A chicken for every pot: the economics, evolution and ethics of the modern chicken

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ABSTRACT

Humans began the transformation of wild jungle fowl into modern day chickens over 8,000 years ago. Over the past 70 years, chickens have become an increasingly important economic and dietary stable throughout the world. There are now over 20 billion chickens on farms worldwide. However, research has revealed that chickens are not as simple as humans once believed. They exhibit complex communication, social learning, numeracy and deception, as well as depression-like symptoms. These findings suggest that chickens posses both access and phenomenal consciousness. This raises critical questions about the effects of selective breeding and the impacts that the current housing systems have on these complex animals.

Key words: Chickens, ethics, animal welfare, consciousness, cognition, communication

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Economics

'A chicken for every pot and a car in every garage' was the promise of prosperity made in one of Herbert Hoover's 1928 U.S. Presidential election campaign flyers. A chicken represented prosperity because, at the time, chicken was actually more costly than beef ($5.84/lb for chicken and $5.43/lb for beef, inflation adjusted costs) (Daniel *et al.* 2011; www.XE.com). Despite the slight difference in price, there was a vast difference in the level of consumption; beef was 11 times more common in the U.S. diet than chicken (Daniel *et al.* 2011). That was due, in part, to the availability of chicken. For the most part, up until 1940's, commercial chicken meat was a byproduct of the egg-industry and was only seasonally available (Lasley *et al.* 1988). In the 1940's, changes in the industry, including the development of new breeds specifically for meat, improved disease control, and changes in housing methods, meant that chicken meat became more consistent in quality and more consistently available (Reimund *et al.* 1981). It also began to be specifically marketed to compete with beef and pork consumption. Since the 1950's there has been a steady rise in the consumption of chicken by Americans (Daniel *et al.* 2011). This rise was coincident with a decline in the price of chicken caused by the integration of production, processing and marketing by larger companies (Ollinger *et al.* 2005). Over that same period, the cost of red meat remained relatively stable (Bureau of Labor Statistics, "Average Retail Food" 2015). Part of the shift towards chicken meat was also driven by the search for a substitute for red meats by health conscious consumers (USDA 2003; Meissner 1989) as well as changes in consumer preference for convenient, pre-packaged foods and chicken parts, such as chicken wings (Lasley 1983), breast meat and thighs, instead of whole chickens (Ollinger *et al.* 2005).

The domestic chickens themselves have undergone dramatic changes over this same period. Through selective breeding, there are now different commercial strains for egg-laying chickens and meat chickens (USDA Poultry production in the United States). At the turn of the last century, an egg-laying chicken would produce approximately 83 eggs per year. The modern laying strain lays approximately 300 eggs per year. These changes were brought about by changes in the diet (inclusion of vitamin D in the feed; Mattila *et al.* 2011), the introduction of artificial lighting to indoor coups (Scanes 2006), induced molting (Hurwitz *et al.* 1998), and selective breeding. In the modern system, approximately 90% of the commercial egg-laying hens are housed in 'cage' systems. In the conventional cage system, each bird gets 400-600cm^2 of unrestricted floor space but in some countries there are no requirements for nest boxes, litter for foraging or dust bathing areas or perches (CSIRO 2002). In the layer-hen industry, chicks are sexed on the day they hatch. Males and unhealthy females are macerated while alive (RSPCA "What Happens with Male Chicks" 2014). Healthy females are raised until egg-laying age and remain in the system until approximately 18 months of age, when they begin to decline in egg production. At this point, in many systems, the hens are captured and transported to a slaughter facility via truck, plane or sea transport where they are rendered unconscious before they are exsanguinated using a cut to the throat (RSPCA layer hen standards 2015).

