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ONE PIGGY WENT TO THE MARKET: Using economic theory to discover animal rationality

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Abstract. The main aim of this article is to use the theory of biological markets to showcase that non-humans possess rationality and the ability to think through their actions without the usage of language. The framework of the theory of biological markets is based on human economic market theory and its principles, thus allowing us to view interactions of animals as an exchange of goods, where the animal makes a choice to act based on rationalising and communicating with itself, and its group members. The objective of this paper is to counter Tim Ingold's 1988 position on animal thinking, where he believes that animals are conscious, but lack the ability to think about their actions as they lack a linguistic faculty allowing for discursive abilities. The results of this paper highlight animals as rational thinkers, sometimes more so than humans who act and communicate based on furthering their own self-interest. Through the unique interactions in the markets of the *Lasius* ants and *Polyommatus icarus* butterfly larvae, *Polistes dominula* wasp, and *Labroides dimidiatus* cleaner fish we are able to conclude that animal choice making is not pre-programmed, but situational, and each interaction is an intricately rationalised choice made for the benefit of an individual or its whole community.

Keywords: animal rationality; theory of biological markets; umwelt; economic market theory; free-riding; collective action problem; zoosemiotics

Üks põssa läks turule: majandusteooria kaudu loomade ratsionaalsust avastades

Abstrakt. Käesoleva artikli peamiseks eesmärgiks on kasutada bioloogiliste turgude teooriat, näitamaks, et mitte-inimesed ratsionaalsed ja võimelised mõtlema läbi oma tegevuste ja ilma keeleta. Bioloogiliste turgude teooria on raamistu, mis põhineb majandusturgude teoorial, võimaldades seega vaadelda loomade interaktsioone kaubavahetusena, kus loom teeb käitumisvalikuid enda ja oma grupikaaslastega komminikeerides ja ratsionaliseerides. Artikli eesmärgiks on vastata Tim Ingoldi 1988. a. positsioonile loomade mõtlemisest, st vaatele, et loomad on teadlikud, kuid neil puudub võime mõelda oma tegevustest, kuna neil puudub keelevõime, mis on diskursiivsete võimete aluseks. Käesolevas töös tuuakse esile loomad ratsionaalsete agentidena, vahel isegi ratsionaalsematena inimestest, kelle tegevuse ja kommunikatsiooni aluseks on isiklike huvide edendamine. Läbi *Lasius* sipelgate ja *Polyommatus icarus* liblikavastsete, *Polistes dominula* herilaste ning *Labroides dimidiatus* kalade turgudel toimuvate unikaalsete interaktsioonide võime järeldada, et loomade valikud ei ole etteprogrammeeritud, vaid

olustikulised, ning iga interaktsioon on peenelt ratsionaliseeritud valik, mis tehakse indiviidi või kogukonna hüvanguks.

Märksõnad: loomade ratsionaalsus, bioloogiliste turgude teooria, omailm, majandusturgud eteooria, tasuta kasutaja probleem, kollektiivse tegevuse probleem, zoosemiootika

Introduction

"Rather than thinking without communicating, an animal communicates without thinking" (Ingold 1988: 95) is the conclusion Tim Ingold reaches in chapter seven of his book *What is an Animal?*[1] Ingold reaches this conclusion by critiquing the theories of Lewis Henry Morgan[2] and Donald Griffin[3], which are based on how animals are capable of rational deliberation but lack an appropriate mode of communication for humans to comprehend. He believes their desires are futile as conversation between humans and non-humans cannot exist, not because of a lack of medium, but because there will be "no intentional exchange of ideas between thinking subjects" (Ingold 1988: 93). Furthermore, Ingold builds on humans[4] as 'thinking subjects' as he distinguishes them based on their ability to "isolate separate intentions from the stream of consciousness, to focus attention of them, and to articulate them in discourse," through a "discursive consciousness that rests upon the linguistic facility and is uniquely human" (ibid, 96). However, it is important to note that Ingold still believes that animals act as "conscious, intentional agents" (ibid, 96), but their actions and communication are based on "pre-programmed force of an instruction" (ibid, 93). This influences their inability to: (1) consider future outcomes before acting [rationality], and (2) think of their own actions discursively (ibid, 96). Therefore, for animals to display thinking in their communication they must showcase discursive consciousness and rationality. In order to discover if the animal has such capacity, this paper will juxtapose Ingold's stance on animal thinking and communication through a model that showcases rationality in non-humans.

