that may have affected the results. The presence of Familymale generally caused all three juveniles to back away from the objects until he had left. Amongst the juveniles, Familyjuv1 appeared to have the most dominance, and both she and Familyjuv2 would chase Familyjuv3 away when she got too close to them. The dominance of Familyfemale was difficult to observe, however during her one approach she did not appear to have any effect on the other birds present.

2.4 Discussion

The aim of these trials was to determine the relative level of neophobia of each individual using the novel object experiments, and relate this back to demographic factors and the past housing scenarios of the individual birds. I was able to use the results of the trials to rank the individual birds in terms of neophobia/neophilia. Figure 2.5 provides a continuum from the most neophilic bird to the most neophobic, based on the combination of approach time, interaction length, interaction types, and chew length. These results are not quantitative, but provide a qualitative summary of the results. We would expect a more neophilic bird to approach novel objects faster, to interact with them longer, and to spend a longer time chewing (as is the case with Familyjuv1). A more neophobic bird would have fewer approaches, a longer approach time, and a shorter interaction length (as is the case with Familyfemale).

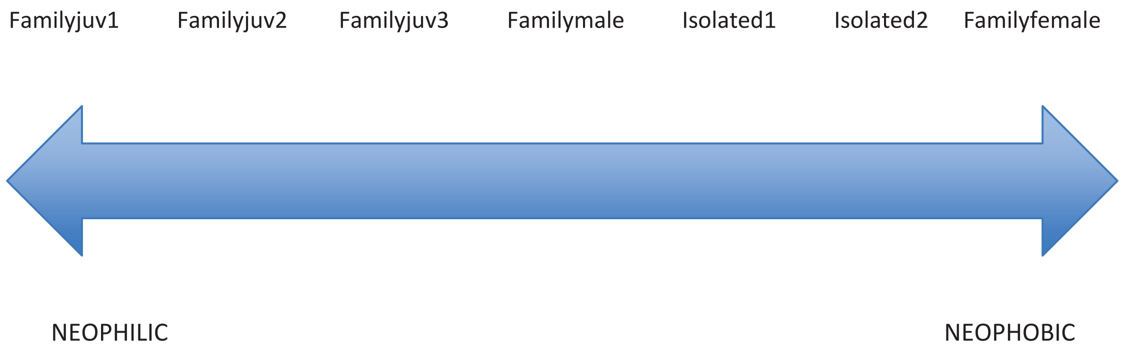

Figure 2.5 Relative ranking of seven captive kea on the neophobia/neophilia spectrum using the combined results of the novel object trials.

My results show a clear distinction between age classes, with the juveniles being more neophilic, and the adults being more neophobic. The approach time showed slight variability from the rest of the data as it indicated that Isolated1 and Familymale were more neophilic than Familyjuv2 and Familyjuv3. However an initial approach does not necessarily mean they were physically interacting with the object or interacting with it for a long period of time. Mean interaction length may give a better indication of neophobia levels. A more neophobic individual would not spend as much time interacting with a novel object as a neophilic individual. This is where we begin to see some distinct differences between the adults and the juveniles. The juveniles, particularly Familyjuv1 and Familyjuv2, spent much longer engaged with the objects and undertook more physical interactions (touching, grabbing, and chewing) than the adults. Of particular interest was the time spent engaged in chewing. This can be considered as the most invasive interaction, and will be discussed more in Chapter 4 in regards to kea strike. All three juveniles, particularly Familyjuv1, spent a large majority of the trials engaged in chewing behaviour, which can be considered a neophilic response. Familymale did engage in some chewing, however the remainder of the adults did not.

Due to the small sample size, we cannot undertake statistical analyses to determine whether these age differences are significant, or whether they are related to group housing versus isolation, particularly as there are no isolated juveniles to compare. However, the age difference in behaviour I report is supported by other findings of other novel object trials in birds. The only other published study on neophobia in kea was undertaken on wild birds, and showed that a higher percentage of novel objects were contacted by juveniles and sub-adults than adults (Reid, 2008). As well as this, there was a significant increase in the percentage of contact by birds above the fledgling age, suggesting that the high level of neophilia found in juveniles may not be present until a certain age (Reid, 2008). The fact that this study was undertaken on wild kea rather than captive ones may mean that comparisons are confounded, however the same results have also been found in many other captive avian species. Studies of captive juvenile and sub-adult common ravens have also shown significantly shorter latencies to approach novel objects than their adult counterparts, with the young birds also interacting with more of the available objects (Heinrich, 1995; Miller et al., 2015). The same results have been seen in captive Chimango caracara, where juveniles had more explorative tendencies and lower neophobia levels than the adults (Biondi et al., 2010). As with other animals, it is thought that the juvenile/sub-adult period of a bird’s life cycle is the key period for learning and development. It is therefore likely to be beneficial for a young bird to be more neophilic, as it allows them to explore their environment, and through trial-and-error learning discover which items are suitable to forage (Heinrich, 1995). As they grow older and learn more about their environment, this neophilia may become risky, and they become less curious (Heinrich, 1995).

However some birds, such as the kea, are more neophilic as a species due to their constantly changing environment, and therefore perhaps the degree to which this curiosity is lost would be less than in a more neophobic species. This hypothesis requires further investigation, ideally by measuring the changes in neophilia of individuals as they age. This pattern may be species-specific however, as a study on the mound-building mouse (*Mus spicilegus*) showed a more U-shaped relationship between age and neophobia (Lafaille & Féron, 2014). The 24-month old mice showed similar behaviours to the 2-month old mice, in that they were less anxious and more curious towards novel situations. This was unexpected, as the 6-month old mice were more fearful and anxious in the same situations. This demonstrates the variability found among species, and the care that needs to be taken when making comparisons.

My results show no obvious effect of social versus isolated housing on the level of neophobia within the adult kea. There is clear variation in response to novel objects among the adult kea (Figure 2.5), but personality appeared to be the most important factor in explaining this variation. It is still possible that social isolation may also have an effect on levels of neophobia and exploration, although my trials would have to be repeated with a much larger sample size to confirm this hypothesis. For the majority of the analysis, Familymale was the most neophilic of all the adults, albeit still much less neophilic than the juveniles. He had a comparatively quick approach time and long interaction length, and also engaged in touching, grabbing, and chewing. Familyfemale however approached during only one trial and did not physically interact with the object during this time, suggesting much more neophobic tendencies than the rest of her family. The question posed here is whether isolation in a particularly social species of birds has an effect on their levels of neophobia or exploration. In captivity it would be ideal to maintain wild behaviours, especially if captive breeding programmes were to be implemented. There is limited research on this topic, particularly in regards to long-term isolation in birds. However those that are relevant to this study show different results than ours. Studies on ex-laboratory chimpanzees have shown that social and maternal deprivation during infancy can negatively affect social skills later on in life (Kalcher et al., 2008; van Leeuwen et al., 2014). Chimpanzees, like kea, are a highly social species, and the majority of learning in these species comes from observing other individuals. To be deprived of this socialisation during the critical learning period of an animal's life has clearly lead to abnormal behaviour in chimpanzees, and could potentially be the same in bird species. While our data did not show these same results, very little is known about the early life of the adults at Wellington Zoo, and whether they were maternally or socially deprived during their fledgling and juvenile years. Historically, kea were kept as solitary pets, and it would be informative to study these birds to determine if there was a more pronounced effect of long term isolation compared to the currently isolated zoo birds.

There are many novel object studies where individuals have temporarily been removed from their group, which can shed some light on whether the absence of conspecifics affects neophobia levels. In the novel object trials undertaken by Reid (2008), wild kea that were apart from their group contacted a higher percentage of novel objects than those who were with their group. Another study focused on the reaction of isolated mice (*Mus musculus*) towards a novel environment (Bartolomucci et al., 2003). It was found that the isolated mice had much higher corticosterone concentrations in comparison to group-housed mice, however the isolated mice were also more explorative of the novel environment. This suggests that the stress response is higher in individuals that are not surrounded by conspecifics, but this does not necessarily affect levels of neophobia. A similar outcome was found in European starlings (*Sturnus vulgaris*) (Apfelbeck & Raess, 2008). Individuals had higher overall corticosterone concentrations when they were separated from their group, however showed similar neophobic responses.

Perhaps the fact that these studies were based around short-term isolation explains this different outcome. This also provides an idea for future research – if the isolated individuals were housed with the group individuals, would they show more neophilic responses towards the novel objects? On the other hand if this increase in neophobia is a permanent result of isolation, it suggests that in captivity kea should ideally not be housed alone (especially in the case a potential captive breeding programme in the future). It is worth considering that in my trials, the family group were well integrated with an established hierarchy. We may not expect the same result to occur in a flock of unrelated individuals that has a dynamic hierarchy and less stable bonds between individuals. That is, caution is advised before extrapolating the patterns seen in my results to all flocks of kea.

There are also reasons other than neophobia that may explain why Familyfemale in particular showed less interest in the novel objects, such as our trial set-up or the hierarchy among the group. My trials used novel objects as an enrichment device, whereas a lot of similar studies place the novel objects next to a food dish, which forces the animals to have some kind of interaction towards them (e.g. (Fox & Millam, 2007; Sandra & Lefebvre, 2000). Perhaps this kind of experimental protocol could have elicited more response from the adults, particularly Familyfemale. Based purely on my observations, there was also a clear hierarchy among the family group. In the presence of Familymale, all the juveniles stopped interacting with the object until he had left. Even among the juveniles there appeared to be a hierarchy. Familyjuv1 would chase away or push away with her foot Familyjuv2. However both Familyjuv1 and Familyjuv2 chased away Familyjuv3 whenever she came near an object. In an ideal experimental setting, a more accurate measurement of neophobia levels would have been gained by carrying out these trials on individual kea rather than the group to avoid these confounding factors. If this were to occur, it is possible that all of the individuals would have appeared more neophilic, as they would have been free from the more dominant individuals. I do not believe this would have affected the response of Familyjuv1, however it is likely that Familyjuv2 and Familyjuv3 would have been more explorative, and spent a larger proportion of time interacting with the novel objects, without the presence of Familyjuv1. It is also possible that both adults would have been more explorative in the absence of their family, however neither of them appeared to be particularly interested in the objects anyway. Familyfemale in particular showed very little curiosity, and it is likely that factors other than hierarchy were affecting this. Unfortunately in this instance I was constrained by the logistical requirements of the zoo, hence no individual trials could be undertaken, however if this research were to be repeated it would be of interest to do both individual and group trials.

While our data does not provide any concrete evidence behind factors affecting levels of neophobia in kea, it does provide some observations that are supported by other published research. The juveniles in our trials appeared to be more neophilic than the adults, as indicated by their faster approach times, longer interaction lengths, and more invasive behaviours towards the novel objects. One conclusion that can be taken from this data is that even though the family group live in the same environment (and in the case of the juveniles have been raised together) there is still measurable variation among personalities. Therefore while differences in neophobia levels may be related back to different factors, it is necessary to keep in mind that individuals do have different responses to a novel environment.

Chapter 3: Problem solving via a multi-access box

3.1 Introduction

Studies of non-human intelligence have historically concentrated on primates and other large mammals, while studies on birds have focused on behaviour and ecology (Emery, 2006). It is only recently that some avian species (particularly parrots and corvids) have been suspected of having equivalent intelligence levels to primates (Emery, 2006). This has led to large amounts of research on avian cognition, as there are so many different aspects of it that can be studied. This chapter will focus on intelligence in the form of problem solving, which is a particularly well-studied topic in relation to avian species. Kea are especially well known for their problem solving ability, and there are already many studies investigating this (e.g. Miyata et al., 2011; Werdenich and Huber, 2006).

