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Yet More Behaviour of Animals

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An independent academic psychologist, based in England, who has written extensively on different areas of psychology with an emphasis on the critical stance towards traditional ideas.

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1. MOVEMENT ECOLOGY

1.1. OVERVIEW

"Throughout history, people have been drawn to the phenomenon of animal migration, pondering how and why some animals make their way across mountains and oceans they have never seen before" (Fudickar et al 2021 p480). The newly emerging field of "movement ecology" covers migration (Fudickar et al 2021).

Dingle (2014) outlined the fundamental questions about migration:

- What is it?
- Who does it?
- Why do it?
- How to do it?
- What determines timing, distance, and direction? (Fudickar et al 2021).

Fudickar et al (2021) added some other important questions: "How does migration differ from dispersal? Does it require a round trip? Is it migration if an individual completes only a part of a journey that requires multiple generations to initiate and complete?" (p481).

Migration is common across the animal kingdom. "Insects and mammals migrate in most regions of the globe, and fish migration is common in both salt- and freshwater ecosystems" (Fudickar et al 2021 p480).

The main "bird-migration systems" include (Fudickar et al 2021):

a) Nearctic-Neotropical (between North American breeding grounds and tropical wintering grounds).

b) Palearctic-Paleotropical (eg: Europe to southern Africa).

c) Austral migration (southern latitudes to the north).

There is also "altitudinal migration", where birds (and other animals) breed at higher elevations before migration downhill during the non-breeding season, and "intra-tropical migrations", "which occur wholly within the tropics, are still poorly understood and likely to be more common that currently appreciated" (Fudickar et al 2021 p480).

Species who migrate tend to fall into one of three broad categories (Fudickar et al 2021):

i) Obligate - all individuals of a population migrate at the same time each year, say.

ii) Irruptive - nomadic species that migrate when resources are depleted.

iii) Facultative - individuals migrate after reproduction depending on factors like food availability or weather, but may not migrate in some years.

There is also "partial migration", "in which some individuals of a population migrate while others remain resident year-round, can be obligate or facultative depending on whether individual strategies are consistent across years" (Fudickar et al 2021 p481).

At an individual level, it has been observed that "individuals with greater vulnerability to seasonal conditions outside of the breeding season are most likely to migrate, such as individuals that are sub-dominant to others and thus less likely to gain access to diminished resources" (Fudickar et al 2021 pp481-482).

Ketterson and Nolan (1976) described a pattern called "differential migration" from their study of the dark-eyed junco. Females make longer migrations than males. These researchers proposed that "males experienced greater mortality during winter than females, probably returned earlier to the breeding range than females, and probably benefited more than females from early return. They speculated that the larger body size in males made them better able to fast during winter storms" (Fudickar et al 2021 p482).

1.2. EVOLUTION

The term "migratory phenotype" has been used to describe a phenotype "in which the whole body, the organism, prepares and executes migration, and it is reflected in the organism's behaviour, physiology, and morphology" (Fudickar et al 2021 p482). While "migratory syndrome" (Dingle 2006) refers to specific "sub-traits" that accompany the migratory phenotype, like appetite, energy storage, and reduced fear of the unknown (Fudickar et al 2021). "Animals may become hyperactive and hyperphagic. They may switch from diurnal to nocturnal activity, alter their diets, and in insects, even grow wings... When these attributes co-occur, they have been said to form a syndrome" (Fudickar et al 2021 p483).

In terms of the actual inheriting of these different aspects of migration, onset, duration and termination are well researched in the laboratory and the wild, but "the heritability of migration distance is difficult to quantify for both offspring and parents in the wild and impossible to measure in captivity in most taxa" (Fudickar et al 2021 p483).

Focusing on birds, Akesson and Helm (2020) talked of a "migratory programme". They stated: "The majority of songbirds rely on a genetic programme inherited from their parents that will guide them during their first solo-migration" (quoted in Fudickar et al 2021). How much of this programme or the migratory phenotype are genetically determined (ie: no role for non-genetic factors like learning or the environment) is open to debate. Translocation studies of birds, where they are move geographically before being released to migrate, have been used to investigate innate migration direction or the learning of it. The findings of such studies are debated (Fudickar et al 2021).

Modern genomics allow the possibility of finding specific gene(s) related to aspects of migration (eg: CpG methylation of the "Clock" gene) (Fudickar et al 2021).

The "migratory threshold model" (Pulido et al 1996) proposes that migratory behaviour is a product of inheritance of "enough migration-associated genes to exceed a threshold" (Fudickar et al 2021 p484).

The main theory of the evolution of migration is the "optimality approach", which argues that migration evolved where its benefits are greater than the costs. The benefits include occupying regions with abundant resources and avoiding depleted ones, escaping predators and/or tracking prey, and the ability to survive winters. The main costs are related to the transit, and establishing oneself in a new area.

The optimality approach has been studied by comparing the mortality in a species which contains individuals who migrate and those who do not. Some recent studies with birds have found a higher mortality in migratory birds (Fudickar et al 2021).

An alternative approach to the evolution of migration is related to breeding-site fidelity (Winger et al 2019). This is the idea that "breeding-site fidelity is highly beneficial, and migration should be viewed as one of several adaptations that allow individuals to stay in the same place when highly seasonal environments force them to retreat. Migration should therefore be studied alongside other adaptations to seasonal environments, such as hibernation or freeze tolerance" (Fudickar et al 2021 p486). Reproductive success has been reported as higher among birds returning to familiar sites to both breed and forage (Fudickar et al 2021).

1.3. MIGRATION AND DISPERSAL

Migratory birds can disperse seeds very long distances via ingestion. "In this mode of dispersal, the seeds pass through the bird's digestive tract unharmed and are deposited in faeces, which provides fertiliser that aids plant growth" (Daru 2021 p34). For example, analysis of the guts of birds on the Canary Islands showed evidence of seeds from the mainland (nearly 200 km away) (Viana et al 2016).

This process of dispersion will become even more important with climate change as a key way for plants to move to cooler areas as the planet warms. Gonzalez-Varo et al (2021) analysed data on 949 different seed-dispersal interactions between 46 bird and 81 plant species from thirteen woodland communities in Europe.

Over 80% of plant species had seeds dispersed on a southward migration towards the equator, and one-third in the opposite direction. Some plant species are dispersed in both directions. The southward dispersal "will probably be less able to keep pace with rapid climate change" (Daru 2021 p35). The key northwards dispersers were the blackcap and the blackbird.

1.3.1. Climate Change

Anthropogenic climate change will lead to changes in migration departure and arrival times as well as geographical distribution. Long-term data are needed. For example, Gill et al (2019) studied black-tailed godwits (a long-legged shorebird), and found that migration strategies varied between generations (ie: juveniles colonising new areas while older individuals are not able to change) (Kravchenko et al 2020).

Kravchenko et al (2020) analysed twelve years of data on a migratory bat, the common noctule (Nyctalus noctula) in the Kharkiv region of Ukraine. Surveys covered 3394 individuals between 2007 and 2016. There was a significant decline in longer distance migrants over the study period.

The area of study was a new wintering area for the bats in the last thirty years. This "recent change in the distribution has led to a partial overlap of hibernation and breeding areas, resulting in populations consisting of both migrating and non-migratory individuals. Presumably, these changes in migratory behaviour may be driven by milder winters and longer plant growth periods" (Kravchenko et al 2020 p2). This is evidence of the bats moving northwards with global warming.

1.3.2. Endozoochory

Another interesting dispersal is fish able to colonise remote lakes or ponds. One speculation is that eggs are transported on the feathers or feet of waterbirds, but there is "no evidence of this" (Lovas-Kiss et al 2020 p15379) (appendix 1A).

However, Lovas-Kiss et al (2020) provided evidence of dispersion "inside terrestrial vertebrates following ingestion (endozoochory)" (p15379). Captive mallard ducks were fed common carp or Prussian carp eggs, and the faeces wee collected and analysed 1, 2, 4, 6, 8, 12 and 24 hours after feeding.

Eight common carp eggs (0.2% of total ingested) and ten Prussian carp eggs (0.25%) were recovered in the faeces, mostly one hour post-feeding. Twelve contained viable embryos and three eggs hatched. This experiment established the survival of fish eggs through the digestive tract of vertebrates.

"Although only 0.2% of eggs survived gut passage through mallards, endozoochory of fish is likely to be frequent in nature, given the frequent feeding by birds on fish roe, which are rich in proteins and lipids" (Lovas-Kiss et al 2020 p15398). Birds can consume large numbers of fish eggs (eg: over 200 found in the stomach of one mallard duck in another study; thousands in the case of gulls) (Lovas-Kiss et al 2020).

In terms of dispersal, mallards could travel around sixty kilometres in one hour. "Despite the relatively short retention times of fish eggs within the digestive tract of mallards, these birds are still likely to play a significant role in long-distance dispersal of carp" (Lovas-Kiss et al 2020 p15399).

Fish can be mass or multiple spawners. Mass spawners produce large masses of eggs synchronously, where birds might gorge on large quantities of eggs within a short period of time, increasing survival of gut passage. Multiple spawners produce eggs asynchronously, ensuring availability of eggs over a longer time frame, exposing these to a larger pool of bird species, and increasing chances of overlap with their migratory periods" (Lovas-Kiss et al 2020 p15399). Advantages to high fecundity.

The mallards were force-fed the fish eggs in the experiment. A number of the eggs died due to fungal infection. Lovas-Kiss et al (2020) explained: "Our experimental setup may have facilitated fungal infection, due to weak anti-fungal treatment, small water volume, a shared tank for eggs placed for hatching, and insufficient water circulation around the eggs" (p15399).

Silva et al (2019) previously found that eggs of killifish survived passing through the gut of coscoroba swans. "However, killifish possess adaptations that enable them to survive hostile environments. Killifish zygotes often enter diapause for years during periodic droughts in their ephemeral habitats, while the highly specialised chorionic membrane isolates the embryo and allows it to survive anoxia, hyper-salinity, or desiccation" (Lovas-Kiss et al 2020 p15397).