Modern meat chickens have been selectively bred for fast growth and are fed diets that facilitate weight gain. On the typical 1950's diet, a meat chicken strain from that era would take almost 3 times as long to reach the same weight as a modern, selectively bred chicken would on a modern diet (Havenstein *et al.* 2003). To maintain the desired weight increase, bird health and fat composition, long periods of feed removal (up to 10 hours per day; Benyi *et al.* 2010) have been recommended depending on the strain and the environmental rearing conditions (Tsiouris *et al.* 2014). Until the 1950's, many farms kept flocks of chickens as a side business (~50 to 100) and backyard poultry flocks (10 to 50 birds) were common. At the time, commercial flocks, which were predominately layers, would have 400 or more birds (Stewart 1946). For comparison, modern meat chicken flocks raised in the conventional housing system consist of between 20,000 and 50,000 animals housed in 100 m by 12 m sheds (Robinson and Hulme 2004), which equates to approximately 42 birds per square metre at the maximum stocking density. Approximately 90% of meat chickens are raised in the conventional housing system and 10% are raised in free-range systems, which has the same shed type housing but birds have access to an outdoor range (Australian Meat Chicken Federation, Inc. "Harvesting" 2013). Both male and female chickens are used in the meat industry. Birds are captured from the sheds as early as 30-35 days and no later than 65 days after hatch (Australian Meat Chicken Federation, Inc. "Harvesting" 2013).

Evolution

Domestic chickens possess a remarkable suite of cognitive and communicative capabilities that are likely derived from their wild ancestors. Evidence suggests that the domestication of chickens by humans began over 8000 years ago (West and Zhou 1988) and that all domestic strains (*Gallus gallus domesticus*) are descended from red jungle fowl (*G. gallus,* Fumihito *et al.* 1994; Fumihito *et al.* 1996) and green jungle fowl (*G. varius;* Sawai *et al.* 2010) from the forests of Southeast Asia. Domestic breeds can still inter-breed with wild jungle fowl and there are instances of domestic strains thriving in the wild after escaping from farms (Geering *et al.*2015). Wild jungle fowl live in stable, mixed-sex groups composed of 6-19 individuals of varying ages (McBride *et al.* 1969). Within each group, there is a dominant pair and all others are subordinate to the dominant of their same sex (McBride *et al.* 1969). This hierarchy is maintained by visual and vocal signals, although fighting and injuries can occur. The birds' habitat consists of open and forested areas and group members may be frequently out of sight of conspecifics (Collias and Collias 1967). In this habitat, both ground and aerial predators prey upon the birds. Dominant males maintain territories of up to 1 hectare during the breeding and groups frequently interact at watering holes or ephemeral feeding sites (such as insect swarms; Collias and Collias 1967). Smaller groups of bachelor males often remain on the periphery of a male's territory (McBride *et al.* 1969).

Chicken communication is complex, consisting of up to 24 different vocalizations (Collias and Joos 1952) as well as visual signals (Davis and Domm 1949). Both males and females with chicks produce specific calls in response to the type of predator (Gyger *et al.* 1987) and in response to the presence of food (Evans and Evans 1999). These calls are known as functionally referential signals because they are produced in the specific context and listeners respond as if they had experienced the event directly themselves (Evans and Marler 1993). In essence, they appear to refer to events that are external to the signaler, which is a cognitive ability that was assumed to be limited to humans (Evans 1997).

Food calls are often accompanied by rhythmic movements of the head and neck, including repeated picking up and dropping of the food item. The combined movements and sounds are known as 'tidbitting' (Davis and Domm 1949; Smith and Evans 2009, Figure 1). The chicken's behaviours surrounding tidbitting and feeding suggest a suite of underlying cognitive abilities. Females alter their tidbitting display for their chicks if they perceive that the chicks are ingesting unpalatable food items (Nicol and Pope 1996), which suggests teaching by the hen. Furthermore, females observing a hen obtaining food will copy that bird's feeding behaviour, which suggests social learning (Nicol and Pope 1996; McQuoid and Galef 1993).