John Maynard Keynes, the father of modern economics, attributed the irrational choices displayed by human beings to "animal spirits" (Crair 2017), whereas Adam Smith believed that "human beings rationally pursue their economic interests" (Akerlof, Shiller 2009: 3). In both cases the behaviour of rational self-interest was described to be a human trait and could not be found in non-humans. This was the foundation that built the economics we practice today and continues to guide the way goods are exchanged from one individual with another. However, in 1994 the theory of biological markets was formulated by Hammerstein and Noë, which showcased a different outlook on the patterns of cooperation between con-species, and mutualism between different species (Noë 2001). They suggested that human economic market theory and its principles could help understand the interactions of animals as an exchange of goods. Through their theory they sought to explain how non-humans also display rational behaviour and

concluded that sometimes they can be even more rational than human beings (Crair 2017). This paper will leverage the theory of biological markets to contradict Ingold and showcase that animals do think before they act and communicate by breaking down their rational actions based on furthering their self-interest.

For biological market theory to be applied rational thinking must be defined as "a decision-making process that is based on making choices that result in the optimal level of benefit or utility for an individual" (Hayes 2020) or a collective. If an animal were pre-programmed, they would not be able to have such "prior intentions"[5] that would lead them to make choices amongst alternative options. Also, their choices are then reflected based on their communicative and discursive abilities. Therefore, this paper will follow that line of thinking and assess: (1) if an animal is capable of having a decision-making process, (2) the discursive consciousness of animals leading to their choice, and (3) complexity of thinking in animal communication. Based on the assessment from the aforementioned questions we can gauge the animal's ability to both think and communicate[6].

When it comes to the rational decision-making process of non-humans, other approaches such as evolutionary biology suggest that it is simply a behaviour conditioned by natural selection to "maximise individual reproductive success" (Parker, Hammerstein 1985 in Nunn, Lewis 2001: 47). Therefore, it is important to note that this is a zoosemiotic approach, and the economic terms are to assist in a cross-disciplinary study where it is not the terms themselves, but their utility functions that are of importance to the animal. Furthermore, this paper will leverage the concept of umwelt introduced by Jacob von Uexküll to analyse the application of animal thinking of different non-humans based on their 'self-world' (Uexküll 1934: 319). By doing so we look past animals as mechanical beings and start viewing them based on their subjective experience of not just their physical environment, but also their relationships and ability to make meaning of their surrounding worlds (Uexküll 1934: 319). Therefore, in each example rationality and discursive consciousness in communication and thinking might manifest in different ways for each animal, as what might be in their self-interest may differ from another animal. Utilising umwelt theory also allows us to avoid the case of Ingold's bee example, where the lack of symbols in the waggle dance leads to the conclusion that they "lack concepts to grasp" (1988: 94). Instead, it makes us look for rationality and concepts through their perspective.

Capacity of animals to make decisions

Ingold (1988: 95) suggests that an animal emits signals, but they relate to bodily states and not concepts. Moreover, he suggests it is because animals lack language, which is different than communication, as language is an "instrument of thought" whereas

communication is just a medium (ibid, 94). But it must be questioned why Ingold believes that a lack of language must signify a lack of thoughts. In the case of biological markets, thoughts must include an active decision-making process based on an exchange of goods that must be conducted by deliberating the actions of the market and its players (Noë 2001). In economic terms there must be an understanding of supply and demand with their given costs and prices in a given market where "exchange transaction takes place freely, and the two involved have both acted to fulfil their respective goals" (Kirzner 1963: 1). Therefore, the behaviour of one individual participant must also directly or indirectly be "conditioned by the actions of participating individuals" (ibid, 2).

The natural application of these principles can be demonstrated through the mutualism between *Lasius* ants and *Polyommatus icarus* butterfly larvae (Noë 2001: 99). The larvae produce a sugar-rich solution, called 'nectar' from their 'nectar gland' and exchanges it with the ants as payment for protecting it against parasites and predators. The amount of nectar produced by the larvae is dependent on the number of ants desiring to protect it, where an increase in ants will decrease the nectar produced, and a decrease in ants will increase the nectar produced — indicating that "the nectar is produced at a cost" (Noë 2001: 99). This is demonstrated in Figure 1 where at an equilibrium E^n there is a quantity of ants QE paid with nectar at price PE.