1.3.3. Sprint Migration

The speed of migration in birds is determined by factors like fuelling rate at stopover, body size, flight speed and style, and wind support. The fastest birds can achieve 200 - 400 km per day (Akesson and Bianco 2021).

Geolocators placed on birds can show the details of migration (eg: common swifts (Apus apus); Akesson and Bianco 2021). Adults leave Swedish Lapland in mid-August and arrive south of the Sahara in late September (average six weeks) with 1-4 periods of stopovers before crossing the Sahara. The spring migration northwards in May averaged fifteen days. In summary, more days were spent travelling and in stopover during the southward (autumn) migration. Furthermore, a longer route was taken in the autumn.

The speed in spring was 570 km per day compared to 250 km in the autumn. Tailwinds were calculated to be higher in the spring (resulting in a 20% gain in speed), and these can impact the timing of migration, flight altitude, drift, and migration speed (Akesson and Bianco 2021).

1.4. MAGNETIC FIELDS

Keller et al (2021) marvelled: "Navigating thousands of kilometres to a target location through a three-dimensional ocean is among the most impressive feats in nature and has important implications for the evolution, ecology, and conservation of many marine species" (p2881).

The Earth's magnetic field (or geomagnetic field; GMF) plays an important part with such navigation, providing map and compass information. "The map allows animals to garner spatial information relative to their location, while the compass allows animals to maintain a directed heading, and together, these facilitate successful migrations toward targeted locations" (Keller et al 2021 p2881).

Keller et al (2021) explored this in sharks, and specifically in the bonnethead (Sphyrna tiburo). Twenty juveniles caught off Florida, USA, were tested experimentally in a marine laboratory. A tank was positioned in the centre of magnetic coils that could produce "magnetic displacement". There were three conditions - (i) a magnetic field that mimicked the home site (as a control condition), (ii) a magnetic field representing 600 km south of the home waters (ie: weaker intensity and decreased inclination), and (iii) a field equivalent to 600 km north (ie: stronger intensity and increased inclination). Keller et al (2021) outlined their expectations: "If sharks derive positional information from the GMF, then we predicted northward orientation in the southern magnetic field and southward orientation in the northern magnetic field (in each case to compensate for the perceived displacement), but no orientation preference in the magnetic field at the capture site" (p2881).

These predictions were partly supported by the data. In the control condition (i above), the sharks moved around randomly, but when the sharks "exposed to the southern magnetic field [ii above], orientation was significantly northward" (Keller et al 2021 p2882). There was no difference in orientation between the northern field (iii above) and the control condition. "Bonnetheads appeared to perceive the southern magnetic field as different from the field at the capture site and responded to the magnetic displacement with homeward orientation" (Keller et al 2021 p2882).

The northern field was unusual to these sharks who normally moved southwards. Keller et al (2021) commented that "the lack of response to the northern treatment is also consistent with findings in animals with innate magnetic maps; hatchling loggerhead sea turtles (Caretta caretta) failed to orient in magnetic fields far outside of their normal migratory route, but were strongly oriented within the typical population range" [Fuxjager et al 2011] (p2882).

1.5. DISPERSAL

"Context-dependent dispersal" is where the local physical and social environment influence animal dispersal. Animals move to avoid inbreeding and kin competition, and for better habitat selection (Pasukonis et al 2019).

Parents can aid their offspring's dispersal, as in frogs transporting tadpoles from land to water or to different water sites. Pasukonis et al (2019) radio-tracked tadpole transporting males of two poison frog species - three-striped poison frog (Ameerega trivittata; At) and dyeing poison frog (Dendrobates tinctorius; Dt) - in Amazonian Peru. A tadpole transport event was defined as a frog depositing all tadpoles at a water site and returning back to their home territory.

Eight At and 15 Dt tadpole transport events were successfully tracked (ie: seven and eleven individuals respectively).

Pasukonis et al (2019) summed up their findings: "Males of both species carried their offspring to several sites farther away than the closest pool available from their respective home areas. The frogs moved directly toward distant pools and sometimes ignored nearby pools that had been used by other individuals even when passing next to them. We thus suggest that patterns of pool availability and quality cannot fully explain the observed movement patterns. We propose that adaptive benefits related to offspring dispersal could also shape the spatial behaviour of parental poison frogs" (p619). At males travelled an average of fifty metres further than the nearest pool, and Dt males 20 metres.

This behaviour has a number of benefits including reducing competition and inbreeding risk between parents and offspring, and spreading the risk of loss of offspring from predation or pools drying up. Pasukonis et al (2019) continued: "It is particularly surprising that the territorial males invest so much time in tadpole transport, because leaving the territory unattended may lead both to loss of mating opportunities and loss of the territory to competitors. In addition, movement may increase the predation risk... The fact that frogs nevertheless travel such long distances suggests that the benefits, which remain to be quantified, outweigh the potential costs" (p619).

1.6. RANGE OF SPECIES

"Species' distributions change over time. Although in a given time span a species' range may seem static, it may have undergone major changes in the past and it is likely to change in the future. For example, ranges can change in size by expanding or contracting, or shift in space while either preserving or changing their size" (Rafajlovic et al 2022a p1).

Range changes, however, are not in isolation. "A change in one species' range may have impacts that extend to other species, and to the communities and ecosystems in their new or abandoned habitats" (Rafajlovic et al 2022b p1).

Global climate change and changing ranges of species is now a key topic. "Importantly, a change in a species' range may impact on populations, species, communities or ecosystem functioning in the newly occupied or abandoned habitats, with the invasion of non-native species often expected to induce negative effects" (Rafajlovic et al 2022a p1).

Rafajlovic et al (2022b) asserted: "From an ecological point of view, a species' range is expected to end where environmental conditions exceed the limits of its ecological niche, ie: where its population growth rate at low density is no longer positive. However, this limit may not be realised owing to historical factors, such as temporal changes in the environment, stochastic variation in conditions or spatial barriers that take time to overcome" (p2).

The problem may be prediction, as Bridle and Hoffmann (2022) pointed out: "Despite the urgency of such rapid environmental change, we still struggle to predict which species will contract, maintain, or expand their distributions, and where (and when) in their geographical ranges this will happen, even though we see more and more examples of each of these changes across taxa and biomes" (p2). This is partly because predictions are commonly based on species distribution models (SDMs), "where the current range of a species is associated with a suite of climatic factors that defines its niche. The future position and size of a species' range is then determined by where these climatic factors will prevail in the future" (Bridle and Hoffman 2022 p2). But SDMs have limitations like the inability to account for micro-climates (eg: few metres in distance or few minutes in time), and not taking account of interactions between species (Bridle and Hoffmann 2022).

In understanding evolutionary limits to species' ranges, Bridle and Hoffmann (2022) distinguished "hard" and "soft" limits. The former are "those that "will always restrict a species’ distribution when populations are exposed to a given set of conditions, because they reflect inherent limits or trait thresholds that cannot be easily overcome, at least without the spread of novel or rare mutations that alter existing phenotypic trajectories or key developmental or ecological trade-offs" (Bridle and Hoffmann 2022 p3). The "soft" limits are specific to a population and environment, and are "more fluid and dynamic" (Bridle and Hoffmann 2022 p3). An example of a "hard" limit may be seen in an insect that has evolved to feed on a specific plant that exists in a small area. The physical features of the insect "fit" the physical features of the plant, which makes change to another food source dependent upon physical changes. A "soft" limit could be the insect feeding on one plant in its range, but it has the option to feed on others if forced to move to another area. "Climate change vulnerability will ultimately involve a combination of 'hard' and 'soft' evolutionary limits to species' margins" (Bridle and Hoffmann 2022 p11).

1.6.1. Temperature

Temperature is an environmental variable that can limit the distribution of a species, either directly through temperature exceeding physiological tolerance, or indirectly through interactions with potential stressors (eg: greater parasite numbers at certain temperatures) (Noer et al 2022).

Heat tolerance is the particular focus with concerns about global warming. Laboratory studies do not take account of thermoregulatory behaviour - ie: "species have no opportunity to behaviourally shape their thermal environment, which will often alter responses to environmental stressors" (Noer et al 2022 p2).

Meanwhile, naturalistic studies often use "coarse, interpolated and low-resolution climate data that is measured in the air, high above the ground level, and at distances spanning several km^2. Such data ignore the climate-forcing processes that operate near the ground, and thermal heterogeneity across the environment, and studies report that the microclimate can deviate by up to 35°C from air temperature. Thus, the conditions met by small organisms in the field bear little resemblance to the macro-climate. Further, currently used climate data usually consist of long-term measures (monthly averages) and do not account for fine-scale spatio-temporal variability, thereby disregarding exposures to eg: extreme conditions on the short time-scale (minutes, hours, days). Ignoring the frequency that organisms are exposed to stressful conditions may cause inaccurate predictions of species' ranges" (Noer et al 2022 p2).

Noer et al (2022) aimed to overcome these weaknesses in their study of seven insect species (eg: common fruit fly; Oleander aphid) in temperate Melbourne, Australia, and five species in tropical Cape Tribulation, Queensland, Australia (eg: arboreal ant). The captured insects were placed in glass vials and submerged in a water bath at certain temperatures, and the length of time before the insect went into a heat-induced coma was recorded. The longer the period of time, the more heat tolerant the insect. Finally, the "heat knockdown time" was calculated - ie: the temperature that induced a heat coma within 20-40 minutes.

There was a high degree of variability in heat tolerance in both sets of species, and within and across days. Overall, the "data suggest that species have the potential for adjusting to new temperature and humidity regimes within a species' current range, and perhaps also to conditions outside their current distribution range. This could allow some species to exhibit larger range sizes in the future" (Noer et al 2022 p7). But the authors worried that the adaptability to heat may have fitness consequences (eg: ability to find food).