Males alter their tidbitting behaviour depending on the sex, status, distance and attentional state of the other individuals that are present (Karakashian *et al.* 1998; Smith *et al.* 2011). Tidbitting behaviours by males are important because they affect his mating success (Pizzari 2003). Females prefer to mate with males that provide food more often to any female in the flock. This reveals that females eavesdrop on the behaviour of the males because they do not rely solely on their own experience.

Figure 1. Male tidbitting with corn and female food searching

Photograph depicts the component of the tidbitting display where the male bobs his head up and down with his beak pointed towards the food. Female responds by approaching the male and searching for the food.

Furthermore, females must remember this prior behaviour and recall it later because mating does not always occur immediately after tidbitting. This suggests that fowl have reputation (Pizzari 2003). Males hence compete to present food to the female. If the dominant male finds food, he will usually tidbit with the food and the female will approach and take the item. If a subordinate tidbits in the presence of the dominant male, the dominant male will attack the subordinate male, who typically drops the food and flees (Davis and Domm 1949). The dominant will then tidbit with the food for the female. To avoid losing the food item, but still attract the female, subordinate males change their tidbitting behaviour by omitting the vocalizations and only performing the visual signal. This demonstrates facultative signals changes in response to the attentional state of the alpha male (Smith *et al.* 2011).

Not every tidbitting signal is honest. Previous research reveals that some males tidbit in the absence of food (Gyger and Marler 1988; Pizzari 2003). Males are more likely to tidbit deceptively when the female is farther away (Gyger and Marler 1988) and subordinate males are more likely to perform these displays than dominant males (Pizzari 2003). Experimental manipulation of a male's tidbitting reliability reveals that females are also more likely to ignore males that tidbit deceptively (Smith *et al.* 2016). It is unclear what role deceptive behaviour plays in the reputation of males, however, observations of free-living groups show that females are less likely to respond to displays by subordinates (Smith *et al.* 2011).

Chickens do not respond reflexively (i.e. automatically) to food calls. The conditions surrounding the specific call (e.g. caller identity, honesty, distance) affect the likelihood of approach. Research also reveals that the female's prior knowledge of food in the signalled location affects her responses as well (Evans and Evans 2007). Food calls are hence representational, which means that the call stimulates the retrieval of specific information about an external event and that the call 'stands for' that something specific. This type of nominal representation is considered to be the lowest level of cognitive complexity in a hierarchy of cognitive complexity (Gallistel 1990).

Chicken alarm signals are equally revealing of the birds' cognitive abilities. Both males and females produce alarm calls in response to the presence of a ground predator, such as a fox (Evans and Marler 1993). Terrestrial predators tend to use ambush tactics to hunt and are more likely to break off a hunt if detected. Ground alarm calling is therefore likely directed at the predator (Gyger *et al.* 1997). In contrast, only hens with chicks and adult males call in the presence of aerial predators. Aerial predators are fast moving hunters and any noise increases the likelihood of detection and capture (Wood *et al.* 2000). Therefore aerial alarm calls are risky. Calling is hence subject to a set of criteria and males employ a suite of risk mitigation tactics when calling. First, an appropriate audience must be present; lone males and females without chicks do not call (Karakashian and Marler 1988). Alpha males are more likely to aerial alarm call than any other male, and males are more likely to call if they have recently mated than if they have not (Wilson *et al.* 2008). This suggests that the males are investing in their mates and their potential offspring (Wilson *et al.* 2008). Calling is also more likely to occur when the male is under cover, and hence less vulnerable to capture by the predator, and if another male is out in the open. Alpha males are also likely to produce longer calls, which may be more likely to be detected by the females, if the subordinate male is close by (Kokolakis *et al.* 2010). These calling behaviours simultaneously reduce the caller's risk while increasing the risk to a rival male.

Male fowl also alter the characteristics of their alarm calls in response to the specific risk.