The methodology that this chapter will follow was first used to compare the cognitive abilities of kea and New Caledonian crows (Auersperg, von Bayern, et al., 2011). A problem that arises when trying to compare species is that they can have different behavioural and physical adaptations depending on their environment. The multi-access box (MAB) was designed to account for these differences between the tool-using crows and the non-tool using kea. The aim was for the birds to retrieve a food reward in the middle of a perspex box by using one of four different access routes – two of which required tool use. These two species are both renowned for their intelligence, and the ultimate finding of this study was that both species retrieved the reward in very different ways. The kea were more haptic in their exploration of the box, that is they used touch to investigate the apparatus, while the crows would observe the box from afar before attempting to take the reward. As well as this, the crows' neophobia often meant that they would not approach the box at all, or that they took much longer than the kea. They did however use the tools, in particular the stick, more readily. The curvature of the kea's beak makes handling tools such as sticks very difficult. Despite these issues, one individual of each species managed to use all four routes to gain access to the reward. Although this study did provide some insight in regards to intelligence in kea and New Caledonian crows, it highlights the idea that comparisons of intelligence can be problematic. It also provides evidence relevant to this thesis, in that this apparatus can be used to demonstrate individual cognitive variability within a species in regards to problem solving.

Problem solving can also be used to look at other aspects of intelligence. For example, Werdenich and Huber (2006) looked at whether kea are capable of understanding the relationship between cause and effect. They did this by hanging pieces of food tied to a string from a perch. The aim was to determine if the kea associated the string with the food, and whether or not they would pull the string to obtain the food (spontaneously, and without trial-and-error learning). The performance of all the birds across the different trials was very high, and the study supported the idea that kea are capable of understanding causal relationships. In another study, a follow up to the original MAB trials undertaken by Auersperg, von Bayern, et al. (2011), stick use was investigated in kea. In the initial study, one of the birds managed to successfully manipulate the stick tool to retrieve the food reward from the MAB. This was despite kea not naturally using tools in the wild. The curvature of their beak makes it very difficult to manipulate tools, however this particular kea showed high levels of beak and foot coordination in order to control the stick. Auersperg, Huber, et al. (2011) then used the same kea to determine whether this behaviour could be transmitted through the group, and whether the tool could be directed in a specific direction to retrieve a food reward. Four of the six kea achieved this task, again demonstrating their high problem solving and social learning abilities.

While we undertake this research into captive birds, it is important to take into consideration why kea are so adept at problem solving – i.e. how it is beneficial to them in the wild. It is thought the trait may have evolved in response to their constantly changing alpine environment (Emery, 2006). This environment is fraught with challenges, including constantly changing weather conditions and food sources (Temple, 1996). Being able to take advantage of new resources is therefore beneficial, as it means all potential food sources are accessible to the kea. An example of this has been seen at a hotel on the ski slopes of the Southern Alps. Kea are often observed opening the lids of rubbish bins in order to obtain food scraps (Gajdon et al., 2006). Humans have taken over a large portion of kea habitat, which would normally be an issue for most birds. However kea have taken advantage of this, and exploit these new resources we have provided. This fact highlights the importance of intelligence and problem solving ability in wild kea, and these traits therefore need to be maintained in captive kea, particularly in the event of a captive breeding programme.

In regards to the individual birds investigated in this thesis, it is worth considering the effect of social isolation on cognitive approaches to problem solving. As mentioned above, social learning plays a large role in the spread of innovative behaviours such as tool use (Auersperg, Huber, et al., 2011) and utilising human resources (Gajdon et al., 2006). The ability to engage in social interactions can be negatively affected by isolation, particularly during early development (e.g. van Leeuwen et al., 2014). However even later in life, the spread of innovative behaviours is not possible if a bird is not housed with other conspecifics. Innovation and social learning are both important traits for wild kea due to their unpredictable environment, hence it is also important to maintain these behaviours in captivity in the event of future wild releases.

The aim of these trials was to determine relative levels of problem solving for each individual using the time and routes taken to solve the Multi-Access box. These factors will also be used to look at neophobia levels that will later be related back to the data found in Chapter 2. Problem solving ability will then be looked at to determine whether demographic factors (e.g. age) or housing situations (i.e. group versus isolation) has an effect on individuals, as well as the role of social learning.

3.2 Methodology

This task involves the observation of problem solving ability in kea in response to a puzzle box. The same seven birds were used, all of which were housed in the same enclosures as the previous task (see Appendix 1). A multi-access box (MAB) originally designed by Auersperg, von Bayern, et al. (2011) was used. The box used was constructed by Clio Reid (unpublished study) who conducted the same trials on wild kea. The box itself consists of four perspex walls mounted onto a wooden frame. Each wall provides a different route through which a food reward (in our case a macadamia nut) can be retrieved. The reward sits on a platform in the middle of the box and can be accessed in four different ways: by pulling on a string attached to the nut; by inserting a stick to knock the nut off the platform; by inserting a marble to knock the nut off the platform; or by opening a small door and reaching in to grab the nut. Figure 3.1 shows the MAB used by Auersperg, von Bayern, et al. (2011).

For this study, a trial lasted either until the reward was successfully retrieved, or after ten minutes had passed. The box was placed in the enclosure on a flat surface with two marbles and two sticks placed on the corners. Video recording started once the keeper had moved one metre away. If a trial was successful, the box was reset with the marbles and sticks replaced in their original positions and a new macadamia nut placed inside. The box was also randomly rotated between trials. Once a particular route had been used to successfully retrieve the reward at least four times, this side of the box was blocked off (i.e. the string was removed and the door was taped shut). This ensured the birds tried alternative methods of retrieving the reward. The aspects that were observed were: latency to approach within one metre; the proportion of the trial spent interacting with the box (including being within one metre of it); the proportion of time spent interacting with each side of the box; and the time and route used to solve the puzzle.

Data were extracted from the videos using the software B.O.R.I.S, and processed using R 3.3.2 to calculate descriptive statistics and to produce graphs. No further statistical analyses were undertaken due to the small sample size.

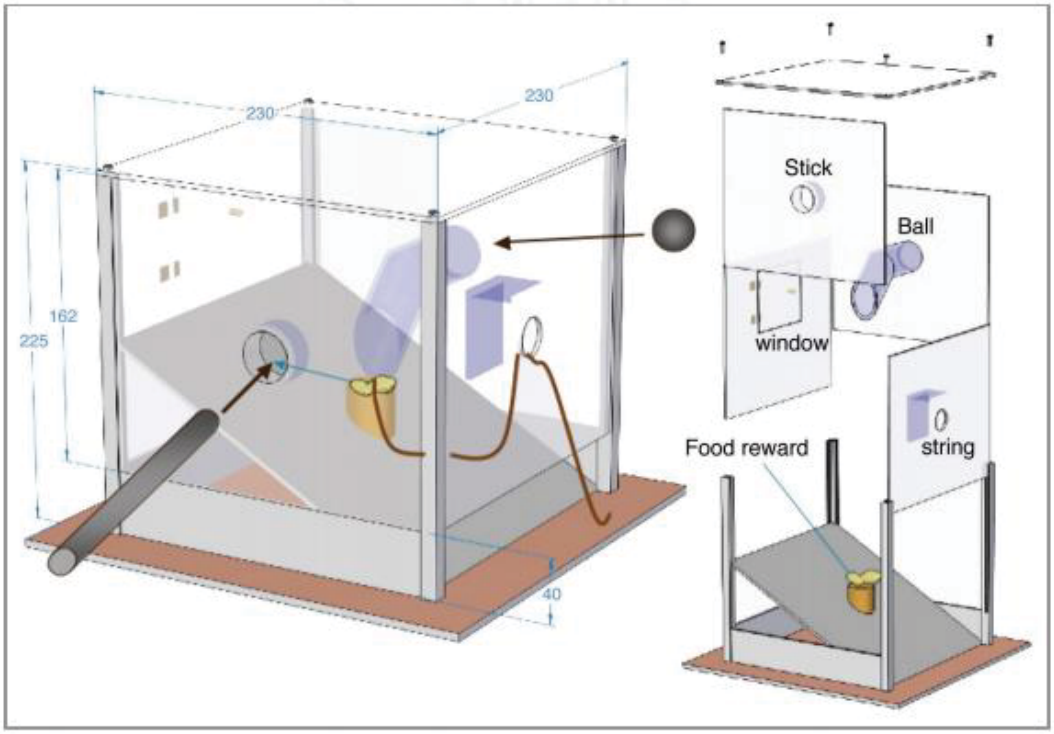

Figure 3.1. The multi-access box designed by Auersperg, von Bayern, et al. (2011). A similar apparatus (built by Clio Reid, unpublished study) was used in this study.

3.3 Results

Ten trials were successfully recorded and analysed for the isolated individuals, and 24 for the family group, as there was no way to separate the family group and I was thus unable to attempt ten individual trials per family member. Table 3.1 shows the frequency of approaches made by each bird. With the exception of Familyjuv1 and Familyjuv2, there was very poor trial participation for this task, with even Familyjuv3 only approaching during 50% of the trials.

Table 3.1 Frequency of trials during which an approach was made for each bird. Birds are shown in order of descending approach frequency, and this is used as an indicator of increasing neophobia.

Bird ID	**Trials approached**	**Total number of trials**	**Percentage of approaches**
Familyjuv1	24	24	100.0%
Familyjuv2	23	24	95.8%
Familyjuv3	12	24	50.0%
Isolated1	3	10	30.0%
Isolated2	2	10	20.0%
Familymale	3	24	12.5%
Familyfemale	1	24	4.2%

Figure 3.2 shows the range of approach times for each bird. With the exception of a couple of outliers, the three juveniles and Familymale all had little variation in the range of approach times, and approach times were short. For the majority of the trials Familyjuv1 approached during the first few seconds of the box being reset, with Familyjuv2 approaching not long after. Familyfemale only approached during one trial, hence her result is represented on the boxplot as a single line, and this was very late in the trial. Isolated1 had a larger range of approach times, and took longer to approach than the others.