1.6.2. Endemism

"Human-induced biodiversity declines are increasing and affect all corners of Earth. Current species extinction rates are estimated to be two to three orders of magnitude higher than 'background' extinction rates" (Murali et al 2021 p1). What to focus the limited conservation resources upon? "Much scientific attention is directed toward rare, unique, and at-risk species" (Murali et al 2021 p1).

"Endemics" (ie: range-related species) are highly vulnerable to extinction "due to different causes such as hunting, invasive species, climate change, and land-use change" (Murali et al 2021 p1). Endemics (or "phylogenetic endemism"; Rosauer et al 2009) can include "the most geographically rare and evolutionarily unique lineages" (Murali et al 2021 p1). Isolation on islands is an example of this.

A number of hypotheses have been proposed to explain endemism, including (Murali et al 2021):

i) Barriers that limit dispersal and promote specialisation, like the sea around islands.

ii) Climate stability that encourages stability.

iii) Unique local climates that select for local adaption and specialisation.

Murali et al (2021) surveyed data on land vertebrates for endemism. Key environmental factors encouraging specialisation were found to be low seasonal temperatures, and physical barriers, like mountains or other movement restrictors (eg: west of the Andes or east of the Great Dividing Range in Australia). There were more endemic species in the Southern Hemisphere. But the hotspots for endemic species varied between animal types (taxa)(eg: reptiles in the southern Andes while Central America for amphibians and mammals). "While phylogenetic endemism hotspots cover 22% of Earth, these regions currently have a high human footprint, low natural land cover, minimal protection, and will be greatly affected by climate change. Evolutionarily unique, narrow-range species are crucial for sustaining biodiversity in the face of environmental change" (Murali et al 2021 p1).

1.6.3. Albatross and Site Fidelity

Spatial site fidelity (ie: visiting repeatedly the same location) is a type of niche segregation (which describes differences between individuals in a population). This is distinct from habitat fidelity (ie: "using a variety of locations with the same habitat conditions"; Patrick and Weimerskirch 2017 p675).

Three main hypotheses have been proposed to explain this behaviour (Patrick and Weimerskirch 2017):

a) "Win-stay, lose-shift" tactic - The location is associated with prior success. So, only unsuccessful individuals move.

b) Competition between individuals in a population is reduced through niche specialisation. Put simply, different individuals go to different locations (ie: all specialists).

c) Individuals display varying degrees of site fidelity (ie: in a population some are specialists and some generalists).

Patrick and Weimerskirch (2017) investigated these different ideas with eleven years of biologging data (2004-2015) on black-browed albatrosses at Canon de Sourcils Noirs, Kerguelen Islands (sub-Antarctic French Overseas Territory in the Indian ocean). Overall, sixty-one adults were studied within a year, and seventeen between years.

The outcome measure of reproductive success was the number of chicks fledging. Foraging site fidelity was calculated from the movement of the birds (eg: decreased speed and increased turning).

Site fidelity was found to correlate with reproductive success, "with more specialised birds having higher reproductive success within years, with a tendency between years. Interestingly, it was females, who are often suggested to be less competitive than males because of their smaller size..., that appeared to benefit most from site fidelity within years. Together, these results suggest that although black-browed albatrosses are highly faithful in the habitat that they use, it is site fidelity that is associated with increased reproductive success" (Patrick and Weimerskirch 2017 p678).

The findings suggested that the birds were all specialists. In a previous study of gannets, Wakefield et al (2015) found "high site fidelity but little habitat fidelity across breeding seasons" (Patrick and Weimerskirch 2017 p675).

Patrick and Weimerskirch (2014) used data from the black-browed albatross on the Kerguelen islands to investigate foraging behaviour and personality.

Personality was scored for shy-boldness by the response to a novel object (a large pink volleyball on a long pole) - pecking at it (made contact), lunged at it (no contact), or vocalisation. Averages were calculated for the 154 individuals tested, and each bird was given a boldness score. The foraging behaviour of fifty-five individuals was measured by GPS data, and based on duration and length of trips, a foraging personality score was created.

A negative correlation was found between the two measures "with bolder birds making shorter trips away from the colony" (Patrick and Weimerskirch 2014 p5).

Boldness and foraging personality scores showed no correlation with reproductive success (scored as chick survived to fledging) overall. But when taking account of food availability in a year, bold females did better in good years, while shy females and males had greater reproductive success in poor years. So, for females, high boldness may be "more adaptive" - ie: "increased boldness may help individuals compete for food with the strength of this relationship being stronger in years of high quality, and perhaps high competition" (Patrick and Weimerskirch 2014 p6).

1.7. BIOLOGGING AND PHYSIOLOGGING

Biologging has been defined as the "investigation of phenomena in or around free-living organisms that are beyond the boundary of our visibility or experience" (Boyd et al 2004 quoted in Hawkes et al 2021a). The first symposium on biologging was held in 2003 (Hawkes et al 2021a).

Biologging has shown the remarkable feats of animals, including the 100 000 km migration by Arctic terns, or elephant seals diving to two kilometres deep (Hawkes et al 2021a).

"With an ever-increasing access to technologies capable of determining real-time physiological changes in free-living animals, a 'second age of biologging' has well and truly arrived for eco-physiologists [1]. This age will undoubtedly create new and exciting opportunities for measuring biological phenomena in free-living animals. Such information will not only provide important information about basic function and physiology, but will be critical to predict how major forces such as disease and climate change may impact the performance, health and welfare of both individuals and populations of free-living animals" (Hawkes et al 2021a p3).

The development of miniature electrical devices has allowed for "physiologging" - "the recording of physiological metrics (eg: metrics that describe causality, homeostasis and energy expenditure) onboard miniature electronic devices carried by animals both in captivity and at liberty in the wild" (Hawkes et al 2021b p1). Common metrics include heart rate, body temperature, movement, brain activity (eg: EEG), and compounds in the blood (eg: hormones, glucose). "Physiologging does not include analyses of physiological variables ex situ (eg: processing a blood sample in the field with a hand-held instrument, or bringing an animal to a measurement device not mounted on or in the animal)... [and] not considered to include metrics that describe the three-dimensional location or orientation of an animal (eg: GPS or satellite location, dive depth or flight height, magnetic direction etc)" (Hawkes et al 2021b p1). Coupled with observation. physiologging gives insights into physiological changes and actual behaviour.

"Arguably, the first and most fundamental physiologging metric is the recording of heart rate" (Hawkes et al 2021b p2). This was first reported in birds in the 1960s (eg: Eliassen 1962), and has produced findings including that flying birds can maintain a heart rate of 500 beats per minute for hours. Meanwhile, the diving whale has been recorded with a heart rate of two beats per minute (Hawkes et al 2021b). Recording brain activity is popular.

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[1] The "first age" has been the use of biosensors with humans (eg: measurement of blood glucose for diabetes) (Hawkes et al 2021a).

1.7.1. Reindeer Example

Organisms survive by balancing energy input (food) with energy expended (eg: exercise). Energy supply is not constant, so animals evolve adaptations to cope.

Mammals and birds maintain a high core body temperature, which is energy demanding, and even more so during winter months when the environmental temperature drops. But food is less available in the winter. The extreme adaptation is hibernation or torpor.

There is growing evidence that "many non-hibernating temperate animals also display seasonal adjustments in metabolic rate through reduced body temperature and activity levels" (Trondrud et al 2021 p2). Trondrud et al (2021) studied this among Svalbard reindeer (Rangifer tarandus platyrhynchus) using physiologging.

These animals live in the high Arctic where there is continuous darkness from mid-November to the end of January, and mean air temperature drops below 0°C. Plant growing occurs from June to August, and gestation runs from October to June (Trondrud et al 2021).

Nineteen adult females were captured and implanted with a physiologger in March-April 2018 for one year. The device recorded heart rate and body temperature. Heart rate varied greatly from the peak of 103 bpm in July to 40 bpm in December. The animals were half as active during the winter. The body temperature showed "peripheral heterothermy" (ie: cooler skin temperature than the core body temperature). This is "likely to be an important mechanism to reduce heat loss and save energy by minimising the temperature gradient between the body shell and the environment" (Trondrud et al 2021 p7).

The higher heart rate in the summer suggested "a substantial upregulation of the metabolic machinery in order to recover body reserves and ensure survival during the coming winter" (Trondrud et al 2021 p7).

"Overall, the strong seasonal pattern in heart rate contributes to the increasing evidence that seasonal animals upregulate energy expenditure in periods of high supply and downregulate it when food is scarce" (Trondrud et al 2021 p8). This is an evolutionary adaptation to life in the high Arctic.

1.7.2. Challenges to Field Research

"While laboratories are often presented as stripped-down 'placeless places' that produce knowledge which can be universally applied across contexts, fields promise greater realism at the expense of control. Of course, it is widely acknowledged that there is not a firm distinction between laboratories and fields, as exemplified by hybrid spaces such as 'semi-field stations' and mesocosms, and the incorporation of laboratory-like elements into the field and vice versa such as in 'natural experiments'" (Palmer and Greenhough 2021 p1).

Palmer and Greenhough (2021) considered the social, ethical, and regulatory challenges faced in studying animals in the field as compared to in the laboratory. This was based on interviews with thirty individuals and 24 informal conversations at sites classed as "Places Other Licensed Establishments" (POLEs) under the Animal (Scientific Procedures) Act 1986 in the UK. POLEs include wildlife field sites, farms, fisheries, zoos, and veterinary clinics.

The researchers focused on four key challenges:

i) The relationship with the public and stakeholders that ate relevant to research success - For instance, "members of the public may come across research activities incidentally, such as while out for a walk. Though these encounters are not necessarily adversarial, they may be disruptive. For example, Annika, whose research involves the use of biologging technologies in fish, noted that she has had curious members of the public come by to ask what her team is doing. Sometimes this happens when the team has been undertaking invasive procedures. Annika reflected that while she always tries to engage with people and explain the research, she would never do this at the expense of the fish: she would always ask people to wait if speaking with them would compromise fish welfare" (Palmer and Greenhough 2021 p2).