Call characteristics change in response to the size, speed and proximate distance of the approaching aerial predator, which may allow others to respond with the appropriate escape behaviours (Wilson and Evans 2012). More than one aerial alarm call may be given during a predator encounter. The first call of the series often includes a broad bandwidth pulse followed by a tonal, narrow bandwidth sound (Figure 2). Subsequent calls eliminate the pulse. Broadband sounds are more easily localizable than narrow bandwidth and thus the first call is more likely to alert conspecifics and the predator and subsequent calls reduce the caller's risk but continue to alert group members about the threat (Bayly and Evans 2003).

These food and alarm calling examples reveal both behavioural flexibility (Smith *et al.* 2011) and risk mitigation tactics (Kokolakis *et al.* 2010). They show that fowl are capable of social learning, teaching, and functionally deceptive behaviours. It also suggests that chicken communication is nominally representational (Evans and Evans 2007)

Beyond their communicative capabilities, chickens demonstrate numeracy and perceptual abilities akin to some higher primates. Research with young chicks reveals that they are capable of understanding a basic number line and being trained to count up to a specific number (Rugani *et al.* 2008; Rugani *et al.* 2010). Furthermore, chicks appear to be able to do rudimentary addition and subtraction (Rugani *et al.* 2009). Chicks were imprinted with five objects and were then tested by hiding the objects, one-by-one, behind either of two screens. Chicks approached the screen behind which the larger number lay. Follow up tests transferred objects, one-by-one, from behind one screen to behind the other. Chicks were able to track the transfers and again, make the correct choice, demonstrating addition and subtraction capabilities (Rugani *et al.* 2009).

In addition to numeracy, chickens are able to infer the relative status of a series of objects or individuals (Beaugrand *et al.* 1997; Daisley *et al.* 2009). Hens that observe interactions between an individual of known

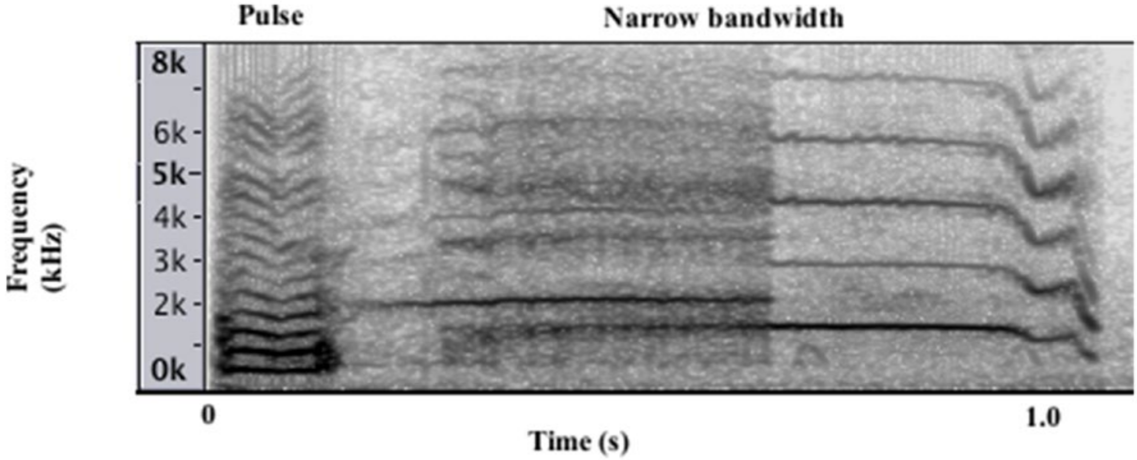

Figure 2. Aerial alarm call of male fowl

Aerial alarm calls are composed of a broad bandwidth pulse followed by a narrow bandwidth, tonal sound. The pulse is more conspicuous to conspecifics and predators than the narrow bandwidth segment and is often omitted after the first call. This flexibility in calling behaviour reduces the risk to the male while still alerting conspecifics.

status with a new individual are then able to infer their own status relative to the unknown individual and to respond appropriately in future interactions (i.e. dominantly or submissively, Beaugrand *et al.* 1997). Chicks tested on an experimental task, where series of pairs of items were presented with different reward values (e.g. eight pieces of corn compared to four pieces of corn), were able to infer the relative reward value of each item relative to the established reward hierarchy when presented in a novel pair (Daisley *et al.* 2009). This ability, known as transitive inference, has been suggested to be a measure of logical reasoning ability (Piaget 1928).