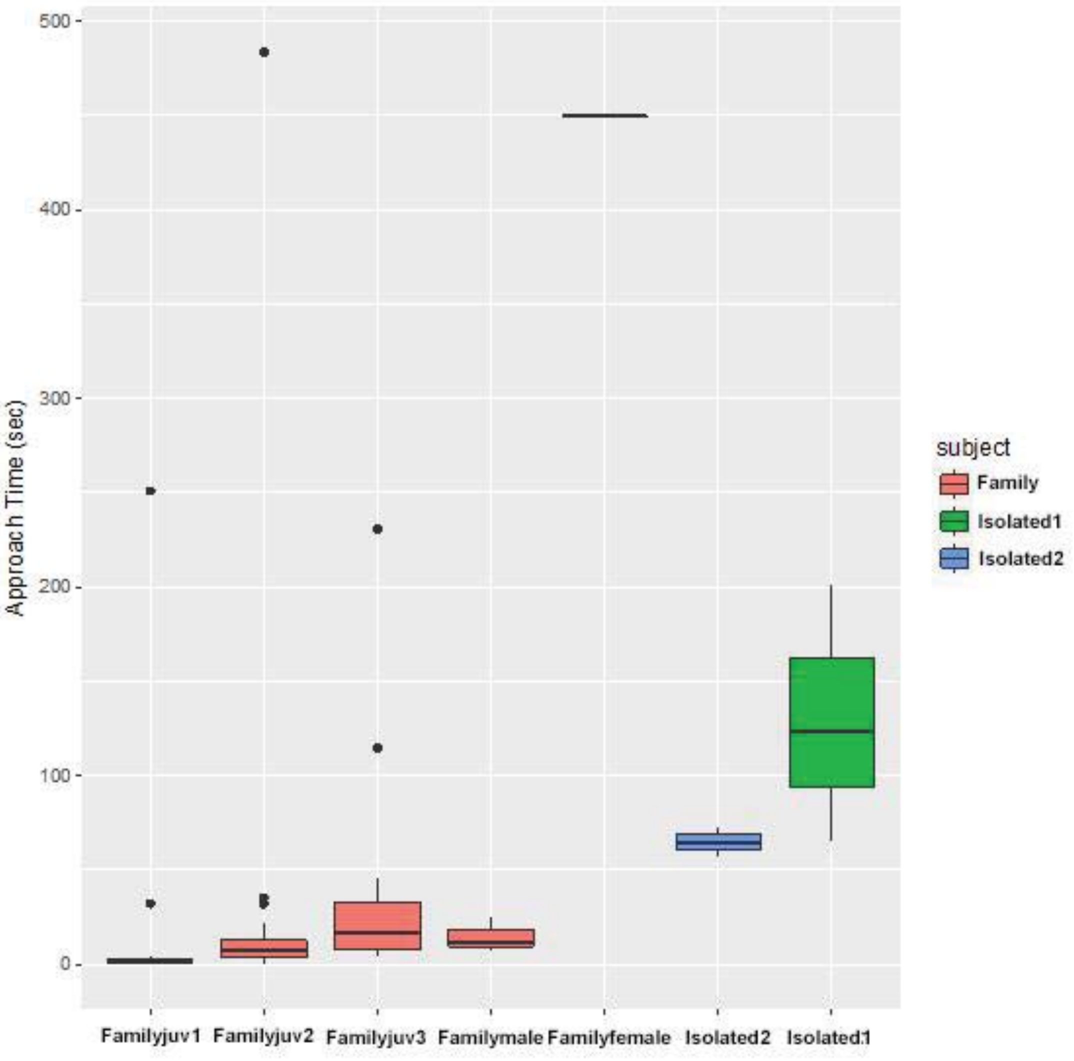

Figure 3.2 The time in seconds for each bird to approach the Multi-Access Box across all trials.

Figure 3.3 shows the proportion of time per trial that was spent interacting with the MAB. This is shown as a proportion rather than in seconds due to the fact that each trial was a different length (a trial ended once the puzzle was solved). Familyjuv1's average interaction length was nearly 100%, and Familyjuv2's was also very high. Familyjuv2 and Familyjuv3 had a much higher spread and therefore more variability in their interaction lengths than all the other birds. Familymale and Isolated1 spent on average less than half of the trial length interacting with the box, while Isolated2 spent even less time - approximately 10% of the trial length. Familyfemale's one interaction did not last for long at all, hence her singular line around the 5% mark.

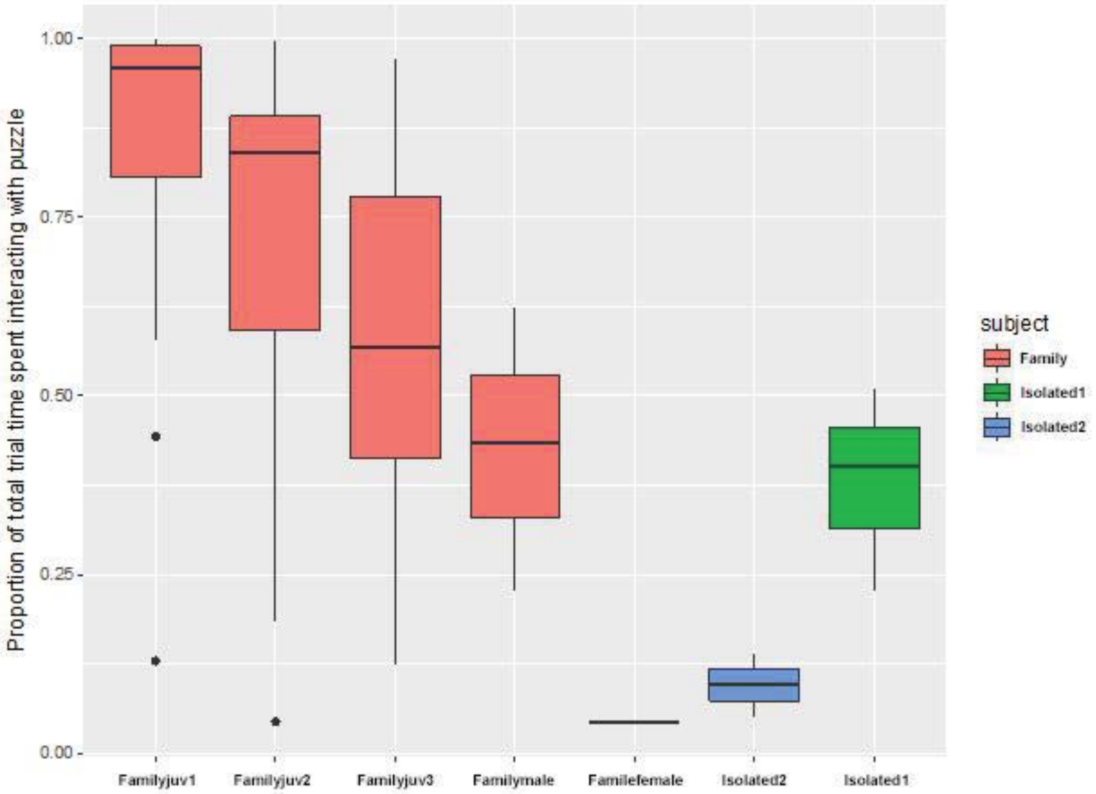

Figure 3.3 The proportion of each trial that each kea spent interacting with the Multi-Access Box.

Of the seven individuals, only the three juveniles managed to successfully retrieve the reward. Figure 3.4 shows the time taken for each of them to solve over all the trials, with Familyjuv1 having the quickest mean solve time. However, there are a number of other things to take into consideration. The box can be solved in four different ways, and after one of these routes was used successfully at least four times, it was then blocked off. This has led to a lot of variability in the data, and because of the small sample and trial size, no significant trends about solve time can be pulled out of this information (shown in Table 3.2). There are some differences in the way each bird solved the puzzle however. Familyjuv1 used the door nearly every time, while Familyjuv2 and Familyjuv3 only used the string. Familyjuv2 and Familyjuv3 even had one trial each where the door (perhaps the most obvious route) was still available and still used the string. Following previous trends, Familyjuv1 did solve the puzzle more times than the other two. Once the string and door were removed as options, none of the birds managed to retrieve the reward.

Table 3.2 Information for each trial on how the Multi-Access Box was solved, by which bird, and which routes were available to them. Trials 1-12 were undertaken on the first day, and 13-24 on the second day.

Trial	Bird	Time (s)	Route	Routes available
1	Familyjuv1	30	Door	All
2	Familyjuv1	12	Door	All
3	Familyjuv1	7	Door	All
4	Familyjuv1	14	Door	All
5	Familyjuv3	72	String	Door blocked off
6	Familyjuv2	12	String	Door blocked off
7	Familyjuv1	8	String	Door blocked off
8	Familyjuv3	13	String	Door blocked off
9	Familyjuv2	162	String	Door blocked off
10	Familyjuv3	58	String	Door blocked off
11	Familyjuv2	40	String	Door blocked off
12	-	-	-	Door blocked off, string removed
13	Familyjuv1	33	Door	All
14	Familyjuv3	80	String	All
15	Familyjuv2	32	String	All
16	Familyjuv1	15	Door	All
17	Familyjuv1	37	Door	All
18	Familyjuv2	63	String	Door blocked off
19	Familyjuv2	70	String	Door blocked off
20	Familyjuv1	56	String	Door blocked off
21	Familyjuv2	75	String	Door blocked off
22	-	-	-	Door blocked off, string removed
23	-	-	-	Door blocked off, string removed
24	-	-	-	Door blocked off, string removed

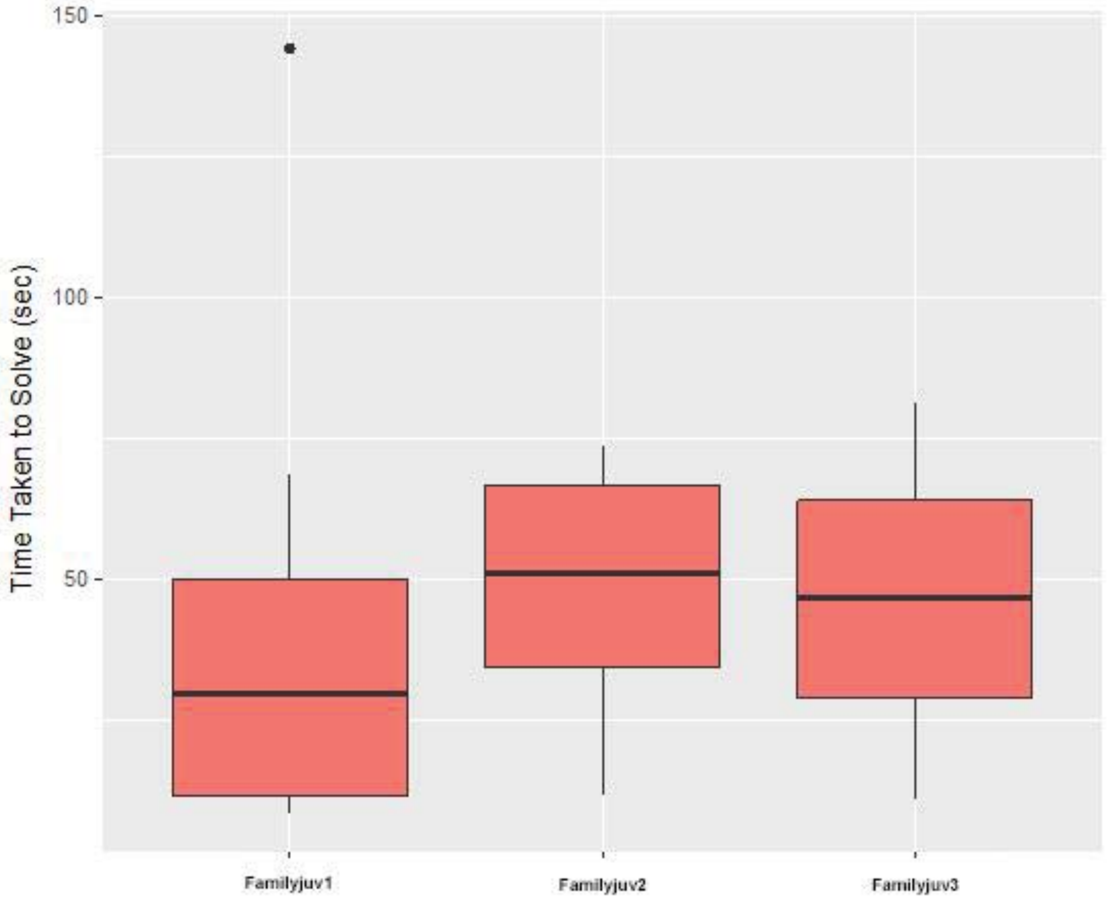

Figure 3.4 Time taken in seconds for the three juveniles to solve the Multi-Access Box.