This could encourage researchers to "hide" their activities. "Researchers working with animals sometimes perceive a personal risk associated with transparency, the concern being that the public may misunderstand their work or animal rights activists will threaten them. This may in some cases be less of a risk for wildlife researchers given that public perceptions of such work are often, as researcher Genevieve put it, 'Disneyesque' and shaped by positive portrayals of such work in film and other media... But the public may conflate wildlife research with practices they object to. For example, deliberate sabotage of traps during the hunting season can occur when anti-hunting activists fail to distinguish between traps set for research purposes and those set by hunters" (Palmer and Greenhough 2021 p3).

Conflict was a concern, either direct disagreement with stakeholders, or collaborating with whom the researchers disagree. For example, "Greg" studies fish caught by anglers, but he said: "I want [to work with] people that show high levels of empathy and I don't equate fishing with empathy" (p3). While "Gavin" noted that fishing management groups "may be reluctant to permit research that involves killing fish, or invasive procedures that could harm the welfare or survival of the fish, since they perceive such work as a threat to their stocks" (Palmer and Greenhough 2021 p3).

On the other hand, "Annika" "draws on anglers' expertise, not only to make them feel included but also because it benefits her research, since anglers often hold detailed knowledge of where fish are located in their local area" (Palmer and Greenhough 2021 p3).

ii) Issues not present in the laboratory - Uncontrollability was the over-riding issue in the field.

In terms of equipment, "Hugh" talked of being limited to "what's in the van" (p4), while stories of poor weather were common.

Referring to traps, "Genevieve" said: "you don't know what you're going to catch" (p4). Thus, "bycatch may be unavoidable and may result in harm to the bycaught animal, if for example animals are injured as a result of traps being designed for a different species. Non-target species may even need to be killed" (Palmer and Greenhough 2021 p4). The A(SP)A asserts that "animals taken from the wild found to be 'injured or in poor health' should not be 'subjected to a regulated procedure unless and until it has been examined by a veterinary surgeon or other competent person; and, unless the Secretary of State has agreed otherwise, action has been taken to minimise the suffering of the animal'. What this means in practice is that researchers may release captured animals that are in poor condition before undertaking research, to avoid non-compliance with research animal welfare regulation" (Palmer and Greenhough 2021 p4). Many interviewees complained that the A(SP)A was "not written with field research in mind" (Palmer and Greenhough 2021 p5).

There is also a wider impact on the ecosystem, even if the researcher's behaviour is positive - eg: "Graham" said: "I confess I've found lizards with ticks on them and I've pulled them off. But that's wearing my compassionate hat; if I'm wearing my hard-headed ecologist hat I'd say let them go" (p5).

iii) Legal complexities of the regulations - "Field research is often governed by a broader range of laws and regulations than laboratory research. Thus, wildlife researchers in the USA have expressed a feeling of 'running the permit maze' [Paul and Sikes 2013]" (Palmer and Greenhough 2021 p5). In the UK, along with the A(SP)A, researchers may have to deal with requirements of the Wildlife and Countryside Act (eg: regulation of killing and possession of wildlife), the Animal Welfare Act (eg: prohibits animal cruelty), and regulations on Invasive Alien Species (eg: requirement to kill caught grey squirrels) (Palmer and Greenhough 2021).

"Gareth", for example, argued that the A(SP)A should be extended to cover wildlife "involved" in science.

iv) Relationships with regulators - These include Home Office Inspectors (HOIs) (under the A(SP)A), and veterinary surgeons. "Gretchen" described a disagreement with vets over an unwell captured animal: "I made very clear under certain circumstances they needed to consider euthanasia. As soon as I mentioned euthanasia, everybody shut down. And I find the concept of, that you'd rather release an animal that is potentially suffering acceptable in comparison to kill it and have no suffering, I find-, it's a completely different approach" (p7).

While "Evan", talking about HOIs, found it "frustrating when inspectors change because you build up a relationship, but you also I think build up knowledge with your inspector. They learn to know what you're doing with the kind of rather strange animals that we sometimes work with, and then you're back to square one with a new one" (p7).

Palmer and Greenhough (2021) ended that "invasive research with free-ranging animals involves a range of different social, ethical and regulatory challenges compared with laboratory research. While not all of these challenges are resolvable, our qualitative research suggests that flexibility — in policy, personal relationships and animal care practices — and mutual respect between researchers, stakeholders and regulators are important aspirations, which when achieved can help ensure that research with free-ranging animals supports positive outcomes for ecosystems and animals used in research" (p8).

1.7.3. Brain

"Evolution can modify brain structures through diverse means, such as by increasing or reducing the production or survival of cells of a given type, altering the molecular and cellular properties of shared cell types, reallocating or redeploying cell types in new locations, losing a cell type or inventing a new cell type" (Krienen et al 2020 p262).

Primates and rodents had a common ancestor around 90 million years ago, but today they "exhibit profound differences in behaviour and cognitive capacity" (Krienen et al 2020 p262). Analysing RNA in the same brain regions in humans, macaques, marmosets, mice, and ferrets, Krienen et al (2020) explained the difference in terms of inter-neurons. Those particularly involved in releasing the inhibiting neurotransmitter GABA. There were differences in both the type and quantity of certain cells in particular areas of the brain (eg: striatum). Not only are there differences in the neocortex in primates and rodents, but also in other "common" areas of the brain.

Mouse 1

"The behaviour of an animal is determined by metabolic, emotional and social factors. Depending on its state, an animal will focus on avoiding threats, foraging for food or on social interactions, and will display the appropriate behavioural repertoire. Moreover, survival and reproduction depend on the ability of an animal to adapt to changes in the environment by prioritising the appropriate state" (Fustinana et al 2021 p267). How do such behaviours associated with particular brain areas and systems?

Working with mice, Fustinana et al (2021) explored the role of the amygdala, and specifically the basolateral nucleus of the amygdala (BLA). Two stranger mice were allowed to interact freely for 8-9 minutes, and from video-recordings, five distinct social behaviours were observed: approach, initiated interactions, reciprocal interactions, avoidance, and aggression. Other behaviours included freezing, exploring, and self-grooming.

The mice had deep-brain implants which recorded BLA neuronal activity. Two different patterns of activity were measured for social exploration (eg: initial interactions), and spatial exploration (of the environment).

Fustinana et al (2021) ended that the "findings demonstrate that, in mice, the BLA functions as a low-dimensional but flexible and hierarchical classifier that encodes the animal's state, as defined by its engagement in exploratory behaviour as a function of the external world. The amygdala may - by means of its widespread connections to many cortical sensory and associational, as well as sub-cortical and neuromodulatory, targets - broadcast state signals across larger brain systems, and thus orchestrate and prioritise brain activity for context-dependent perception, action selection and learning" (p270).

Mouse 2

"The ability to recognise information that is incongruous with previous experience is critical for survival" (Chen et al 2020 p270). Chen et al (2020) identified an area of the hypothalamus (the supra-mammillary nucleus) in mice that responded specifically to novel information. But also to the distinction between contextual and social novelty. Contextual novelty would be placing the mouse in a new environment, while social novelty was tested by placing the mouse in the familiar environment but with a new partner.

The brain activity was studied with single cell recordings from electrodes placed in the brain, and with a transgenic mouse line (ie: a genetically engineered breed that had specifically altered biochemistry).

Mouse 3

Survival requires the ability to form memories for fearful events when stimuli are threatening, but to extinguish (forget) such memories when the threats have gone. Hagihara et al (2021) found that specialist cells in an area of the mouse amygdala (intercalated neurons; ITCs) maintain the balance between remembering and forgetting fearful events.

Mice were classically conditioned to associate a sound with a foot shock while cells in the amygdala were recorded, and then the association was broken to allow the extinction of the memories.

Extrapolating to humans, "aberrant ITC function could contribute to susceptibility to various psychiatric conditions" (Hagihara et al 2021 p407).

Mouse 4

The hippocampus includes specialist cells, like "place cells", which increase their firing rate as the individual moves through specific locations in a given environment (O'Keefe and Dostrovsky 1971). Specialist hippocampus neurons also respond to time, audio frequency, odours, and taste, and it is believed that "the hippocampus constructs task-dependent cognitive maps, in which hippocampal neurons not only encode spatial position, but whichever environmental variable is relevant to the task at hand" (Nieh et al 2021 p80).

Nieh et al (2021) investigated this with transgenic mice and virtual reality. The mice learned an immersive virtual-reality T-maze, which presented visual cues randomly on the left or right walls. At the end of the maze (ie: the junction), turning to the side with more cues led to a liquid reward, while the other direction had no reward. Cells in the hippocampus were recorded for electrical activity.

The researchers found that the specialist cells responded to physical (ie: place in the maze) and abstract information (ie: amount of cues).

Monkey

Attention to one stimulus over another, and working memory (holding certain items of information available to use) involve both the same areas of the brain (lateral prefrontal cortex as a "domain-general controller"), and different areas in the parietal cortex and visual cortex, according to work with rhesus monkeys (Panichello and Buschman 2021).

Two monkeys were trained to switch between two tasks that involved working memory and attention. The former was tested by holding two items in the memory for the short time (eg: the colour of a shape) before choosing one ("retro" task).

In the "pro" task, the monkeys had to attend to a particular shape and ignore distractors. The shapes and colours were presented on a computer screen very quickly. Meanwhile, the neural activity of the monkeys was recorded in different areas of the brain.

Barn Owl

Studies of the hippocampus area of the rat's brain have found neural representations of space (eg: "place cells") that are the basis of spatial memory (eg: O'Keefe and Dostrovsky 1971).