Taken together with their alarm calling behaviour, this evidence suggests that chickens have self-assessment and the ability to assess the state of others. Further evidence of this is revealed by mother hen's responses to threats to her chicks. When a mother hen's chicks are threatened, her physiological stress responses and behaviours are the same as if she were directly threatened (Edgar *et al.* 2011). This also suggests the hens possess empathy, which includes the ability to take the perspective of others.

Chickens also exhibit anxiety and depression like syndromes, which can be counteracted with anti-depressants designed for humans (Lehr 1989; Warnick *et al.* 2009; Salmeto *et al.* 2011). Approach to ambiguous stimuli and levels of vocalizations have been used to test the internal state of chicks. These tests have revealed that chicks present with cognitive biases, wherein 'anxious' chicks are less likely to approach an ambiguous aversive stimuli (e.g. a silhouette that has some similarity to a hawk) and chicks in a 'depressed' state are less likely to approach the ambiguous aversive stimuli and less likely to approach an aversive positive stimuli (e.g. a silhouette of a chick; Hymel and Sufta 2012). Chicks are becoming an accepted model for testing human antidepressant treatments because they present with all the typical stress and depression biomarkers (Warnick *et al.* 2009).

The remarkable communicative and cognitive abilities possessed by all domestic chickens are likely in response to the combination of predation pressure, social structure (Dunbar and Shultz 2007), social competition (Jolly 1966; Humphrey 1976; Byrne and Whiten 1988) and habitat (Overington *et al.* 2011; Lefebvre *et al.* 1997) experienced by their wild ancestors.

Ethics

One argument for the ethical treatment of animals is that animals have consciousness (Bekoff 2008). Although there is no specific, agreed definition of 'consciousness', it is generally regarded as a continuum extending from lower levels (referred to as 'primary consciousness') to higher order consciousness, which includes self-awareness and meta-self awareness (to be aware that the one is aware; Morin 2006). Animals possessing primary consciousness are broadly regarded as possessing an awareness of the environment and self and the ability to react to changes in both, including the ability to alter future behaviour based on past experiences. Higher consciousness requires the animal to be able to integrate this awareness across the past, present and future (Edleman 2003).

Consciousness has further been dived into 'access consciousness' and 'phenomenal consciousness'. The former is the ability to think and reason and the later involves the ability to experience pleasure or pain and positive of negative emotions in the present (Block 1995).

Several criteria have been proposed as evidence for access consciousness including the ability to communicate semantic information, to form and recall memories, and to plan for the future. In addition, the animal's subjective experience should alter their future responses (Beshkar 2008). Behavioural versatility, such as the ability to create and use tools, solve problems or behave deceptively, has also been proposed to indicate higher levels of consciousness

(Speak and Griffin 2004). These criteria lend themselves to behavioural tests that can quantify an animal's responses and can facilitate cross species comparisons (Shettleworth 2010). Encephalization, as measured by either the size of the whole brain or the ratio of specific areas, is another method that has been used to predict cognitive abilities. These methods attempt to correlate brain size with higher cognition as demonstrated by more complex behaviors (Shultz 2010). Some researchers have also suggested using benchmarking of animals' capabilities against human capabilities using neuroanatomy as a means of testing levels of consciousness (Edelman *et al.* 2005).