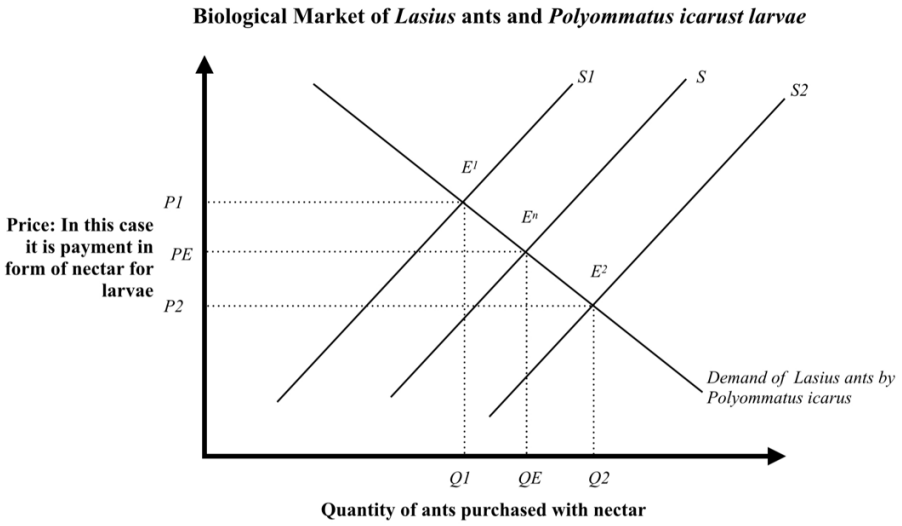

Figure 1: Effect of a change in supply in ants desired by a larvae.
Graph constructed by Colaso with information drawn from Noë (2001).

As we see a reduction in the supply of ants due to the competition in the market with other larvae there is a higher price of nectar required by the ants at P1 for them to be swayed by an individual larva. However, if the larvae sense there are sufficient amount of ants for its protection at S2 it will produce less nectar at P2 for a larger quantity of ants at Q2. In this way we see how this biological market follows similar rules of a human economic market that exchanges goods. In this case the larvae and the ants exist in a

market whereas individual members of society they are "aware[7] of numerous opportunities for exchange and are free to take advantage of them" (Kirzner 1963: 2). This illustrates how an individual ant makes a decision to protect a particular larva at a price they are willing to be bought at, while the larvae decide its nectar production after deciding when it must compete, and when it has provided a sufficient amount. In this example both parties act in a way where they look to improve their position whenever possible — act rationally in their self-interest. Moreover, the manipulation of the nectar decreasing with the number of ants increasing after a certain point showcases an understanding of the 'Law of Diminishing Returns' where "the number of ants increases linearly with the amount of nectar produced, the value of protection does not" (Noë 2001: 99). On an individual level each player in this market is affected by another including the ants competing within themselves for the nectar, as they might choose to switch larvae to one that is less competitive and is producing more nectar to attract a larger group of ants.

There are some *Lycaenid* species that live in a community and during their larvae stage produce nectar together to attract ants for communal protection (Noë 2001: 100). During this stage they are able to reduce their total output of nectar and reduce competition for ant protection that exists in individual larvae. Similar to humans when "multiple individuals simultaneously offer the same commodity in order to get some collective benefit" (ibid, 100). By participating in cooperative behaviour, the cluster larvae are actively deciding to work together to exchange commodities for their mutual benefit. This behaviour yields a net advantage in comparison to the solitary larvae who compete against other larvae and must increase their price to gain attraction. Although, biological markets do account for cheaters who actively decide to deceive their species to gain a further advantage by 'free-riding'[8] and receiving the protection of ants without producing any nectar themselves (Axén, Pierce 1998). In such cases there is a 'collective action problem[9],' and the market finds a way to enact a policing effect to punish the free-riders. For the non-nectar producing larvae, the ants who are meant to protect them from predators make a rational decision to eat them. The decision is based on the thought process that "the body has more value to be eaten than the sugar it will produce in the future" (Noë 2001: 106).