Other mammalian species (eg: bats), and a few birds have been studied. For example, "relatively few" place cells were found in the avian hippocampal formation (Hp) of zebra finches, but "numerous and robust" (Agarwal et al 2021) numbers in the tufted titmouse (Payne et al 2021). Agarwal et al (2021) tried to explain the diversity by suggesting that place cells would be found in birds that cached food items and needed to memorise the locations of caches (like the tufted titmouse), in migrating species, and central-place foraging species (that always return to the same place after foraging).

Barn owls (Tyto alba) are an example of the latter group, who navigate in extremely low light levels back to preferred perching-branches. Agarwal et al (2021) implanted micro-electrodes in the brains of six captive-bred barn owls to record single neurons as they flew between two perches in a room.

Around 300 different cells were recorded. Cells were found in the Hp that responded to the owl's location during flight ("place tuning" cells; 29% of recordings), the flight-direction (from east to west or vice-versa; 28% of recordings), and the perching position between flights (east or west perch; 38% of recordings).

It can be speculated that these cells represent "mental maps" of the environment.

Bats

Mapping 3D space in the brain is a similar area of interest, and Ginosar et al (2021) studied four freely flying Egyptian bats. Neurons in the medial entorhinal cortex (known as "grid cells") were measured through wirelessly recorded single neuron electrodes.

1.8. APPENDIX 1A - RAFTING

In terms of the arrival of species on an island, say, the "rafting hypothesis" is one of the main (though controversial) ideas. Species travel on "floating islands" of vegetation from the mainland to islands. Alternatively, plate tectonics in past has meant varying sea levels and temporary "land bridges" (Lawton 2021) [2].

[2] Plate tectonics is used to explain "continental drift" (ie: landmasses have not always been in their present position on the Earth) (vicariance - earth moves) (Masters et al 2021).

The rafting hypothesis has also been called "sweepstake colonisation or dispersal" (Ali and Huber 2010). "Very occasionally, animals living in or near rivers get stranded on rafts of soil and vegetation ripped from the riverbank by flash floods. The rafts can be huge, and stocked with enough food and water for even quite large animals to survive for weeks. Some wash out to sea and get carried away on currents. The vast majority drift aimlessly and break up, and their passengers end up starving, dying of thirst or exposure, drowning or getting eaten by sharks. But very occasionally, a raft will catch a favourable current and make landfall on some distant shore. If enough members of a single species make it - especially if their number includes a pregnant female - then they may establish a new colony. Each of these possibilities is remote, but over geological time they stack up to become quite probable" (Lawton 2021 p51).

Other possibilities include "stepping-stone colonisation" (or "island hopping" (Whittaker and Fernandez-Palacois 2007) (where animals move along an island chain, but many of the intermediate islands subsequently disappear with tectonics), or small animals travelled deliberately or accidental with pre-historic humans (Lawton 2021).

Focusing specifically on Madagascar, Masters et al (2021), from a critical position, outlined assumptions of the "rafting model", including:

- Natural rafts can remain intact for long periods and long distances across the ocean. But how do "rafts" actually form and survive?

- Mammals coped the journey with hunger and thirst by entering a state of hibernation. But "a natural raft of vegetation would hardly provide the quiet, dry conditions required for sustained hibernation" (Masters et al 2021 p496).

- Animals of the rafts were pregnant females, and/or groups of individuals that could reproduce.

In the case of Madagascar still, three short-lived land bridges have been proposed - 66-60 million years ago (MYA), 36-30 MYA (shallow marine corridors), and 12-5 MYA ("Stepping stones"). Masters et al (2021) accepted a combination of these (vicariance), "island hopping", and "limited rafting" (p492).

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2. SURVIVAL

2.1. SHARKS AND FOOD CHOICE

The white shark (Carcharodon carcharias), at around six metres in length, is "an interesting species in the study of shark behaviour thanks to the relative ease with which it can be observed from the surface, especially near pinniped colonies on rocky islands where sharks congregate" (Micarelli et al 2021 p1).

White sharks hunt by smell mainly. They have "the largest olfactory bulb among sharks, and thanks to their perceptions, they are able to trace wounded prey, whale carcasses, seal colonies or sea lions even at great distances" (Micarelli et al 2021 p1). But vision is also important. Based on comparing reactions to different floating shapes, Strong (1996) proposed that sharks initially located prey via smell, but vision was involved in the actual approach.

Martin et al (2005) performed a study of the Seal Island white shark population in South Africa. It was observed that the Cape fur seal prey was selected for age based on size and direction of movement, and hunting occurred at times and in locations that maximised the probability of predator success. This behaviour suggested that hunting is "not a simple stimulus response reflex, but rather a complex tactical situation with plastic responses" (Micarelli et al 2021 p2).

Micarelli et al (2021) investigated this behaviour with reference to the use of vision along the South African coasts in Gansbaai (Dyer Island Nature Reserve). Observations totalling 247 hours were made between 2008 and 2013. Seal-shaped decoys and floating baits of tuna pieces were passive target preys used. In total, 240 interactions of the sharks with the passive target preys were recorded.

The sharks showed a significant preference for the seal-shaped decoy (ie: more interactions) than the floating baits. This suggested "a real food choice" by the sharks. Micarelli et al (2021) explained: "White sharks must be selective when there is an abundance of food; therefore, according to the Optimal Foraging Theory, they prefer the most caloric sources over low-energy ones. In response to the question 'Do white sharks tend to exhibit a real food choice or indiscriminate attacks on the two passive prey (bait and seal shaped decoy)?', it is possible to conclude that there was a real food choice rather than an indiscriminate attack, and that this strategy was adopted by the majority of specimens, helped by the ability to visualise the energetically richer preys, also with respect to the odorous source represented by the tuna bait" (p6). This confirmed previous research with other shark populations.

For example, Anderson et al (1996) had used decoys of different shapes with the Californian Farallon Islands sharks between 1989 and 1992. "In that study, it was observed that vision played a major role in the approach and predation activities: the sharks were attracted, not by smell, electric fields or vibrations coming from the baits, but only by the presence of odourless prey on the surface" (Micarelli et al 2021 p6).

2.2. PANDA AND CAMOUFLAGE

The black-and-white colouration of the giant panda (Ailuropoda melanoleuca) makes them an iconic (conspicuous) mammal, but Nokelainen et al (2021) argued for "the counter-intuitive hypothesis that their colouration provides camouflage in their natural environment. The black fur blends into dark shades and tree trunks, whereas white fur matches foliage and snow when present, and intermediate pelage tones match rocks and ground. At longer viewing distances giant pandas show high edge disruption that breaks up their outline, and up close they rely more on background matching" (p1). The dual function colouration is because pandas live in very different visual backgrounds in winter and summer.

Nokelainen et al (2021) analysed fifteen photographs of giant pandas in their natural habitats in south-central China with computer software. This allowed the pandas to be seen as felid (cat) and canine (dog) visual systems would perceive them. Also the researchers debunked "the common misconception that the giant panda would be conspicuous to human vision in their natural habitat" (Nokelainen et al 2021 p5). At short distances (as in captive settings), the pandas were conspicuous, but not so at longer distances.

2.3. BEE DECLINE

Insect pollinators face environmental pressures including land-use change and intensive agriculture, climate change, and invasive alien species and pathogens. The combination of these factors is the greatest concern (Vanbergen 2021).

Intensive agriculture creates problems (stressors) for bees in terms of agro-chemicals (eg: pesticides), food shortages from lack of wild flowers, and exposure to pathogens. Siviter et al (2021) performed a quantitative meta-analysis of these factors, finding ninety relevant studies.

Three possible relationships of the stressors were investigated:

i) Synergy - the combined effect is greater than the sum of the individual effects.

ii) Additive - the combined effect is equal to the sum of the individual effects.

iii) Antagonism - one factor lessens the effect of the others (ie: the combined effect is less than the sum of the individual effects).

It was found that the factors influenced bee mortality synergistically, with agro-chemicals driving the overall effect, particularly the interaction of pesticides. Pathogens and food shortages together had an additive effect on bee mortality. For fitness, behaviour, parasitic load, and immune response, however, the relationship of the stressors were either additive or antagonistic.

Certain variables also influenced the relationships, including the type of pathogen, the bee genus, and managed or wild populations of bees.

Siviter et al (2021) warned: "Environmental risk assessment schemes that assume additive effects of the risk of agro-chemical exposure may under-estimate the interactive effect of anthropogenic stressors on bee mortality and will fail to protect the pollinators that provide a key ecosystem service that underpins sustainable agriculture" (p389).

2.4. BATS THAT BUZZ

Ancillotto et al (2022) described an example of acoustic mimicry where "the distress calls the greater mouse-eared bat (Myotis myotis) broadcasts when handled imitate sounds of stinging bees or wasps to discourage the bat's avian predators" (pR408).

The researchers tested this behaviour in a playback experiment with two species of captive owl that predate on these bats. Eight barn owls and eight tawny owls were played the buzz made by a bat, a honeybee, a honest, or non-buzzing bat sounds as a control. The owls' behaviour were scored as "alert", "attack", "escape", and "inspection".

The owls responded to the bat, bee, and hornet buzz sounds in the same way, by moving away from the playback speaker, but approached when hearing the control sound. The escape behaviour was stronger in experienced than naive owls.

2.5. SEA ANEMONE

Cnidarians (eg: sea anemones) have the ability to continuously build new parts throughout their lives (known as "life-long organogenesis") (Ikmi et al 2020). While some animals can regenerate limbs, say, after injury, "life-long organogenesis is subject to environmental modulation. This strategy allows cnidarians, like plants, to continuously adjust their developmental patterns to unpredictable fluctuations of food supply" (Ikmi et al 2020 p2).

Ikmi et al (2020) studied over one thousand growing sea anemones (Nematostella vectensis) in the laboratory, and found that tentacle development was linked to food available. When food was lacking, the polyps grew four tentacles only, but new tentacles were added (up to sixteen) when food was available.

This was an example of how different organisms have "evolved strategies to both sense and adapt to changes in their environment" (Ikmi et al 2020 p10).