3.4 Discussion

The aim of these trials was to investigate levels of problem solving ability in regards to how quickly the MAB was solved, and whether different (perhaps more difficult) solutions were used. This data will also be used to assess levels of neophilia in regards to approach time and interaction time. I used the results of these trials to rank the birds in terms of neophobia/neophilia and problem solving ability (Figure 3.5), however this is not an assessment of intelligence, simply a qualitative summary of these results. The continuum is identical to the one created in Chapter 2, suggesting that levels of neophobia and problem solving ability are closely related.

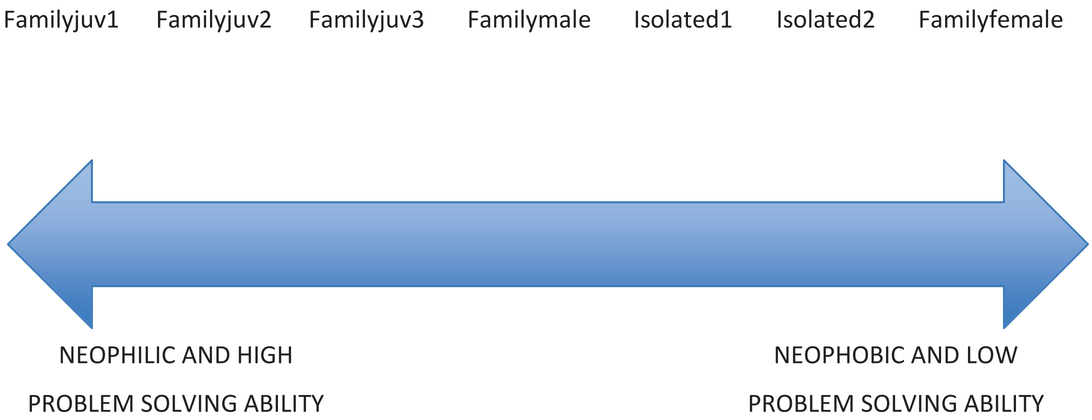

Figure 3.5 Relative ranking of seven captive kea in regards to neophobia level and problem solving ability using the combined results of our Multi-Access Box trials.

As with the novel object trials, my results show a clear distinction between age classes. In this case, the juveniles are more neophilic, and more adept at problem solving than the adults. In regards to neophobia levels, Familymale was not far behind the juveniles. Although he never successfully solved the puzzle box, he had a quick approach time, and a similar interaction length to Familyjuv3. Isolated1 did have a similar interaction length to Familymale, however she spent the majority of her time throwing both the stick and marble around her enclosure, and was not very focused on retrieving the food reward from the box. On the other hand, Familymale and all the juveniles did make attempts to get the reward. As for being successful in retrieving the reward, all three juveniles achieved this, while none of the adults did. This finding shows similar results to a study carried out on the closely related kaka (Loepelt et al., 2016). Multiple problem solving tasks were presented to a range of different aged kaka, and the younger ones consistently showed more explorative tendencies and a higher problem solving ability than the adults. Again this type of behaviour can be explained by the idea that juveniles need to acquire information about their environment and develop foraging skills (Heinrich, 1995; Loepelt et al., 2016).

Amongst the adults, isolation did not measurably affect either neophobia or problem solving ability. The two isolated birds are in the middle of the other two adults on the spectrum, and Isolated1 showed more explorative behaviours towards the box than both Isolated2 and Familyfemale. We may have expected the group adults to show more interest towards the box and a higher problem solving ability due to social learning. For example, among the juveniles I saw evidence of each of them observing the others and attempting to use the same solutions. Despite solving the door route first, Familyjuv1 was not successfully able to master the string until after the other two juveniles. Familyjuv2 also mastered the string only after watching Familyjuv3 master this access route. It is possible that after successfully mastering the door route to obtain the reward, Familyjuv1 did not consider other options until the other juveniles demonstrated them. However, neither Familyjuv2 nor Familyjuv3 learnt to solve the door access route from Familyjuv1. This may suggest hierarchies in social learning, individual variability in social learning, or more simply variability in cognitive problem solving that prevent certain strategies from being adopted (as discussed by Laland, 2004).

Social learning was not evident in Familymale or Familyfemale. The isolated birds on the other hand had no other individuals to observe either approaching or solving the box. This departure from our expectations may come down to the different rearing environments of the individuals (e.g. each individual may not have grown up in the same conditions they are now housed in) or reflect different personalities and cognitive abilities. There are many studies that look at isolated rearing environments and the effect of this through to adulthood, and the general consensus is that it has a negative effect – in this case it can reduce problem solving ability or flexibility. Again it is important to note that we know little about the rearing environment of our kea, and they may not have been exposed to an isolated environment to the extent that all these studies have shown, which could explain why our results are dissimilar to this literature. One study undertaken on hybrid-bred rats compared the flexibility in problem solving ability between individuals raised in impoverished conditions, and those in enriched environments. They found that rats brought up in an enriched and social environment showed more flexibility towards changing problems (Receveur & Vossen, 1998). The same results have been seen in ex-laboratory chimpanzees (Kalcher et al., 2008). These individuals show decreased social skills, which in a highly social species could be detrimental for future social interactions. It may also mean a decrease in social learning ability, and therefore a decrease in the learning of innovative behaviours. In the case of kea, this could be disadvantageous for captive bred birds being released into the wild, but could also be detrimental to the welfare of captive birds.

Another topic of discussion is the ways in which the juveniles solved the puzzle and how they all differed from one another. Familyjuv1 used both the door and the string solutions successfully, while Familyjuv2 and Familyjuv3 both used only the string. There are some differences between these trials and the original trials undertaken by Auersperg, von Bayern, et al. (2011). While I considered a successful trial to be any retrieval of the food reward, they only considered a trial successful if there were no attempts made to retrieve the reward via any other route. This means it took the birds much longer (25 trials on average) to have a successful trial. All of the kea first solved the string solution, and the second solution was a mixture between the door and ball solutions. In comparison, one of our juveniles (Familyjuv1) solved the door in the first trial. She became adept at this very quickly, and often would not make unsuccessful attempts at all, instead opening the door as soon as the box was reset. My kea may seem less adept at tool using than those used by Auersperg, von Bayern, et al. (2011), however their birds had previous experience with other problem solving tasks, and had many more trials than mine. Once the string and door options of the MAB were blocked off, both Familyjvu1 and Familyjuv2 spent a lot of time repeatedly throwing the marble at the box, and came very close to putting in the correct hole. Familyjuv1 also placed one of the marbles in a cardboard tube within their enclosure, tipped the tube up so the marble rolled down, and then retrieved it from the other end. I believe that these actions suggest that more trials would have resulted in successful tool use by the juveniles. Kea are not a naturally tool-using species, which is why they may require more exploration opportunities to successfully use the stick and marble routes.

It is important to note that due to the set-up of these experiments, individual problem-solving ability was hard to quantify among the family group – particularly in the juveniles who were the only successful birds. This could have been overcome by testing the birds separately, however as kea do live in social groups it did allow us to see some evidence of social learning. Generally when one juvenile was investigating one side of the box, the others would also investigate that side, particularly if a food reward had been retrieved. Also towards the end of the trials when Familyjuv1 began throwing the marble at the box, Familyjuv2 began to do the same thing shortly after. A study on starlings tested novel problem solving tasks in both group and isolated settings, and this provided data on individual birds as well as how they reacted with other birds around (Boogert et al., 2008). This would have been ideal for the kea, as we could have measured the effect of different factors on the problem solving ability of each bird, but also looked at the social learning aspect. Despite this limitation, the data we did extract gives us an idea of how innovation and problem solving can spread throughout a kea population, and will be particularly important when it comes to looking at how the behaviour of kea strike may be adopted by a flock of wild kea (Chapter 4).

Chapter 4: Sheep Analogue

4.1 Introduction

With the expansion of human civilisation, conflict with wildlife is inevitable. This type of conflict can be detrimental to the humans, the wildlife, or both, as is the case with kea. Kea strike is a little known behaviour of kea whereby they attack sheep. This behaviour was first observed in 1867 by farmers who noticed wounds on their sheep (Temple, 1996), but it was not until 1868 that a kea was first observed sitting on the back of a sheep and ripping its flesh away. This was perceived as a common occurrence, and the sheep would often die, mostly due to a bacterium (*Clostridium spp.*) being transferred from the kea into the wounds and causing blood poisoning (Temple, 1996). This behaviour led to the government placing a bounty on kea, and it is believed that approximately 120,000 kea were killed between 1868 and 1970 (C. Reid, pers. comm. 2017). The total kea population now numbers between 1,000 and 5,000 individuals – a drastic decline since the arrival of humans (Robertson et al., 2017). Although kea are now fully protected, farmers are allowed to apply for permits to kill nuisance birds, and the number of illegal killings is unknown (C. Reid, pers. comm. 2017). An important part of kea conservation is minimising this conflict, and showing farmers and tourists alike that this bird is not just a nuisance, but an important part of New Zealand's native fauna.

There are plenty of examples of human-wildlife conflict around the world, as well as different techniques that have been used in an attempt to minimise the conflict without harming the species involved. One of the biggest conflicts between humans and wildlife is predation on livestock (as with the kea and sheep). This is particularly apparent in more poverty-stricken countries, where farmers' livestock are vital for their survival. An example of conflict in Africa is between farmers and cheetahs (*Acinonyx jubatus*), one of the most threatened felids found in Africa (Boast et al., 2016). There have been different strategies to minimise the loss of livestock to cheetah, including translocations, the use of livestock guarding dogs, and educating the farmers (Boast et al., 2016; Marker & Boast, 2015). Translocations have been deemed unsuccessful in Namibia, as relocated cheetah had low survival rates, and farmers did not see a decrease in livestock deaths (Boast et al., 2016). If this method was to be applied to kea, there are concerns it would be impractical and costly. The only suitable habitat for translocation of kea is the area in which they already live, and there is little of the country that is not covered by livestock farming. Another, more successful technique for cheetah, has been the use of livestock guarding dogs and proper fencing, both of which farmers have been trained in. Approximately 73% of farmers who had guard dogs reported significant decreases in livestock killing (Marker & Boast, 2015). Other strategies to minimise human-wildlife conflict have included relocating individuals when population numbers become too high in an area (e.g. lynx, *Lynx lynx,* in Switzerland), education of the public about the conservation of nuisance species, and compensation schemes for lost livestock (World Wide Fund for Nature, 2017).

These examples show that human-wildlife conflict is a difficult issue to overcome. Promoting co-existence through education and awareness is obviously an important tool, and is something that is already emphasised for the kea (e.g. through the Kea Conservation Trust). However, for longer-term solutions, it is important to also understand the drivers behind the behaviour, as it is suspected that the behaviour is innovative rather than an innate predatory behaviour. That is, not all kea are inclined to attack sheep, and as a first step in mitigating the problem it is important to understand which individuals may be more likely to develop the behaviour.

Innovative behaviours are those behaviours that arise in a population and allow individuals to take advantage of new resources, or use existing resources in a new way (Greenberg, 2003). These behaviours can then spread through a population if they are beneficial to the species. For example in the kea, by attacking sheep they are exploiting a new food source, which may allow them food in an environment where nothing else is available. Studies on innovation have shown that many different factors can influence the development of such behaviours. Personality in particular is often associated with innovation. For example individuals that are more neophilic and approach new objects quickly and without fear are often more likely to develop a new behaviour in relation to that object (Greenberg, 2003). A study on the common myna (*Sturnus tristis*) observed their reactions to a novel food source and the propensity to develop a new foraging technique (Sol et al., 2012). Exploration of the food source and development of novel foraging techniques was associated with high levels of neophilia. It was also associated with high motivation to feed – that is when they were food deprived before the start of the experiment. This food deprivation may increase the likelihood of innovative behaviours in wild animals, and may be the driver behind wild kea learning to open human rubbish bins (Gajdon et al., 2006).