The larvae have tentacle organs that produce pheromones to indicate the presence of nectar to the ants, however it can also be used to manipulate the behaviour of the ants (Noë 2001: 108). Pheromones might not act like human language that "function primarily as symbols rather than signs" (Ingold 1988: 94), however just because the ants and larvae do not use language to communicate, or coin the term collective action problem, does not entirely mean they do not understand the concept of it. Therefore, when Ingold suggests that animals reference an "external world of objects" only and not an "internal world of concepts" it is incorrect (1988: 94). Moreover, ants showcase a rational thought process when eating the non-nectar producing larvae and therefore must have a method of communicating their rational deliberation to do so with each other and other larvae thereby demonstrating a certain discursive consciousness.

Additionally, if the individual larvae did not grasp the concept of price or the cost of production of its nectar it would constantly be producing nectar at an equilibrium price of PE (in Figure 1) without ever finding the need to reduce or increase its price. Therefore, at some level the animal is rationally making decisions to behave in a certain way that we as humans understand and build symbols for as economics and market theory.

Prior intentions & discursive abilities of non-humans

Ingold (1988: 96) argues against Griffin's belief that animal's intentionality comes from them being guided by "mental images of desired future states". He suggests that it is a hypocritical approach to think that animals rationally working toward a plan is a determinant of their consciousness when we as humans often fail to do so. For Ingold animal thinking must demonstrate a rational discursive capacity to think about their thinking before acting, what he terms as 'prior intentions' (ibid). Additionally, planning in advance is not the same as having prior intentions, therefore, to analyse if non-humans can have prior intentions, we must find a situation where the choice is made deliberately and voluntarily in a novel way that breaks from "stock-in-trade habitual patterns" (ibid, 97).

The theory of biological markets reveals a chain of cause and effect that link and coordinate transactions occurring throughout a market that an individual must understand and make a choice amongst all alternative options it has present (Kirzner 1963: 12). In this an animal must utilise a complex rational thought process to weigh all options, including new ones that may be introduced in an experiment and then make a choice. Such a choice might differ from habitual patterns and therefore break from the practical consciousness Ingold boxes animals into. Furthermore, to make such a choice an individual must also be discursive with both itself and other group members in a cooperative society to understand the implications of its decisions. As an example, we can look toward the *Polistes dominula,* also known as paper wasps. The exchange in this market[10] is based on subordinate wasps known as 'helpers' providing goods in the form of foraging and defence efforts (cost), with dominant 'breeders' providing group membership[11] as the price (Grinstead, Field 2016).

A dominant female breeder is able to alter her reproductive output based on group size, which means more subordinates will increase the number of offspring produced (Grinstead, Field 2016: 2). In the occasion that there is a decrease of helpers and foraging efforts are reduced, excess larvae and eggs are fed to the larger and more valuable larvae, which means that "every additional helper has an extra value to the dominant" (ibid, 2). In contrast foraging is costly for subordinates as it "correlates positively with individual mortality" (ibid, 3) and will reduce the ability of the individual to reach the position of a breeder. This is important for the creation of a market as the

price the subordinate is willing to pay for group membership is lower than what the breeder wants to accept. During the 2016 experiment by Grinstead and Field the paper wasps were provided alternative options, which challenged the habitual patterns of the subordinate paper wasps.

The experiment was conducted in two stages to understand if there is an entrepreneurial behaviour present in the subordinate paper wasps. A subordinate can increase its social rank or become a breeder itself in the case the dominant breeder dies or if it is challenged, which in this case is the habitual pattern (Grinstead, Field 2016: 2). This ability to change from subordinate to breeder provides a less strict definition of trader classes that was present in the larvae and ant example as their market is simpler and based on the manipulation of the ratios of their trader classes[12]. In the first stage of the experiment, only nesting options were created without an increase in the supply of subordinates available, which did not have much influence on the helper market (ibid, 4). However, in the second stage an increase in both nesting spots and the supply of subordinates delivered a decrease in foraging efforts from subordinates in dominant nests as they had now become a pricey commodity (ibid, 5). Another reason was that some subordinates left their position as helpers to become dominant breeders themselves and search for helpers to increase their group size. "Initiating a new nest is a high-risk/high-reward option for a subordinate" (ibid, 4) and therefore showed an insignificant amount of interest in the first stage. But when the subordinate utilised discursive consciousness it was able to weigh its options and break from its habits to start its own nest. Moreover, it must have had to communicate with other helpers to gain their interest in joining its new nest and signify its shift from being a helper to a dominant. Most importantly, the previously subordinate wasp must have to think and have a dialogue with itself about becoming a dominant, and whether it can live up to the task of its new nest. The provision of novel alternate options indicates the ability of prior intentions in wasps and how they must deliberate and choose amongst options. This also contradicts Ingold's idea that the thought process of non-humans is a "pre-programmed force of an instruction" (Ingold 1988: 93) as the wasps had the ability to change behaviours and choices when faced with new situations that were altered from the ones that had been 'programmed'.