2.6. HUMAN-WILDLIFE INTERACTIONS

The incursion of humans into the wild has led to animals encroaching on our habitats. For example, in North Bengal in India, the teak and sandalwood forests were removed for tea plantations, and the elephants that lived there now wander into villages and eat crops. Many people die each year from elephant attacks (Glausiusz 2021).

While in North America bears have moved from declining forests into urban areas to feed on waste. In Aspen, Colorado, for instance, "bear-resistant dumpsters" with locks have been introduced for restaurants (Glausiusz 2021).

Another issue is the introduction of alien species into an ecosystem by humans, like stoats to New Zealand in the nineteenth century. Originally introduced to control rabbits, the stoats also eat birds' eggs and chicks (Glausiusz 2021).

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3. COGNITION

3.1. BASIC MATHS AND FISH

"Numerical discrimination" is the ability to know which group has more when faced with choices. in fishes, for example, this ability is limited to 3 vs 4 or 4 vs 5 (eg: guppies; Lucon-Xiccato et al 2017) (Schluessel et al 2022).

There is some evidence that this discrimination includes the ability to add or subtract one (eg: honeybees; Howard et al 2020). Schluessel et al (2022) tested eight cichlids (Pseudotropheus zebra) and eight freshwater stingrays (Potamotrygon motoro). The fishes were taught to swim through a doorway into a "decision area", and one stimulus (eg: colour) or two was associated with food. Using a "delayed matching to sample" procedure, one colour is shown before the doorway opens, and then the fish swims through and is faced with a decision of direction to swim. Once this basic behaviour was learned, the stimuli were varied in colour and symbols.

Next one colour was associated with addition (blue), and another with subtraction (yellow). So, for example, 2 blue symbols are presented before the fish enters the doorway, and then they are faced with a choice of three symbols (correct) or one symbol (incorrect). After the training, three transfer tests were performed (table 3.1).

Both fish species chose the correct answer significantly more often than chance (50%) (table 3.2).

Schluessel et al (2022) summed up: "Cichlids as well as stingrays successfully learned to complete a delayed matching to sample task in addition to performing a simple arithmetic task, depending on the colour of the test stimulus first presented to them. Transfer tests showed that learning was independent of straightforward symbol memorisation" (p5). There were individual differences between the fish, and addition was learned better than subtraction.

The researchers made the observation that the "good results obtained in this study are somewhat surprising, when considering that the available ecological

Test		Blue (= +1)	Yellow (= -1)
A	Stimulus	3	3
	Correct	4	2
	Incorrect	2	4
B	Stimulus	3	3
	Correct	4	2
	Incorrect	5	1
C	Stimulus	3	3
	Correct	4	2
	Incorrect	2	4

Table 3.1 - Three transfer tests performed by Schluessel et al (2022).

Test	Stimulus	Cichlids	Stingrays
A	Blue (+)	117/141 (83%)	58/60 (97%)
	Yellow (-)	96/141 (68)	54/60 (90)
B	Blue (+)	84/120 (70)	54/60 (90)
	Yellow (-)	79/120 (66)	52/60 (87)
C	Blue (+)	95/120 (79)	57/60 (95)
	Yellow (-)	89/120 (74)	55/60 (92)

Table 3.2 - Number of correct choices (%) on the transfer tests.

information on the species, as well as results of previous cognition studies indicate, that the two species do not have an obvious ecological or behavioural need for excelling in numerical tasks, let alone in arithmetic processes. Both are opportunistic feeders not hunters, that show no mating- or reproduction related behaviours relying on numbers (eg: counting stripes or eggs). Neither species nests nor is there any information available about preferences for particular sized social groups. Nonetheless, there may still be important yet so far unknown behaviours in both species relying on quantitative skills, including numerical competency" (Schluessel et al 2022 p8).

Six of the eight cichlids had participated in cognition experiments previously, whereas the stingrays were all experimentally naive.

3.2. HORSE AND SELF-RECOGNITION

The "mirror self-recognition" (MSR) test (Gallup 1968) was introduced as a measure of "awareness of the self". A mark is made on the body of that animal that is only visible in the mirror. If they are self-aware, noticing the mark in the mirror, they will search on their body.

With appropriate variations, the MSR test has been tried with a number of different animals, including non-human primates, bottlenose dolphins, magpies, and elephants, with varying degrees of success (Baragli et al 2021).

A number of criticisms of the MSR test studies have been made, including (Baragli et al 2021):

- Very small samples.
- Animals not mirror naive.
- Marks that are irritating (ie: can be felt).
- Non-blinded scorers.
- Lack of standardised procedures for comparison of studies.
- Testing animals together or in the presence of others.

Baragli et al (2017) performed a pilot study of the MSR test with the domestic horse (Equus caballus) (n = 4). Baragli et al (2021) developed this work with fourteen horses.

The horses were based at a riding school in Italy, and were tested in a "novel pen" individually. The experiment had four phases:

1 - Covered Mirror (CM) (Day 1) - The horse was placed in the arena for familiarisation, and the mirror was positioned (but covered).

2 - Open Mirror (OM) (Day 2) - The mirror was uncovered. No mark on the horse.

3 - Sham (S) (Day 3) - Transparent marks were placed on the horse's cheeks to check for tactile or olfactory sensations.

4 - Mark (M) (Day 4) - A cross-shaped marked was painted on both cheeks before entry into the arena (in yellow or blue).

Each session lasted thirty minutes and the horse was alone in the arena. It was video recorded and scored by an expert in horse behaviour unaware of the study aims.

One horse showed fear at the presence of the mirror, so they were removed from the study, as well as two others that showed no response to the mirror.

"Face scratching" (Face-SCR) was used as the main measure of MSR. This involved the horse rubbing its cheek with forelimbs or on a surface (the ground, wooden poles, or the mirror). Nine of eleven horses showed this behaviour in the M condition compared to five in the S condition. Also the horses "spent a longer time in scratching their face when marked with the coloured mark compared to the sham mark (S vs M conditions). This finding indicates that horses did not see the sham mark and that it was not the tactile sensation that induced the animal to touch its own face. The increased level of Face-SCR during the M condition suggests that by using the reflective surface the animals were able to visually perceive the coloured spot on their face" (Baragli et al 2021 p1106).

The researchers also saw differences in behaviour between the OM and CM conditions. In the OM condition, the horses attended to the mirror and explored it, including looking behind. They showed "contingency behaviours" - "highly repetitive non-stereotyped or unusual movements only when animals are in front of the reflective surface, probably to verify if the movements of the image in the mirror match their own movements" (Baragli et al 2021 p1105). One of these behaviours was "peek-a-boo" - movement out and back in sight of the mirror. Contingency behaviours have been reported in studies with magpies, elephants, jackdaws and crows (Baragli et al 2021).

The researchers included a number of controls for potential confounders, including:

The colour of the mark was noticeable, and within the horse's colour perception range.

- The grooming of the horse before applying the marks in the S and M conditions to avoid cueing the horse about the marks on the cheeks.

- A measure of "body scratching" to compare to Face-SCR to check that the latter was not a chance occurrence in the M condition.

"The behavioural motivation of removing something from one's own body, and to respond to the coloured mark, is considered a hotspot in the discussion about the validity of the mark test for demonstrating MSR" (Baragli et al 2021 p1106). A larger sample allows for individual differences in motivation. "Such individual motivation can also be affected by a series of species-specific features (eg: anatomical difference in properly reaching the marked area, visual perception of specific colours, visual acuity, predominant sensory modality different from vision), including personality and cognitive style. Therefore, the sensory and cognitive systems, as well as the motivation to behaviourally respond to the mark, are substantial preconditions to keep in mind when we decide to test animals' self-recognition abilities" (Baragli et al 2021 p1106).

Baragli et al (2021) ended that "despite the strong inter-individual variability, our results suggest the presence of MSR in horses" (p1106).

3.3. JAYS AND MAGIC TRICKS

"The success of most magic effects is dependent on their ability to take advantage of the perceptual and attentional shortcomings of the spectator" (Garcia-Pelegrin et al 2021 p1). This observation has been the basis of the "science of magic" (Kuhn et al 2008) or "NeuroMagic" (Macknik et al 2008) - ie: the use of magic tricks to understand cognition.

This also includes studying non-humans, like the Eurasian jay (Garrulus glandarius). Garcia-Pelegrin et al (2021) performed three different experiments with six birds and eighty humans.

1. "Palm transfer" trick - An small object is held in the right hand, say, and as the hands are joined together it appears to be transferred to the left hand. However, the object is covertly held in the fingers of the right hand, so no transfer occurs. The object is in the right hand (correct answer), but appears to be in the left (incorrect answer).

The jays chose the correct answer significantly more often, but the opposite was the case for the human participants (table 3.3). Humans were slightly better in giving the correct answer with a slow version of the palm transfer. But in a control condition where the object is changed to the left hand (ie: no magic trick), humans are always right, while jays randomly chose a hand.

A possible explanation for the findings was that the poor performance of the jays on the control version suggested that the birds tended to choose the hand that had held the object before the transfer and this is why they chose the correct answer more often in the palm transfer version.

2. "French drop" trick - This is where an individual holds a small object in the right hand, say, and appears to grab it with the left. But as the fingers obscure the object, it is dropped back into the right hand. The object being in the right hand was the correct answer, but it appears in the left (incorrect answer).

Jays chose the correct hand significantly more often, while humans did not.

The possible explanation is that humans are susceptible to this trick because of the "inherent expectations associated with hand mechanics" (Garcia-Pelegrin et al 2021 p5), which the jays did not have. Garcia-Pelegrin et al (2021) explained that "this is perhaps because jays lack the appendages themselves, thus also lacking the attached inherent expectations regarding their mechanics and manoeuvres. Interestingly, our jays were raised in captivity, hand-reared, and have participated in a plethora of experiments, some of them involving intricate hand manipulations by the experimenter. Thus, it is possible that, at least in Eurasian jays, such intricate expectations regarding hand mechanics cannot be gained through observational experience" (p5).