The criteria for phenomenal consciousness are less well defined. The study of phenomenal consciousness was perhaps inhibited by radical behaviourism, which posited that it was not possible to empirically test the mental states of animals and therefore was beyond the ability of science to study (Skinner 1974) as well as the challenges associated with defining and quantifying emotions in humans. Darwin was the first to argue for a continuum of emotional states between humans and nonhuman animals (Darwin 1872) and there is an evolutionary argument for emotions and mood in animals (Bekoff 2000). Emotions can be defined as "… an intense, short-lived affective response to a stimulus or an event accompanied by physiological and behavioural reactions and subjective experiences" (Désiré *et al.* 2002). Emotions may hence reinforce certain behaviours that may lead to increased changes in survival or reproduction (Dawkins 2000). Mood can also be seen as advantageous in an evolutionary context. Mood is a longer-term affective state that is brought about by an experience in a specific context that changes the individual's subsequent threshold for responses to future events (Nettle and Bateson 2012). Although progress is being made in the field, phenomenal consciousness, including mood and emotions, is primarily still studied using the method that Darwin used (Bekoff 2000). He collected anecdotal evidence from humans and other animals under a variety of conditions and then compared these responses cross species (Darwin 1892). Modern studies are now bringing to bear advances in neurochemistry, stress physiology as well as the study of behaviours to identify and test the potential emotional states of animals (Panksepp 1998).

Examining the evidence presented in the published literature it would appear that wild and domestic chickens meet many of the criteria for access consciousness, including semantic communication and the ability to access past events to alter future responses (Table 1). There is also physiological evidence to suggest chickens possess phenomenal consciousness too. The research showing that chickens can have cognitive bias, which can be treated with anti-depressants, may be an indication that chickens experience emotions, such as depression. Chickens also appear to exhibit empathy. Research focusing on responses to injuries, such as broken legs or keels, reveals that chickens behave as if this damage causes pain and the behaviours associated with pain can be alleviated with analgesics (Hocking *et al.* 2001; Knowles *et al.* 2008).

Welfare under current farming practices

The selective breeding of meat chickens has developed a bird that, at 6 weeks old, weighs substantially more than its adult wild counterpart. At 6 weeks of age, wild jungle fowl would just have become independent from their mother (McBride *et al.* 1969). Although these birds are juveniles, much of the research has been conducted on chicks less than this age, which does suggest that their cognitive abilities would be present at this age. Research has also shown that the exceptionally high rate of growth and weight gain of meat chickens is associated with a high potential for leg and keel fractures, foot problems, heart failure and other serious conditions, such as obesity, prior to slaughter (Knowles *et al.* 2008; Nasr *et al.* 2012). The need to control their growth rate means that many birds do not have access to feed for numerous hours each day (Duncan 2010). Genetic selection has also changed the thermoregulatory abilities of meat chickens, making them susceptible to heat and cold stress related mortality, particularly during transport and while awaiting slaughter (Mitchell and Kettle 2009).

The high stocking density and the lack of environmental enrichment under some rearing systems has led to aberrant behavior, such as injury inflicted by feather pecking and death by cannibalism (Mitchell and Kettleworth 2013). Feather pecking has been identified as one of the primary causes of death in non-cage housing systems (Rodenburg *et al.* 2008) and in furnished cages systems (Weitzenbürger *et*

Table 1: Evidence of higher-order consciousness in chickens

Proposed criteria: access consciousness	Present?	Evidence?
Ability to communicate semantic information	Yes	Referential signals (Evans 1997), Representational signals (Evans and Evans 2007)
Awareness of past, present and future (form and recall memories)	Yes	Anticipatory behaviour (Wichman et al. 2002; Moe et al. 2009; Zimmerman et al. 2011), Learning (Nicol and Pope 1996), Preferential alarm calling when mate present (Wilson et al. 2008)
Planning for the future	No	
Behavioural versatility (e.g. tool use, problem solving, deception)	Partial	Function deception (Gyger and Marler 1998); Flexibility in food and alarm calls (Smith et al. 2011; Kokolakis et al. 2010) No evidence of tool use