Complexity of thinking in animal communication

Ingold (1988: 91) states Griffin's question "Do animals have any sort of mental awareness of probable events, and do they make conscious choices with the intent to produce certain results?" In other words, Griffin questions if animals have the ability to think of the future, read the environment and assess the choices they have and then make a choice they believe will have a desirable result for them. Ingold suggests an experiment where a

model of a bee that can be remotely controlled is placed into a hive where it conducts the waggle dance to send the other bees toward a food source (Ingold 1988: 92). However, he indicates that if the bee would do a dance corresponding to an image in his mind, the bees should theoretically go on a random chase for the food source as he is communicating in their sign language. Although in reality this could never occur in the world of bees because they have no conceptual connotations, and their dance is only "triggered by an internal organic state that was in turn induced by the preceding flight from a food source" (ibid, 93). By using this example Ingold showcases the bee as an animal that cannot lie about a food source and thereby must not have concepts. Moreover, this behaviour of the waggle dance can only be induced by a biological state and therefore does not require any thought or assessment by a bee about its current or future states. However, this example cannot be utilised as the norm for all animal communication and cognitive abilities. What about animals that communicate concepts and are not triggered by internal organic states, but by rational thinking?

Such is the case of the *Labroides dimidiatus* or cleaner fish market (Bshary 2001), which includes sophisticated interaction with other coral fish who act as their clients. The cleaners inspect the body surface, gill chambers and mouths of their clients in search for parasites and dead or infected tissues at their so-called cleaning stations (ibid). Occasionally, cleaners may even take a bite of their client's mucous, which is more nutritious. Clients also visit the cleaners for tactile stimulation (Losey 1979) whereby the cleaners use their pelvic fins to stimulate specific sites on their clients' bodies. From a cleaner's perspective, the client is divided into two classes based on their access to coral stations: 'residents' who have access to only one station and 'floaters' who can access two or more stations (Bshary 2001: 148). Additionally, the cleaner further divides those classes based on their clients being herbivores or predators, which creates a hierarchy of "predator floaters, harmless floaters, predator residents, harmless residents" (ibid, 150). This hierarchy in turn influences their daily decisions as each cleaner has around two thousand interactions per day (Crair 2017) and must therefore adjust their communication accordingly to provide themselves the higher payoff in every interaction.

In this example both the client and cleaner must communicate in order to fulfil the transaction, which results in both direct and indirect communication. First the cleaner fish must advertise its services by performing the 'rocking dance' where it showcases a "side to side motion that holds no locomotive advantage" (Horton 2011: 92). This dance move is performed to indicate the cleaner is open for business, and to attract fish who are not able to see stationary objects as they have poor visual power (ibid, 91). The dance is not pre-programmed as the cleaner is able to judge when it must communicate its services and when not, such as if it already has clients, if it is older and has a loyal base of consumers, or if there are no floaters passing by. Moreover, this dance is performed mostly in the morning when the cleaner knows that clients will have a higher quantity of parasites than later in the day (ibid, 97). On the other hand, the client themselves must respond by communicating what service they would like through special postures — parasite inspection and cleaning or tactile stimulation (Bshary 2001: 146). This

communicative method is referred to as 'posing' (Horton 2011: 91) and is based on gestures. All classes of clients pose in order to receive a service. For predator clients it displays an immense amount of thought as they have to open their mouth and allow a potential food source to clean and then just leave. This also indicates to the cleaner that they will not be eaten, and they can approach to do their job. In some cases, it is possible for a predator floater to cheat and lie to the cleaner fish and get the service provided and then consume it. Therefore, suggesting this whole market interaction is not mindless, but based on simple economics that must be executed at each interaction.