These studies show there are many different factors that can affect the development of innovative behaviours, and this may be dependent on the testing situation or the particular species. However the aim of this experiment is to determine whether specific factors, either demographic or personality related, influence a kea's likelihood to develop behaviours associated with kea strike on sheep. Understanding the potential drivers behind kea strike will allow us to come up with ways in which this conflict can be reduced, and consequently decrease the number of threats kea face in the wild. This information may also help with captive conditions of kea, as in the event of a captive breeding programme it will be necessary to identify high-risk birds, but on the other hand to foster innovative behaviours so that released birds will still have these survival skills.

4.2 Methodology

This task involved observing the kea's response to a mechanical sheep analogue (an apparatus designed to mimic a sheep's back and movements). These observations will be looked at in terms of the personality of each kea to determine whether birds with particular personality traits are more inclined to 'attack' the sheep. Demographic factors will also be taken into account, however due to the small sample size these results will not be further statistically analysed. The seven kea were used for these trials were the same birds used I the novel object (Chapter 2) and Multi-Access Box trials (Chapter 3) as described in Appendix 1.

This experiment and the sheep analogue that was used were both designed by Clio Reid (unpublished study). The sheep analogue comprises of a wooden base with two metal springs attached. The springs support the body of the apparatus, which is a wooden board covered with carpet. Over this, a removable 'fur' can be placed – in this case some black synthetic fur – which attaches to the base with Velcro. A small hidden pocket has been sewn into the fur, in which a food reward can be placed (to act as the food aspect of the sheep). The whole apparatus can be moved backwards and forwards by a pulley system, which will mimic the bucking movements of a sheep as it runs. The analogue was moved slightly whenever the kea made an approach, and more intensely when one of them was on its back.

Before the trials started, a pre-trial was run, during which time the birds had ten minutes to become familiar with the sheep analogue without a food reward. After this the trials began, with ten each for the isolated individuals and 20 trials for the family group. The device was placed on a flat service within the enclosure with the strings leading to the outside, and a macadamia nut was put in the fur pocket. This was done in sight of the kea, however the fur cover was rotated between trials to minimise the influence of visual memory. All trials were video recorded, and the time began when the keeper had moved approximately one metre away from the device, and ended either once the food reward was retrieved or after ten minutes had passed. Between trials the sheep analogue was reset by changing or replacing the macadamia nut and rotating the fur cover. The following aspects were observed: latency to approach within one metre; proportion of the trial spent interacting with the object (including being within one metre); the number of touches, grabs, and chews of the object; the proportion of time spent chewing the object; and the time taken to 'solve' or retrieve the food reward.

Data were extracted from the videos using the programme B.O.R.I.S, and Microsoft Excel was used to calculate descriptive statistics and to produce graphs. No further statistical analyses were undertaken on the data due to the small sample size, as well as the different housing situations (some birds being in a group, some being housed singularly), which may have caused bias.

4.3 Results

The frequency of each kea's involvement in the trials showed great variation (Table 4.1). Two of the birds, Isolated2 and Familyfemale did not approach or interact with the sheep during any of the trials, and these two birds were removed from further analysis.

Table 4.1 Frequency of trials during which an approach to the sheep analogue was made for each bird and therefore accepted as a successful trial for inclusion in the study. Birds are shown in order of descending approach frequency, which will be used as an indicator of increasing neophobia.

Bird ID	Trials approached	Total number of trials	Percentage of approaches
Familyjuv1	19	20	95.0%
Familyjuv2	14	20	70.0%
Familyjuv3	14	20	70.0%
Isolated1	2	10	20.0%
Familymale	2	20	10.0%
Isolated2	0	10	0.0%
Familyfemale	0	20	0.0%

The data shows associations between the frequency of trial involvement and the mean approach time (Figure 4.1). The three juveniles (who approached during the majority of trials) also had the quickest approach times. There appears to be an obvious difference between the quickest approach time (Familyjuv3) and the longest (Isolated1), with the others sitting in the middle.

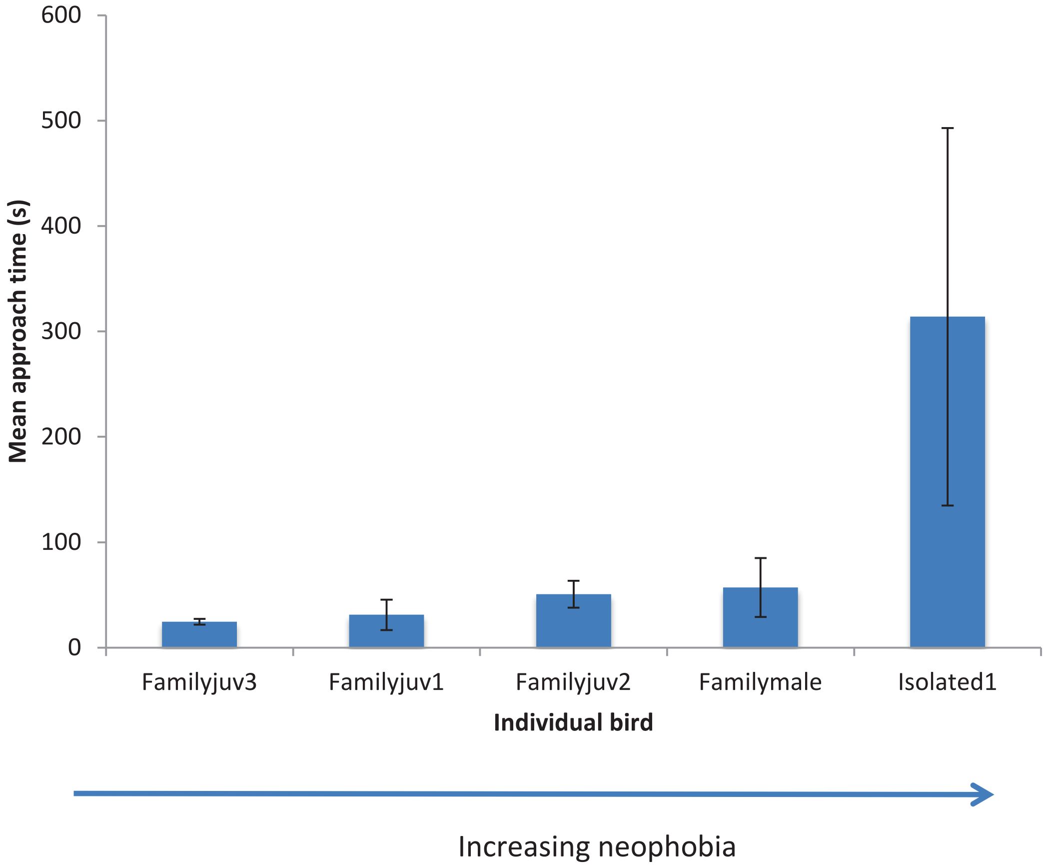

Figure 4.1 The mean time in seconds for each bird to approach the sheep analogue. Error bars represent one standard error. The birds have been ordered by increasing latency to approach using this factor as an indicator of increasing neophobia (baseline arrow). Isolated 2 and Familyfemale have been removed.

The mean interaction length was calculated as a proportion of the total trial length due to the trials running for different times. They show a similar trend to the approach time, with the three juveniles being the quickest to approach, and also interacting for the longest proportion of time. Isolated1, who took the longest to approach, only interacted with the sheep for a short proportion of the trial. Even for Familyjuv1, the proportion of time spent interacting with the sheep barely exceeded 50%, which means a lot of the trial time was taken up by approach time.

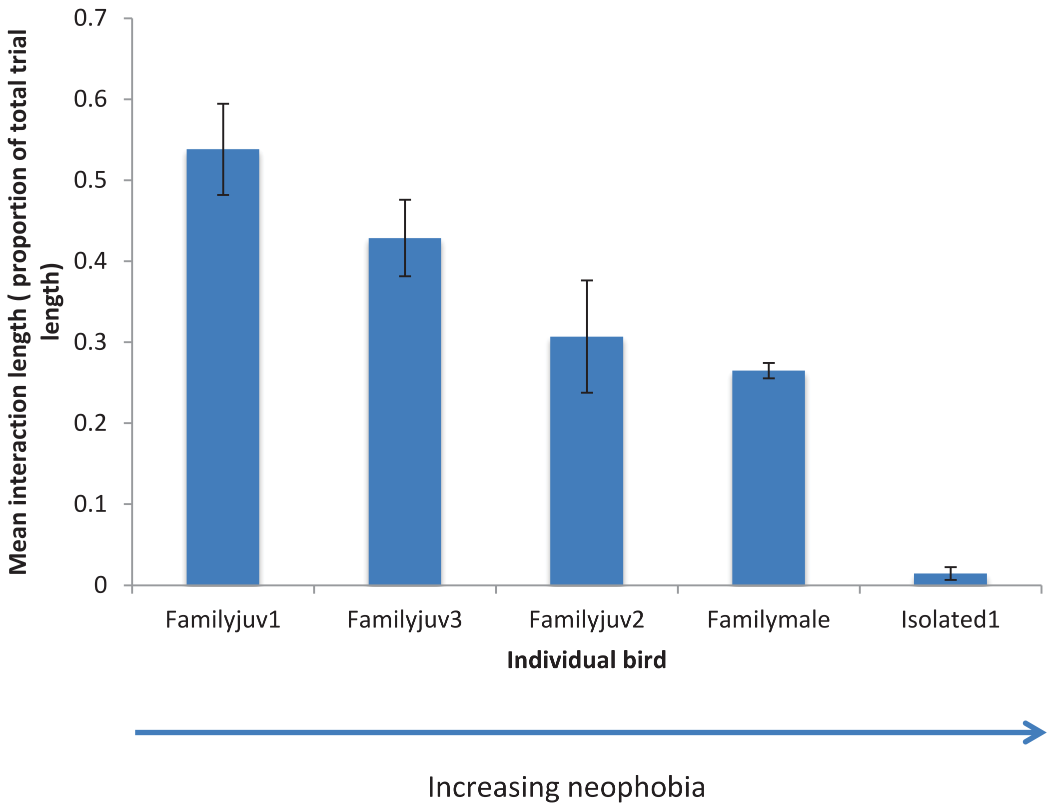

Figure 4.2 The mean proportion of time each bird spent interacting with the sheep analogue per trial. Error bars represent one standard error. The birds have been ordered by decreasing interaction length proportion, which is used as an indicator of increasing neophobia (baseline arrow).

I also observed the different types of interactions that occurred during each trial (touch, grab, or chew). This is particularly of interest in regards to the sheep analogue, as grabbing and chewing are interactions that would be involved in inflicting injuries on sheep. These were measured as a rate of occurrence per trial (Figure 4.3). The trials ended up reducing in duration once Familyjuv1 discovered how to retrieve the food reward, hence there are only a few different interactions per trial. However we can see that Familyjuv1 was more interactive than the other two, particularly in regards to grabbing and chewing. She was the one who was always on top of the device looking for the food, and used grabbing and chewing to obtain it. Familyjuv2 was also very inquisitive, however Familyjuv1 appeared to be more dominant and would push her off the device. Familyjuv3 was often in the vicinity of the device, however she engaged mostly in touching and grabbing, with little very of the invasive chewing.