al. 2005). The main method of controlling these behaviours is to cut off ⅓ to ½ the upper and lower beaks of the chicks within 5 to 10 days of hatching using hot blades or lasers (Dennis *et al.* 2009). This practice is controversial because it does not completely eliminate feather pecking (Lambton *et al.* 2013) and can cause acute pain (Grigor *et al.* 1995) and long-term changes in the sensitivity of the beak (Freire *et al.* 2011). Research is ongoing into possible solutions to prevent feather pecking without the need for removal of part of the beak. Researchers have identified stimuli that elicit pecking responses, such as nipples for drinking water, lighting in nest boxes and specific types of bedding, grit and feed, and have proposed changes to these conditions (Lambton *et al.* 2013). Selective breeding is also being explored including selection of birds with specific feather colours and altered stress responses with a focus on selection at the group level (Rodenburg *et al.* 2010). The success of these methods has been variable and the up take has been slow within the industry.

Although chickens are housed under several systems, including cage, free-range and non-cage systems, including sheds with litter and barns (PoultryHub, "Commercial Poultry"), each housing method has its own welfare implications. Although free-range systems for laying hens and meat chickens may appeal to consumers (Adil *et al.* 2014), the birds may still experience high stocking densities (free-range can have up to 20,000 birds per hectare, compared to 6 - 19 per hectare for free-living wild jungle fowl), feather pecking and the other physiological problems (Hartung *et al.* 2009). In addition, it has been estimated that only approximately 15% of the entire flock ever leaves the shed (Dawkins *et al.* 2003). Cage free systems still house similar number of birds in barns and these birds experience similar rates of leg fracture to birds in a cage system and higher rates or wing and keel fractures than birds in cage systems. Research suggests that approximately 25% of the birds experience a fracture during their lifetime. This would translate to 5,000 birds per cycle in each barn (~20,000 birds/barn with a cycle of < 65 days for meat chickens and ~18 months for laying hens). Cage free systems can also have high rates of feather pecking because of the large number of birds housed together (Hartung *et al.* 2009).

Technical advances in the ability to identify male embryos in the egg-laying chicken breeds may eliminate one of the welfare concerns associate with egg production. Researchers have developed a method to mark the male sex chromosome using green florescent protein (ABC News, "Marking Male Embryos" 2016). Only males would carry the marker, which would allow producers to identify male embryos using a laser. These eggs would then not be incubated thus avoiding the need to kill day-old male chicks, which is the current practice. The technique does involve genetic modification of the chickens but the modification would only be to males and therefore would not enter the food system. The method is not currently in use but, if implemented, offers a solution to one ethical issue of raising egg-laying chickens.

Conclusions

Chickens present a conundrum for our modern society. On the one hand, there currently are over 20 billion chickens living in farms, providing cheap meat and sources of protein to millions of humans, and other animals, worldwide (Statistica, "Number of Chickens"). Over the past decade, poultry production worldwide has risen 3% per year (FAO "Food Outlook" May 2015). There is growing concern about our ability to feed the ever-expanding global population, which puts increasing pressure on agriculture to develop more food faster and using fewer resources (FAO "Global Agriculture towards 2050"). The production of chicken meat has also been suggested to be more environmentally sustainable than that of other meats, such as beef, lamb or pork (Pimental *et al.* 2004), however, any animal protein production requires more resources than vegetable protein production does (Pelletier 2008). On the other hand, the preponderance of evidence suggests that chickens have both access and phenomenal consciousness. Chickens exhibit empathy-like (Edgar *et al.* 2011) and depression-like behaviours (Salmeto *et al.* 2011). They appear capable of self-assessment and the ability to assess others (Beaugrand *et al.* 1997) and to learn from each other (Nicol and Pope 1996). Chickens are also able to communicate about events in their environment (Evans 1997) and to behave deceptively (Gyger and Marler 1988).

Acknowledging the externalities of egg and meat production in light of chickens as living animals is a critical component of any discussion on how we treat animals. Only time will tell if a better understanding of chickens' cognitive capabilities will change how humans balance their own needs versus the needs of other animals.

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