In the duration of the service itself, there can be further communication between the two trader classes. Cleaners utilise their tactile stimulation as a method for conflict management (Grutter 2004) either with predators to showcase how they are preferential clients, or with residents[13] who have been bitten to influence their decision to stay. This indicates that the cleaner has communicated through the stimulation in regard to its future outcome. In the predator interaction better service is provided as the trade-off is the cleaner's own life that could be under threat if the service provided is bad. But, for the bitten residents the communication is more about reputation management of the cleaner. On the other hand, during a service if the client is bitten then they may show aggressive stances, or even injure the cleaner as a threat (Bshary 2001: 149). By doing so the client, who is usually a resident and faces bad treatment because of an asymmetric payoff in the monopoly created, indicates to the cleaner that it must not be cheated or taken advantage of. If the bitten is a predator, the aggression acts as a reminder of who the prey and predator is in this situation.

There are times when the cleaner is indirectly communicating about its services to other clients, and not the one they are servicing at the time. This usually occurs when a floater is judging the potential of a cleaner as it has access to more than one station and can select between cleaners based on service quality (Bshary 2001: 150). Thus, forcing cleaners to compete with each other with good services to attract floaters. This improves the quality of a service provided on the client being serviced at the moment to indirectly signal to the floaters their reputation as quality cleaners. During occasions where the cleaner notices a floater waiting in line, it chooses to give up cheating a herbivore resident and biting their mucous to show the floater it provides only the highest levels of service (ibid, 167). This suggests that the cleaner can gauge its environment, think about the future outcome of the floater leaving and then intentionally not bite into its less valued customer, because it understands the future value of its investment.

This example demonstrates two distinct trader classes as both cleaners and floaters can exert choice thereby keeping the 'choosing' and 'chosen' in constant flux. It also displays the complexity of thinking of the cleaner and client as they assess short term versus long term rewards and then communicate accordingly. The cleaner assesses each client on the basis of their hierarchy[14] indicating an active choice to provide a certain service level depending on who the client is. Unlike Ingold's bee that depends on the change of its own internal state to depict a food source, the cleaner fish showcases immense rationality and intentionality in the way it approaches its food source.

Furthermore, it communicates through a variety of dances, gestures, stimulations, etc. suggesting that in order to find the cognitive capabilities of the bee we should look further than just one dance.

It can be argued that this is an anthropomorphic force-fit of animal actions into human economic and rational behaviour. However, it is Ingold's position of showcasing animals as cognitively lacking that is anthropocentric because it fails to take into account interactions where the animal displays choices, thinking, and rationality in their communications. The theory of biological markets allows us a new lens in viewing these interactions between species and inter-species to see how rational decision-making is core to their communication, sometimes more so than human beings themselves. The cleaner and its clients, ants, larvae, and paper wasps all display the capacity to think of their actions as demonstrated in this essay through their own unique interactions. This suggests we need further research that focuses on the economic markets present in nature, which could help us develop a better understanding of animal cognitive capacities whether it is through creating methods of communication between humans and animals, or by just simply observing them in their own environment.

References

Akerlof, George; Shiller, Robert 2010. Animal spirits. *Animal Spirits: How Human Psychology Drives the Economy, and Why It Matters for Global Capitalism*. New Jersey: Princeton University Press, 1-19.

Axen, Annkristen; Pierce, Naomi 1998. Aggregation as a cost-reducing strategy for lycaenid larvae. *Behavioural ecology* 9(2): 109-115.

Bshary, Redouan 2001. The cleaner fish market. In: Hammerstein, Peter; Noe, Ronald; Van Hoof, Jan. *Economics in Nature: Social Dilemmas, Mate Choice and Biological Markets.* Cambridge: Cambridge University Press, 146-171.

Crair, Ben 2017. The Secret Economic Lives of Animals. *Bloomberg*. Available from: https://www.bloomberg.com/features/2017-biological-markets/; accessed on 24 April 2020.

Chappelow, Jim 2019. Free Riding Definition. *Investopedia*. Available from: https://www.investopedia.com/terms/f/free_rider_problem.asp; accessed on 25 April 2020.

Dowding, Keith 2013. Collective Action Problem. *Encyclopaedia Brittanica*. Available from: https://www.britannica.com/topic/collective-action-problem-1917157/Incentives-and-disincentives-of-collective-action; accessed on 25 April 2020.

Grinsted, Lena; Field, Jeremy 2016. Market forces influence helping behaviour in cooperatively breeding paper wasps. *Nature Communications* 8: 13750 doi: 10.1038/ncomms13750.