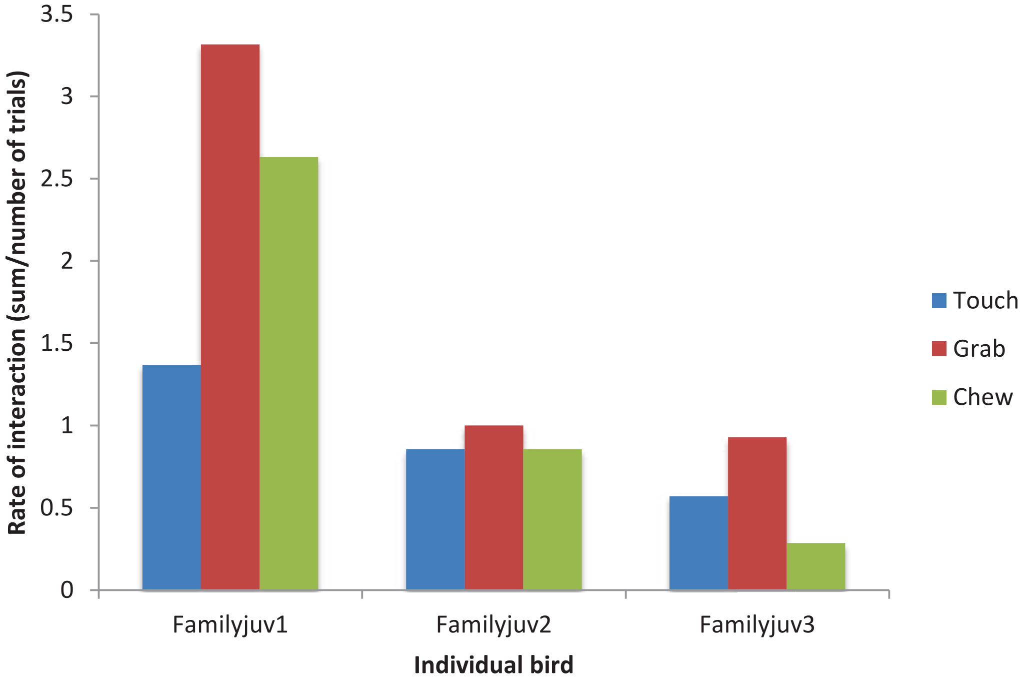

Figure 4.3 The mean rate of different interaction types (touch, grab, chew) per trial. Rate is defined as the total sum of the frequency of the interaction over the number of trials.

The time spent chewing as a proportion of the whole trial is shown in Figure 4.4 Chewing is the most invasive behaviour of the three. Familyjuv1 spent approximately 15% of the trial engaged in chewing behaviour, which is much higher than Familyjuv2 (4%) and Familyjuv3 (1%).

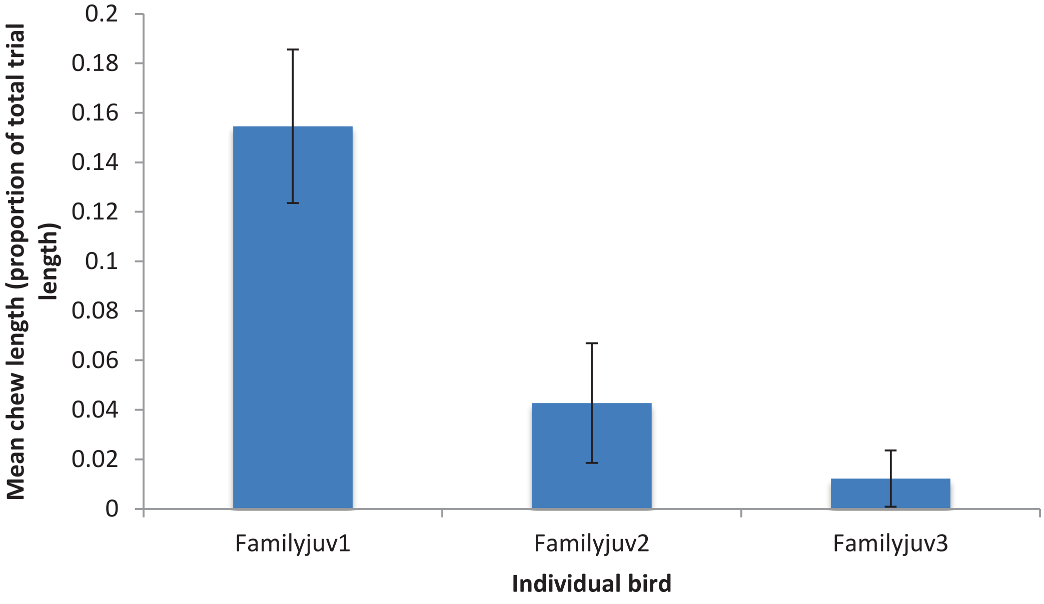

Figure 4.4 The mean proportion of time each bird spent chewing the sheep analogue per trial.

As Familyjuv1 was the only bird to solve the task, Figures 4.5 and 4.6 show the time she took to solve over all 20 trials (Trials 1 and 2 were not solved). Figure 4.5 includes all the data, and does not show a significant improvement in solve time. An R^2 <0.001 suggests a very weak relationship between trial number and time to solve. However Trial 18 appears to be an outlier. Further analysis of the video data did not show any obvious reasons why Familyjuv1 took so much longer to solve this trial, and so the data point cannot be ignored. However, in case this trial did reflect an invalid result, I have also included Figure 4.6, which shows the graph with Trial 18 removed. This shows a much stronger relationship with an R^2 = 0.307, and could suggest that as the trials went on, solving time was reduced.

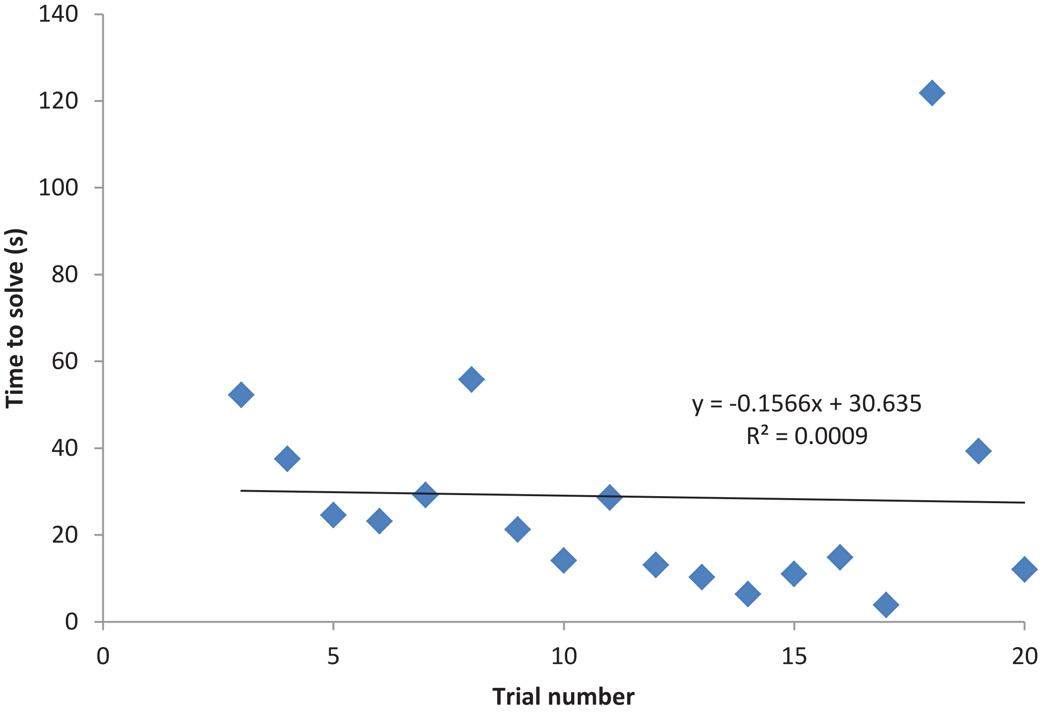

Figure 4.5 The time taken in seconds for Familyjuv1 to solve (retrieve the food reward) each trial. Trials 1 and 2 are excluded, as they were not solved.

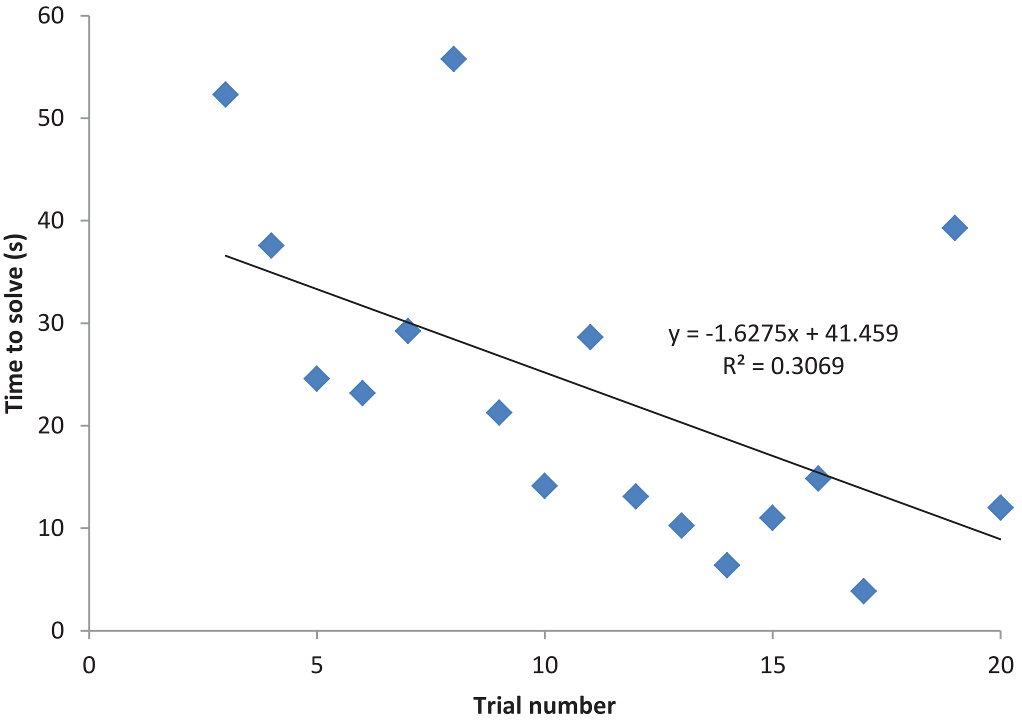

Figure 4.6 The time taken in seconds for Familyjuv1 to solve (retrieve the food reward) each trial, with trial 18 (a possible outlier) removed.

4.4 Discussion

The aim of this experiment was to determine whether particular birds (in terms of demographics and personality) are more likely than others to engage in innovative behaviours likely to result in kea strike, or in terms of this study, more likely to interact with the sheep analogue and retrieve the food reward. Because the sample size is so small and our results are confounded by the group housing of some of the birds, I cannot make any definite conclusions with regards to demographics involved. However there was clear evidence that some personalities are more likely to be innovative than others in a manner that could lead to kea strike in wild birds. Observing the family group also allows us to investigate whether social learning could be involved in kea strike.

I used the results from these trials to create a continuum based on how interactive the birds were towards the sheep analogue (Figure 4.7). This was based on approach time, interaction length, interaction type, and whether or not a bird retrieved the food reward. These rankings may provide an indication of which individual/s would be more likely to attack a sheep for food in the wild.