3. "Fast pass" trick - A small object in the right hand, say, is tossed to the left too quickly to be noticed before closing the right hand. The right hand then opens and is empty. The object in the left hand is the correct answer, while the right hand is the incorrect answer.

Both humans and jays chose the incorrect answer significantly more often.

The possible explanation for this finding is that both humans and jays could not perceive the fast action, but the underlying visual mechanisms are different, argued the researchers.

Garcia-Pelegrin et al (2021) summed up the experiments thus: "both Eurasian jays and humans were misled by the magic effects that involved fast movement. By contrast, the magic effects that capitalised on the spectator's expectations regarding hand manoeuvres did not deceive the jay subjects but did deceive the human participants. Our results suggest that jays might have different expectations from humans when observing these transfer techniques" (p4).

	JAYS	HUMANS
Palm transfer	60	28
French drop	70	25
Fast pass	23	13

(My calculations from data in figures 2 and 3 Garcia-Pelegrin et al 2021)

Table 3.3 - Percentage of correct answers to three different magic tricks.

3.4. REFERENCES

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4. FROGS

4.1. PAIR BONDING

Mating systems vary between species, and usually depend upon the parental investment in the offspring needed. Where offspring require much and/or lengthy parental feeding, say, monogamy is common, while "promiscuous mating" (polygamy by both sexes) usually goes with little parental investment needed.

Frogs as a generalisation tend not to pair bond, but de Sa et al (2020) described an exception in the frog Thoropa taophora [3], that lives inbetween rocks (saxicolous). Found in the Brazilian Atlantic rainforest, males defend freshwater seeps lowing on the surfaces of outcrops and rocky shores as breeding territories for females to deposit eggs, and then defend the tadpoles against potential predators. It was found that a male would mate with two genetically unrelated females (a dominant and a secondary) "recurrently and exclusively" during the ten-month breeding season. This observation represented "the first case of single-male polygyny with reproductive fidelity in amphibians..." (de Sa et al 2020 p1) (or "harem polygyny").

The researchers observed the frogs in Sao Paulo State for a total of 138 hours over fifty three nights, and video recorded sixty hours. The tadpoles were genotyped to establish parentage.

The males defended their territories with aggressive calls, body-raising postures, and physical attacks on intruders.

The genotype of tadpoles in seven breeding seeps found the dominant female was the parent of 86% on average of them, and the secondary female 14%. de Sa et al (202) pointed out: "Overall, developmental stages of tadpoles assigned to the two females overlap entirely, indicating that the dominant and secondary females mate multiply with the same male several times during the breeding season. We define this multiple mating by mated pairs as reproductive fidelity. We found no evidence of females or males mating in more than one breeding seep,

[3] Details of species at https://amphibiaweb.org/species/7305.

even when neighbouring seeps were only a few meters apart" (p2).

The researchers emphasised the scarcity of breeding sites as key to the mating system, as well as the ability of males to monopolise/defend them. "Males reach higher reproductive success not only by monopolising scarce breeding resources but also by maintaining females and aggressively excluding all other conspecific intruder males from their territories. The fitness benefits of breeding site monopoly must be extremely high, explaining male investment in intense and, likely costly, aggressive behaviours. High male intra-sexual aggression can also select for sexual dimorphism in weaponry that females lack. In T. taophora, this is reflected in the enlarged male forearms and keratinised thumb spines..." (de Sa et al 2020 p2).

The males also have to defend one female's set of eggs from cannibalism by the other female. For females, the benefits of "sharing" a male with a high-quality breeding site compensates for the risk of cannibalism. "When critical resources are unevenly distributed, a female mating with an already paired male at a superior-quality breeding site will most likely have equal or higher reproductive success than a female mating with an unpaired male at a poorer-quality site, thus promoting polygyny" (de Sa et al 2020 p2).

4.2. CALL FILTERING

Many frogs calling together causes problems for the listener, including poorer localisation of an individual, and reduced discrimination and recognition of call. Large choruses of males may comprise hundreds of individuals, and from multiple species.

How do females distinguish the individual calls of their species in order to choose a mate? Lee et al (2021) studied 25 females of the American green treefrog (Hyla cinerea) (figure 4.1).

"Among extant terrestrial vertebrates, frogs and other amphibians are unique in having a lung-to-ear sound transmission pathway. The tympanic middle ears of frogs are internally coupled through the mouth cavity via wide and open Eustachian tubes. Sound also reaches the internal surface of each tympanum through the body wall and air-filled lungs via the glottis, mouth, and Eustachian tubes. There is a potentially strong coupling between the frog’s air-filled tympanic middle ears and its lungs, which remain inflated for relatively long

(Source: Alan Schmierer; in public domain)

Figure 4.1 - American green treefrog.

periods punctuated by brief episodes of ventilation, and which remain continuously pressurized above atmospheric pressure during the respiratory cycle" (Lee et al 2021 p1490).

What this means is females when their lungs are naturally inflated can hear only the narrow "biological important range of frequencies" (1400 to 2200 Hz) (ie: the frequency the males of their species are calling at). Because this species breeds in multi-species environments, they are under intense selection pressure to solve the background noise problem. Lee et al (2021) admitted: "To our knowledge, lung-to-ear sound transmission in frogs represents a novel mechanism by which nature has attempted to solve the general biological problem of hearing and communicating in noise" (p1495).

These findings showed "the extraordinary power of evolution to co-opt pre-existing adaptations for new functions. Resonances of air-filled structures such as lungs or swim bladders improve sound detection in aquatic vertebrates, and sound detection via the lungs also played important roles in hearing during the evolutionary transition of vertebrates from water to land. Thus, it is likely that the lungs of the earliest terrestrial vertebrates functioned as accessory sound receiving structures prior to the subsequent evolution of tympanic middle ears and vocal communication" (Lee et al 2021 p1495).

However, "the precise physical mechanism by which a sound-induced lung resonance attenuates sound-induced tympanum vibrations remains unknown and requires further investigation" (p1496) ended Lee et al (2021).

4.3. SYNCHRONY

Greenfield et al (2021) began: "Repetitive expression of a physical action at regular cycles is a fundamental property of a wide range of behaviour. Music, dance and language in humans and movement and communication signalling in non-human animals often include prominent expressions of such repetition, a feature generally termed rhythmicity. These expressions occur in solitary individuals, but within aggregations, the rhythms are normally sustained longer and more steadily, and they can be transformed into collective events exhibiting coordinated features that are not otherwise observed" (p1).

An example of collective rhymicity is synchronisation where multiple individuals have aligned ultradian rhythms (ie: short-term cycles). For example, in a Japanese treefrog (Buergeria japonica), males call in synchronous choruses (Legett et al 2021). "A group of males who synchronise their calls do transmit a more intense collective signal than a group who time their signals randomly, and overall they will attract more females by broadcasting over a greater radius" (Greenfield et al 2021 p4).

4.4. REFERENCES

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5. PETS

5.1. CATS

One study in the Netherlands found that pet cats killed twice as many animals in their local areas as feral cats (Irwin 2020). Changing the behaviour of cat owners may be a way to reduce the impact of domestic cats on wildlife (eg: keeping the cat in the house at night).

Changing the behaviour of a population in relation to the environment, say, can be achieved with "behaviour prioritisation". This is "founded on the principle of engaging with the target audience before, not after, mitigating actions are decided. Early engagement with the target audience helps to define the full spectrum of possible mitigation actions from the myriad possible. It also quantifies which actions the target audience do not currently perform but are, nonetheless, able and most likely to adopt and implement" (Linklater et al 2019 p2).

Linklater et al (2019) applied this idea to the problem of domestic cats as predators of local wildlife. "The impact of pet cats might be small or idiosyncratic in space, time, and among prey species. Nonetheless, it is certain that they kill wildlife that conflicts with growing efforts to improve the biodiversity value of anthropogenic landscapes (ie: reconciliation ecology) or ecological restoration projects around and within them" (Linklater et al 2019 p2).

There are many actions that cat owners could take to control their pets, and the researchers chose nine for their survey (eg: keeping the cat indoors all the time; registering the cat with the local council; de-sexing). A survey was completed by 159 cat owners at ten veterinary clinics in three New Zealand cities, and 173 veterinarians in late 2014. Each behaviour was rated for importance (eg: "conservation impact"), and how likely individuals would be to engage in the behaviours.

Based on a literature review, keeping the cat indoors 24 hours was viewed as best, followed by restricting it outside (eg: to a high-fenced garden). Cat owners thought these two behaviours less important and were unlikely to adopt them. For this group, de-sexing, micro-chipping, and limiting the number of cats in an area were most popular. Vets gave similar ratings. Both these groups agreed on keeping the cat indoors at night.

This study showed that cat owners (and vets) viewed how to control their pets quite differently to experts (literature review). So, imposing policies without consultation faces non-compliance and/or opposition.

Linklater et al (2019) concluded: "By following the behavioural prioritisation process, we identified keeping cats inside at night as a behaviour for a future advocacy campaign. As expected, the prioritised behaviour was not the one with the greatest conservation value (ie: maximum reduction in cat predation) nor did it have the greatest likelihood of adoption by cat owners. Instead, the behaviour identified optimises the trade-off between likely conservation impact and probability of adoption, with strong support from veterinarians" (p6).

5.2. FREE-RANGING CATS

Domestic cats (Felis silvestris catus) mostly live in the human home, but there are also free-ranging cats (FRCs) that have no constraints on their movement. "A FRC can be socialised or unsocialised (feral). Some FRCs may be lost or abandoned pet cats (unowned strays) and some may be cats that grew up outdoors on a farm (ie: farm cat) or on the street (ie: alley cat or street cat)" (Vitale 2022 p2).