Grutter, Alexandra 2004. Cleaner fish use tactile dancing behavior as a preconflict management strategy. *Current Biology* 46(12): 1080–1083.

Hayes, Adam 2020. Rational Behaviour Definition. *Investopedia*. Available from: https://www.investopedia.com/terms/r/rational-behavior.asp; accessed on 23 April 2020.

Horton, Samantha 2011. Factors affecting advertising in Indonesian adult and juvenile bluestreak cleaner wrasse. *Bioscience Horizons: The International Journal of Student Research* 4(1): 90-98.

Ingold, Tim 1988. The animal in the study of humanity. *What is an animal?* London: Unwin Hyman Ltd, 84-99.

Ingold, Tim 2006. Building, dwelling, living: How animals and people make themselves at home in this world. *The Perception of the Environment. Essays in livelihood, dwelling and skill.* New York: Routledge, 172-188.

Kirzner, Israel 1963. The Nature and Tasks of Market Theory. *Market Theory and Price System.* New York: D. Van Nostrand Company, 1-13.

Losey, George 1979. Fish cleaning symbiosis: Proximate causes of host behaviour. *Animal Behaviour* 27(3): 669-685.

Meaning of awareness in English. *Lexico.* Available from: https://www.lexico.com/definition/awareness; accessed on 18 November 2020.

Noë, Ronald 2001. Biological markets: partner choice as the driving force behind the evolution of mutualisms. In: Noë, Ronald; van Hooff, Jan; Hammerstein, Peter (eds.), *Economics in Nature: Social Dilemmas, Mate Choice and Biological Markets.* Cambridge: Cambridge University Press, 93-118.

Nunn, Charles; Lewis, Rebecca 2001. Cooperation and collective action in animal behaviour. In: Noë, Ronald; van Hooff, Jan; Hammerstein, Peter (eds.), *Economics in Nature: Social Dilemmas, Mate Choice and Biological Markets*. Cambridge: Cambridge University Press, 42-66.

Uexküll, Jakob von 1992 [1934]. A stroll through the worlds of animals and men: a picture book of invisible worlds. *Semiotica* 89(4): 319-391.

Notes

1 It is important to note that Tim Ingold repositioned his thoughts on animal thinking in "Building, dwelling, living: How animals and people make themselves at home in the world" (2006: 172-188). Therefore, the quotes in this paper do not adequately depict or reflect Ingold's stance on animal thinking since 2006. However, his thinking in *What is an animal?* is still of great value as it helps in understanding the oppositions in the perception of animal rationality versus that of humans.

2 Morgan uses the essence of 'mind,' which he believes all creatures human, and non-human possess and terms it 'Thinking Principle' (Ingold 1988: 87). He believes animals lack the vocal abilities humans have and therefore cannot communicate their internal thinking processes, thereby appearing 'mute' (ibid, 88).

3 Griffin suggested that animals had the possibility for rational deliberation, but in order to understand human beings had to learn, develop, and participate with an appropriate mode of communication (Ingold 1988: 91)

4 From non-humans whose actions are directed by practical consciousness (Ingold 1988: 96)

5 "Intentions formed before the performance of an action" (Ingold 1988: 96).

6 Rather than thinking without communicating or communicating without thinking.

7 Awareness in this context is used when the species is well-informed about a particular situation (Lexico), thereby suggesting it knows the market it is in, the choices it has, and the ability to take actions or non-actions in a given situation.

8 Free Riding occurs when a burden is created on a shared resource by members of the group who aren't paying their share (Chappelow 2019).

9 Collective Action Problem is a problem created to "discourage joint action by individuals pursuing a common goal" (Dowding 2013).

10 The market is based on the relative demand for helpers versus their group membership.

11 Through group membership subordinates gain "direct or indirect fitness benefits via inheritance or by helping a relative" (Grinstead, Field 2016: 2).

12 Increase in supply of ants decreases the nectar produced by the larvae, and decrease in supply of ants increases the nectar produced by the larvae.

13 Residents, especially herbivore residents are most likely to be bitten by the cleaner as they have only one station to visit, and the cleaner has a plethora of other clients. This forces resident clients to accept a relatively bad service in exchange for the cleaner to feed on not just parasites, but also on the client's tissue which is considered a reward leading to a higher energy gain for the cleaner.

14 Usually done by distinguishing colour, patterns, and the size of the fish (Bshary 2001).