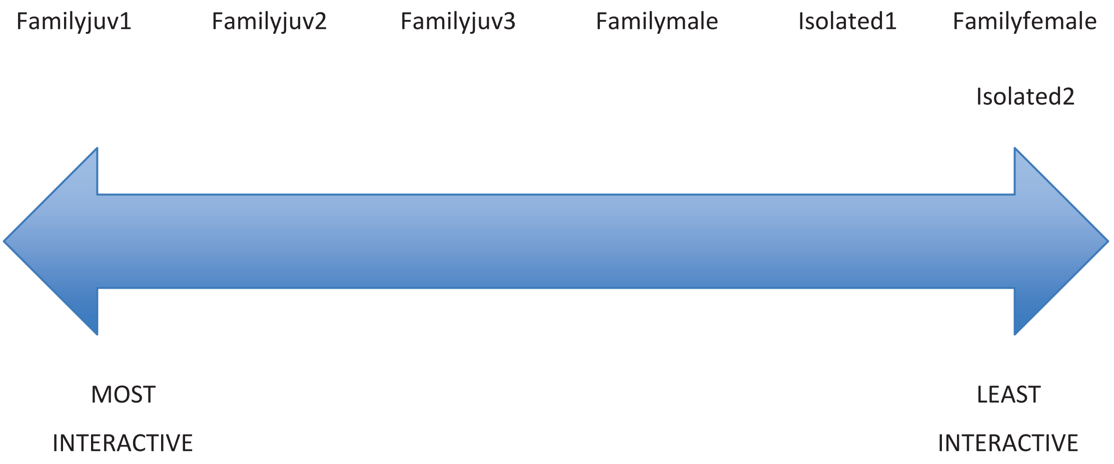

Figure 4.7 Relative ranking of seven captive kea based on interactive they were towards a mechanical sheep analogue.

In wild kea, the attacking of sheep for food is most likely to represent an innovative behaviour, that is, a new behaviour in response a new ‘object’ in their environment. The problem that results from this innovation is that it has led to human-wildlife conflict, and has consequently caused the deaths of approximately 100,000 kea. It is therefore important to understand the characteristics that an individual may have that will make them more likely to develop this behaviour, as well as whether there is evidence of social learning to spread the innovation through a flock of kea. My results show a distinction between the juveniles and adults, in that the juveniles were more explorative of the sheep, especially when they realised it was also a food source. Familyjuv1 approached very quickly, spent more time interacting with and chewing on the sheep, and was the only individual to successfully retrieve the food reward. The other two juveniles also had comparatively quick approach times and long interaction lengths, and although they did not retrieve the reward, they did both engage in physical interactions with the sheep. At the other end of the spectrum however, two of the adult birds, Familyfemale and Isolated2, were the least interactive as they did not approach the sheep during any trial. While Familymale was quick to approach and spent a fair amount of time in the vicinity of the sheep analogue, he only approached during 10% of the trials, and did not physically interact with the device at all, and Isolated1 had even less interaction. Hence they both displayed a very different behavioural reaction than the juveniles to this novel object.

While there have been no similar studies investigating kea strike, the concepts of innovation and problem solving are very closely linked. Therefore, it is worth considering my results in relation to the many studies focused on problem solving in birds. These have shown the same age-related effects as I found. One example is a study by Aplin et al. (2013) who investigated how innovation spreads through a population of blue tits (*Cyanistes caeruleus*). It was found that juvenile females were more likely to develop novel foraging skills than any other age or sex class. Due to the lack of juvenile males in my study, I was unable to make any sex-related comparisons, however this is a factor worth investigating in future studies. As was discussed in Chapter 2 and 3, it is thought that because juvenile animals need to be able to explore their environment, for example to discover appropriate food sources (Heinrich, 1995), that they are likely to be more neophilic and adept at problem solving than adults. It is also possible that juveniles are likely to be more innovative, particularly in regards to finding a new food source, as is the case with kea strike. In contrast, studies on primates have shown the opposite results. A study on red-fronted lemurs (*Eulemur rufifrons*) resulted in adults being more explorative and more innovative than the juveniles (Huebner & Fichtel, 2015). This is thought to be because adults are more experienced and skilled in general, however these particular individuals were kept in captivity, and had previously been subjected to problem solving tasks, which may explain where their experience comes from. However this does highlight the differences between species and between different experimental setups.

The link between kea strike and individual personality will be discussed in more detail in Chapter 5. However it is worth noting that the results from this chapter alone do suggest that a neophilic bird is more likely to be successful in retrieving the food reward from the sheep analogue, as is the case with Familyjuv1. All three juveniles had quick approach times, and long interaction lengths, especially in comparison to Isolated1. They were also the only individuals to engage in physical interactions with the sheep analogue, and Familyjuv1 in particular spent a large proportion of her time engaged in chewing. All these factors suggest very neophilic and explorative personalities, and this is especially evident in Familyjuv1, who was the most neophilic and also the only individual to retrieve the reward. In order for a problem to be solved, or a new behaviour to be formed, an individual must be willing to approach a novel object and explore its possible uses. A study on spotted hyenas (*Crocuta crocuta*) found that individuals who were more neophilic, and more exploratory of a food-access box were more successful at solving it (Benson-Amram & Holekamp, 2012). The differences between hyenas and the birds in my study suggest that this explorative behaviour is not an equally shared innate behaviour of either species. Further, in my study, the desire to interact with the sheep analogue was not driven by an innate predatory response exhibited by all kea. For example, Familyjuv1 initially retrieved the food reward after much exploration, but after this she consistently retrieved the reward, and although we cannot conclude that her solve time significantly decreased, we do see some improvement over successive trials.

Innovation is also associated with social learning tendencies. The study on blue tits mentioned above also demonstrates the ability for a novel foraging technique to be acquired by other population members via social learning (Aplin et al., 2013). My study shows no clear evidence of social learning, as only one bird successfully retrieved the reward. Subjectively however, I saw some evidence of social transmission in my trials. Although Familyjuv1 was the only individual to actually retrieve the food reward, her siblings appeared to learn from her behaviour, and became even more explorative and aggressive as the trials went on. This is something that could (either presently or historically) be important in the recurrent development of kea strike in wild flocks.

It is important to consider that not all innovative behaviours are likely to be detrimental to wild kea survival. Kea survive in harsh, resource poor habitat, and maintaining a diversity of personality types within kea flocks is likely to be necessary to enable the birds to cope with changing environmental conditions. The habit of shooting innovative kea that develop kea strike is likely to reduce this diversity. Further, if a captive breeding and release programme for kea was to be implemented in the future, the conditions that those captive kea are reared and housed in may affect how they survive in the wild. Again there is no published research in regards to the effect of isolation on the development of kea strike, nor is there research on any other birds in this situation as it is such a unique behaviour. My data shows no significant difference between the group-housed and isolated adults, which means we cannot make any conclusions in regards to the effect of isolation on innovative behaviour or kea strike. However, there are studies that have observed the behaviour of other isolated species in terms of problem solving ability and neophobia levels. Receveur and Vossen (1998) compared rats raised in an isolated environment versus an enriched environment. They found that those raised in a social and enriched environment had more flexibility in regards to problem solving. This is particularly important for a species in which flexibility could allow the exploration of potential food sources, as in the kea. Therefore, while the effects of an isolated rearing environment is not relevant to wild kea behaviour, if birds were to be released in the future, they would need to be housed in an environment that encourages innovative behaviours in order for them to survive in the wild.

The results from this study pose a number of further questions that could be investigated in the future. Further investigation of the effect of sex and age on the development of innovative behaviour is recommended. In terms of wild kea, it would be of interest to assess social learning in terms of innovative behaviour, and observe how innovation is spread throughout a group or population. While I saw some evidence of this among the juveniles, it is unknown whether certain individuals are more likely to engage in social learning, and this could mean that the individuals that make up a flock determine how far an innovative behaviour spreads. Understanding more about how innovative behaviours spread will be another important step in minimising kea strike, as it may allow us to target specific groups of kea, or specific individuals, to ensure they are not engaging in the behaviour.

Based on my results I would suggest that a younger and more neophilic kea (such as Familyjuv1) would be more likely to develop the innovative behaviour of kea strike. Because this is such a poorly studied area of New Zealand conservation, it is important to understand as much as possible about the drivers behind kea strike. This will allow us to come up with solutions to minimise the damage caused to sheep flocks, and consequently minimise the number of nuisance kea that are still killed (both legally and illegally) today.

Chapter 5:

Discussion of findings and implications for kea conservation

This study investigated the factors that affect individual personality in kea, as defined by neophobia level and problem solving ability. I was originally hoping to focus on the effect of long term isolation and unenriched environments on personality, however due to a lack of information on the birds' history, the focus shifted slightly. At the time of the study, two of the birds at Wellington Zoo were housed by themselves due to a new aviary being built, and both these birds are thought to have been kept in isolation for extended periods in the past (see Appendix 1). Therefore these two birds were considered as isolated individuals for the purpose of this study. The adults in the family group have always been housed in a pair or group, and the juveniles were born at the zoo and have always been housed with their family, hence these birds were considered as social individuals. For the first part of the study, I therefore considered the effect of short-term isolation on personality, and also took into account demographic factors such as age and sex. This section will be discussed in terms of the potential implications for captive welfare issues, but also in terms of wild behaviours and how to maintain behaviours essential for wild survival, especially in the event of a captive breeding programme. The second part of the discussion will focus on kea strike, and whether there are certain demographic factors or personality types that make a kea more likely to engage in this behaviour. These data will be important in understanding the drivers behind kea strike, and can be used to implement solutions to minimise this conflict.

An important part of housing captive animals for eventual release to the wild is ensuring wild behaviours are maintained. This is vital if captive breeding programmes are ever to be put in place, as survival in the wild may decrease if important traits are lost in captivity. This has been seen in a number of different case studies. An earlier article on the conservation of golden lion tamarins (*Leontopithecus rosalia*) discussed the reintroduction of individuals into the wild after being a part of the Brazilian pet trade (Kleiman et al., 1990). Less than half survived, and the majority of the losses are thought to have been from them not recognising natural food sources or predators. They also found that training the tamarins in these areas was not particularly advantageous, and it was more effective to release the tamarins as soon as they had been confiscated from the pet trade, rather than keep them in captivity for any longer.

Another example is the New Zealand native whio. While there does not seem to be any published literature on this case study, it is known that early releases to Egmont National Park resulted in birds that were unprepared to live in their natural habitat of fast-flowing rivers (Hoskin, 2006). They had been raised in small cages that did not allow them room to fly or swim, both of which are vital skills for wild survival. Since then, a purpose-built hardening facility has been built to allow ducklings to get used to the fast-flowing streams and rapids they will encounter in the wild (Destination Great Lake Taupo, 2017).

Maintaining wild behaviours is also important for the welfare of the animal, as restricting natural activities can lead to the emergence of stereotypical behaviours. Stereotypical behaviours are abnormal and repetitive behaviours with no obvious function, and are seen in many captive species (Mason & Latham, 2004). Among my subjects I saw evidence of these behaviours. Isolated2 would often fly in circles around her enclosure, repeating the same loop over again, similar to the pacing of large carnivores such as lions (*Panthera leo*), tigers, and brown bears (*Ursus arctos*) (Bashaw et al., 2007; Waroff et al., 2017). Familymale showed signs of feather plucking, a behaviour that is particularly common in parrots as they require such high levels of enrichment, and is common among captive kea (Orr-Walker, 2010). Stereotypical behaviour has not been recorded in wild animals, and many authors believe expression of stereotypic behaviours in captivity has its roots in a lack of fulfilment of an animal's behavioural needs (Mason & Latham, 2004). Adding extra enrichment and more feeding times has been shown to decrease the incidences of stereotypical behaviours in kea (Orr-Walker, 2010), however further research is needed into this topic.

The kea is a highly social and intelligent species, and these two traits are important for the emergence and spread of innovative behaviours in the wild (Biondi et al., 2010). This is especially important as the kea's habitat is constantly changing, and food sources are variable. They need to be able to make use of new resources in their environment, and also pass this knowledge on to the rest of the flock through social interactions. Hence, for the reasons discussed above, it is essential that these behaviours be maintained in captivity. I have therefore assessed the personality of each bird in regards to their level of neophobia (fear towards novel objects) and problem solving ability. From this I was able to create two continuums, one from the most neophilic to the most neophobic bird (see Figure 2.5), and the second from the highest problem solving ability to the lowest problem solving ability (see Figure 3.5). These continuums were identical, which suggests these two traits are closely intertwined in the kea. This logically makes sense, as an individual more open to exploring a new object in the environment is more likely to solve it than an individual who does not approach it at all. This is not always the case however, as a species thought to be as equally intelligent as the kea, the New Caledonian crow, is actually highly neophobic. In the Multi-Access box study undertaken by Auersperg, von Bayern, et al. (2011), the problem solving abilities of kea and New Caledonian crows were compared. While both species were equally successful in solving the puzzle box, they did so in different ways. The kea were extremely curious, and explored the box through touch. The crows on the other hand were highly neophobic, and spent a long time observing the box before actually attempting to solve it. Therefore in this example, there was a negative relationship between problem solving ability and neophilia.

The main points I wish to highlight from my results revolve around factors that may affect or influence personality. This knowledge may allow for the tailoring of enrichment programmes to suit the specific needs of individual captive kea. Personality is generally considered to be a fixed state for each individual, and refers to how different individuals react to similar stimuli in the environment in different ways (Cockrem, 2007). However, neophobia in particular is suspected to change with age (Biondi et al., 2010; Heinrich, 1995). My study has also suggested that problem solving ability changes with age, as the juveniles were more successful at problem solving than the adults. However as mentioned above, it is likely that the neophobic tendencies of the adults prevented them from thoroughly investigating the box enough to solve the problem. Perhaps with more time they would have been successful, and this strategy may be reasonable in the wild as a new and unexplored resource is unlikely to disappear within ten minutes as it did with my trials. It is therefore possible that age may affect the time taken to approach a novel object, solve a problem, and also how much exploration of an object occurs. However in order to assess this my trials would have had to run as a more permanent enrichment trial, something that was not possible within the small scope of this study.

The second factor I looked at in regards to personality was the effect of isolation. As there was such a clear distinction between the juveniles and adults, I looked only at the adults when assessing isolation versus group housing. Unexpectedly, there was no obvious effect of isolation on either neophobia level or problem solving ability. There are some factors that need to be taken into account however, the first of which is that there were only four adults, which is too small of a sample size to obtain any significant differences. Secondly, the term isolation refers only to the fact that the two birds were kept in isolation at the time of the study. Although they are thought to have spent time alone before arriving at Wellington Zoo, they have also previously been kept in groups, and were not raised in isolation. Perhaps the effect of isolation is only apparent in birds that have been housed by themselves long-term, or during their critical learning period as juveniles. Many studies have been undertaken assessing the effect of isolation on neophobia, problem solving ability, and social interactions on young animals. Studies on chimpanzees and rats are particularly numerous, and show that animals raised in an unenriched and isolated environment are less able to adapt to changing problems (e.g. Receveur and Vossen, 1998), and have poor social skills (e.g. van Leeuwen et al., 2014). In the case of the kea, all of these skills are very important for wild survival, and for them to be negatively affected would be decreasing their chances of survival in the wild, or possibly affecting their welfare in captivity.

This type of information is particularly interesting in regards to kea due to the fact that they used to be kept as pets, much in the same way species such as cockatoos and macaws are today. To my knowledge there is very little published information on this pet trade, however parrots as an order are known to be particularly social and intelligent. This means they require an enriched and highly social environment, and to be preferably kept with other parrots. With kea being considered one of the most intelligent birds in the world, it is unlikely that these needs were ever met in a pet situation. I originally hoped some of the birds at Wellington Zoo had been kept as pets at one point, however given the small amount of history I do have on each bird, it seems that this is not the case. It would be of interest to find birds that were definitely kept as pets and repeat these trials on them. This would give us a better idea of the effect of an unsuitable captive environment on personality, and could be used to further enhance captive management and housing plans for kea. Since completing my data collection, a new walkthrough aviary has been finished at Wellington Zoo, and all the kea are now housed together. It would be interesting to expand on this research in the future and see whether this more social and enriched environment has a positive effect on the exploration and problem solving skills of the previously isolated adult kea.

A major issue in regards to in situ conservation is kea strike. As discussed in the previous chapters, kea strike is a periodically emergent innovative behaviour where kea attack sheep, which often die as a result. Historically this led to farmers persecuting kea, and an estimated 120,000 birds were killed between 1868 and 1970 (C. Reid, pers. comm. 2017). This was a major driver of kea decline, and despite the species now being fully protected, it is still possible for farmers to get a permit to kill nuisance kea, and illegal killings still occur (Massey University post mortem database). In fact there are several publicised cases where kea have been purposely killed (e.g. Arnold, 2015). It is unknown who was responsible for these killings, however it highlights the fact that kea are often seen in a negative light and as a nuisance species. Developing tools to minimise conflict with humans will be a step forward in creating a positive relationship between kea and humans, and can perhaps engage more people in being involved in their conservation.

In order to minimise the incidents of kea strike occurring, we first need to understand the behaviour and how it arises. It is presumed to be a behaviour that is innovative, and is only undertaken by a few individuals. While multiple birds may be involved in feeding on the sheep, it is usually only one individual who does the attacking (Temple, 1996). Hence social learning and interactions within a flock may also play a significant role in the transmission and emergence of this behaviour. One purpose of my study was to determine whether specific personality types or demographic factors make a kea more inclined to develop this behaviour.

Using a mechanical sheep analogue designed by Clio Reid (unpublished study), I was able to assess whether the kea discovered that it was a potential food source, and if they consequently learned that it would always be a food source. The association between age and personality as discussed above is clearly evident in the results from this task (see Figure 4.7). The juveniles, who are more neophilic and adept at problem solving, were the most interactive with the sheep analogue, and vice versa for the adults. While two of the adults did approach during their trials it was only the three juveniles who physically interacted with the sheep. These data are consistent with the two previous tasks, in that the juveniles were the most explorative, and the adults were the least explorative. It may be necessary for an individual to be neophilic and capable of problem solving in order to develop an innovative behaviour such as kea strike. Without initial exploration of novel objects there is no chance of new behaviours appearing in a population. Of the three juveniles, only Familyjuv1 successfully retrieved the food reward, and she did so in every trial except for the first two (during which there were other enrichment devices in the enclosure the kea were more interested in). There was no significant decrease in the time she took to retrieve the reward, however the fact that she continued to come back and successfully find the food suggests she did learn that it was there. She was also very invasive in her interactions, and engaged in a lot of chewing and grabbing behaviours, consistent with attacking a sheep. Another point to note is that the other two juveniles, particularly Familyjuv2, became much more persistent in their interactions once they saw that Familyjuv1 was obtaining food from the sheep analogue. I believe that they both would have been successful if Familyjuv1 was removed, as she often pushed them away when they got too close to the food. More study is needed, but I suggest that my results demonstrate the innovation of a foraging behaviour analogous to kea strike and social learning of the behaviour within the small flock.

Although the sample size from these trials is too small to make any claims of significance, there are still some obvious patterns that are supported by previously published results. Based on my results, Familyjuv1 is the most innovative, explorative, and neophilic individual. She is closely followed by her siblings in regards to these behaviours, however they appeared to learn from her, and she is the one who engaged in the problem solving and innovative behaviour. These results suggest that juveniles or sub-adults are more neophilic and innovative than their adult counterparts. Heinrich (1995) found that as juveniles, common ravens were more neophilic and open to exploring new objects in their environment. When he retested the same birds as adults, this tendency to explore had decreased greatly. The same results have been seen in terms of innovative behaviours. In blue tits, juvenile females were more likely to develop novel foraging techniques than any other age or sex class (Aplin et al., 2013). There was no distinct difference between ages in the male tits, however other studies have found results in contrast to this, finding no significant differences between the neophobia and exploration levels of males and females (e.g. Biondi et al., 2013; Ensminger & Westneat, 2012). I could not test the effect of sex in my study due to the fact that there was only one male kea, but this provides an opportunity for further research into the topic.

Based on previous studies, innovation is thought to occur in instances of high neophilia and exploration, and high social learning. The juveniles, particularly Familyjuv1, in this study have shown these characteristics, and were consequently more interested and successful at obtaining food from a novel source (the sheep analogue). This data may be used to develop tools to minimise kea conflict in the wild. By understanding which birds are more likely to develop the behaviour, they could possibly be monitored or even deterred. A study on wild kea is currently being undertaken by Clio Reid (unpublished study), and comparisons of my results with this study in wild birds will help to provide more information on the drivers behind kea strike and possible management techniques. However, in the absence of this study being published, I would suggest that more research needs to go into techniques to deter or monitor problem kea, and also to educate farmers about the conservation of the kea, and allow them to be seen in a more positive light.

If innovative kea are more likely to engage in kea strike behaviour and therefore are at a higher risk of being selectively killed, this may have long term implications on the diversity of behaviour present in wild kea populations. The development of innovative behaviour is important in a species such as the kea, where their unpredictable environment means food sources are constantly changing. It is important that they are able to utilise new resources, and this involves the development of new behaviours. If innovative birds are selectively killed, it is therefore possible that the innovation, neophilia, and high levels of exploration that kea are so well known for will be lost, and consequently make it harder for kea to survive in their alpine environment. With climate change and more unpredictable environmental catastrophes occurring, it is even more important that these behaviours are not only maintained in the wild, but that a variety of these behaviours are maintained. This will increase the likelihood of survival with the occurrence of a stochastic event, as the population will have the ability to react to this change. It is therefore even more important to resolve the conflict between humans and kea, as it ensures that not only will innovative individuals be safer, but will also protect the species as a whole.

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Appendix 1: Wellington Zoo kea information

Name	Sex	Age (at time of study)	Notes
Familymale **Murray**	Male	36 years	Parent raised and wild caught. Has been with Two-eye at Wellington Zoo since 2008. Was previously with Two-eye and another female, but is now with Two-eye and their 3 female juveniles.
Familyfemale **Two-eyes**	Female	21 years	Parent raised and captive born. Has been kept with various males and females throughout her life, but always in pair or group situations. Is now housed with Murray and their 3 female juveniles.
Familyjuv1 **No band (Fern)**	Female	2 years	Parent raised and captive born. Has been with parents and siblings her entire life.
Familyjuv2 **Blue band (Puka)**	Female	2 years	Parent raised and captive born. Has been with parents and siblings her entire life.
Familyjuv3 **Green band (Mamaku)**	Female	2 years	Parent raised and captive born. Has been with parents and siblings her entire life.
Isolated1 **Katikati**	Female	24 years	Captive hatch at Staglands Wildlife Reserve (Upper Hutt, NZ). Previous history unknown but at last location was housed with her brother. When a nest box was introduced one year she nearly beat her brother to death, and they were kept separate before arriving at Wellington Zoo.

			She was kept with her brother (who has since died) and Te Anau) but showed excessive dominance and was separated. Was housed separately next to Te Anau at the time of the study.
Isolated2 **Te Anau**	Female	24 years	Captive hatch. Was kept with her sister until she died a few years ago. At her previous location she had a lot of enrichment and attention by keepers. However she is known to have been kept in isolation at a Botanical Garden at one point. Was housed separately but next to Katikati at the time of the study.