FRCs can be solitary or group-living, though this is disputed. Spotte (2014) was adamant, for example, that FRCs should be considered solitary - not social" (quoted in Vitale 2022). Vitale (2022) investigated this debate with a literature review that found thirty-one relevant studies published in English. Two main areas of interest emerged - intra-specific and inter-specific interactions.

Intra-specific interactions are those among FRCs. The number of individuals studied varied from groups of four to over 200 adults. Four categories of social behaviour had been studied:

i) Affiliative behaviours - "friendly" social behaviours (eg: allogrooming - licking another individual). Such behaviour was observed to be initiated more frequently by female than male cats, but the studies showed "variability in both the sociability of individuals in the group as well as the associations between group members" (Vitale 2022 p10).

ii) Agonistic behaviours - "non-friendly" behaviours. Both aggressive and submissive behaviours have been observed in FRCs, which occurred in ritualised threat postures and vocalisations, and so few physical fights. Agonistic behaviours were common around feeding times and sites (when provided by humans).

iii) Caregiving behaviours - co-operative nursing, communal denning, and alloparental behaviour has been observed in two studies (ie: "mothers were seen to share in caregiving of kittens without distinguishing their own"; Vitale 2022 p10).

iv) Reproductive behaviours - courtship behaviours were observed (eg: "waiting"). "Waiting involved the male staying near to the female and following her if she walked away" (Vitale 2022 p12).

Inter-specific interactions are those between FRCs and other species. Vitale (2022) found two studies of FRCs and humans, and one study of non-predator interactions between FRCs and wildlife. The latter study involved thirty-one FRCs on Jekyll Island, Georgia, USA, wearing a "KittyCam" around their neck (Hernandez et al 2018). Interactions were recorded with raccoons, black vultures, and white-tailed deer, for example.

Vitale (2022) drew some conclusions from the review:

a) A number of factors influenced intra-specific interactions (eg: age, sex, body size, familiarity, kin).

b) Great variability - "Some cat groups display strong social bonds with preferential affiliations among group members... while other cat groups are more loosely associated and display little to no social interaction. Even FRCs living in similar environments can differ greatly in terms of social behaviour..." (Vitale 2022 p17).

Where FRCs do form social groups, affiliative behaviours are important. Such groups appear to have social structure. Dards (1983) stated that "[I]t is evident that the domestic cat is capable of a much more complex social structure than has previously been thought, and that this also extends to the adult males, which at first sight appear to be independent of it" (quoted in Vitale 2022). This conclusion came from a study of around 200 FRCs living at the Portsmouth Naval Dockyard in England. While a study of 4-5 cats at Church Farm, Devon, England (MacDonald et al 1987) concluded that "the colony had a social structure and was not simply an aggregation and that the cats' social interactions were structured according to distinct social relationships" (quoted in Vitale 2022).

However, another study of FRCs in a dockyard (Page et al 1992) saw them as "mostly solitary", while FRCs at a waste site (Denny et al 2002) were seen to interact only 10% of 330 observations.

Vitale's (2022) view can be summarised as "that FRCs are 'social generalists' who display flexibility in their social behaviour. The social lives of FRCs exist, are complex, and deserve further study" (p1).

c) Areas for future research include cat social cognition, density of populations and home ranges, and social dynamics. Vitale (2022) also pointed out the need for inclusion of non-English studies: "Given much of this work has been conducted in countries where English is not the primary language (eg: Japan, Italy) it is possible additional work has been published that was not captured within the current review" (p17).

d) Different studies involve different methodological issues. For example, most studies observed social interactions between individuals, but Turner and Mertens (1986), for example, measured "social tolerance" by the overlap of home ranges.

5.3. DOGS

In many countries dogs are "often indoor family members" (Saavedra-Aracena et al 2021 p1), while in others dogs roam outdoors with implications for local wildlife. Free-ranging owned dogs are distinct from feral dogs ("which are completely wild and independent of human subsidy"; Saavedra-Aracena et al 2021 p2).

Saavedra-Aracena et al (2021) investigated the spatial movements of forty-one free-ranging dogs and dog-human bonds in Navarino Island, Chile, over two three-week summer periods. The dogs were fitted with lightweight GPS data loggers. The dogs' caregivers completed a questionnaire about behaviours and including the Monash Dog Owner Relationship Scale (MDORS) (Dwyer et al 2006) (table 5.1).

- How often do you kiss your dog?
- How often do you groom your dog?
- How often do you hug your dog?
- My dog helps me get through tough times.
- I would like to have my dog near me all the time.
- My dog is constantly attentive to me.
- My dog costs too much money.
- My dog makes too much mess.

(Source: Calvo et al 2016)

Table 5.1 - Example of items from MDORS.

Dogs and humans also participated in the Strange Situation Procedure (SSP). This measures the strength of the dog-human bond by a series of three-minute episodes of interactions in two rooms (table 5.2). A dog with a secure bond will prefer the caregiver to the stranger, and respond to the caregiver's return.

Episode	Details
1	D + C in main room. C ignores D and D free to explore room
2	S enters; S attempts to play with D; C leaves quietly
3	D + S; S opens door to side room for D to explore; S leaves
4	D alone in main and/or side room
5	C re-enters main room and greets D, then ignores D who allowed to explore rooms again
6	S re-enters and greets dog; C leaves

(C = caregiver; D = dog; S = stranger)

(Source: Saavedra-Aracena et al 2021 figure 2)

Table 5.2 - Six episodes of the SSP.

Around half the dogs were confined to indoors while the others were free to roam. Birds were the prey most often brought home and livestock were the most common harassed, according to caregivers.

Dogs that travelled further afield alone were older, missing for longer periods without caregiver's concern, and had higher levels of exploratory behaviours in SSP. Having a secure bond as shown in the SSP did not appear important for dogs allowed to roam free compared to dogs confined indoors who roamed in nature with their owners.

Saavedra-Aracena et al (2021) observed: "Asking caregivers about how often their dogs disappear thus seems to be a reliable predictor to identify dogs with more access to wilderness. The fact that caregivers did not try to hide this information from the interviewer (eg: to appear as a responsible pet owner, social desirability bias...) is also an indicator that information in other sensitive questions (eg: prey brought home, diet) is probably not influenced by this type of bias. Following most caregivers, their dogs got missing because they followed other persons or tourists" (p7).

The MDORS was a poor predictor of dog roaming, and this may be because it was developed in industrial countries. "Therefore, questions might not match Latin American and/or free-ranging dog culture. For example, if dogs are mainly kept in the streets, they likely will not to be taken to visit people and kissing free-ranging dogs might be seen as unhygienic" (Saavedra-Aracena et al 2021 p7).

5.3.1. Problem Behaviour

Despite dogs being the most popular companion, each year many of them are rejected by their owners. For example, in the USA, of 77 million dogs, 3.3 million per year are given to animal shelters (Powell et al 2021). "Behaviour problems" by the dogs is the most common reason for rejection (Powell et al 2021).

"Canine behaviour and temperament are influenced by a multitude of owner and dog characteristics, including dog age, sex and weight, owner personality and owner-dog attachment" (Powell et al 2021 p2). For example, Podberscek and Serpell (1997) found that owners of aggressive English cocker spaniels were more likely to be emotionally unstable than owners of non-aggressive dogs.

Do the factors that influence canine behaviour also influence the success of behavioural treatments? Powell et al (2021) investigated this question with 131 dogs and owners referred to the Behavioural Medicine Service of the Ryan Veterinary Hospital at the University of Pennsylvania in 2013-15.

Each dog was observed for thirty minutes, and then the owners were given behavioural modification programmes and/or medications to use with the dogs at home. Follow-ups were made at ten days, and 3, 6 and nine months later.

Three key questionnaires were completed by the owners:

a) Canine Behavioural Assessment and Research Questionnaire (C-BARQ) - One hundred questions about the dog's problem behaviours (eg: aggressive response to strangers or owner; fearful of unfamiliar people). This was completed at three and six months post-consultation.

b) Lexington Attachment to Pets Scale (LAPS) - 23 questions about the strength of owner-dog attachment.

c) Ten-Item Personality Inventory (TIPI) - Ten items measuring the personality of the owner.

The success in behaviour change of the dog was associated with characteristics of the dog, owner personality, and the owner-dog attachment:

i) Dog - Younger, and female dogs were more trainable, and also larger dogs. The researchers were cautious about the latter: "As the safety risk is inherently greater with increasing bodyweight, it is possible that large dog owners followed the safety rules and veterinary treatment plan more diligently than owners of small dogs, thereby avoiding situations that could trigger undesirable behaviour. Strangers are also likely to be more fearful of large dogs exhibiting aggressive or fearful behaviours than small dogs and may have kept a greater distance from them" (Powell et al 2021 p9).

ii) Owner - High scores on the personality traits, Conscientiousness, Extraversion, and Openness to Experience were each associated with decreased aggression by their dogs.

iii) Attachment - A higher level of attachment was linked to success.

The follow-ups were by telephone, and a number of owners did not respond. It was not clear who dropped out of the programme. "It is possible that dogs whose behaviour improved rapidly did not complete the study as their owners did not feel the need for ongoing veterinary support. On the other hand, dogs who did not respond to clinical intervention may have dropped out due to euthanasia or rehoming during the study period. This could yield systematic differences between dogs who dropped out and those who completed the study and may have biased results. It is also possible that owner characteristics, such as personality or attachment to the dog, may have influenced the owner's decision not to complete the study" (Powell et al 2021 p10).

The success of behaviour change was reported by the owners with no independent verification.

5.3.2. Gifted Word Learners

"Gifted Word Learner" (GWL) dogs (Fugazza et al 2021b) are a small number of dogs who are able to learn object names. Pilley and Reid (2011), for instance, reported a border collie who was able to learn over a thousand objects after much intensive training (5-6 hours per day for three years). While Fugazza et al (2021a) found that two GWL dogs could link new names to new objects very quickly (eg: after four exposures during play with the owner), but the memory declined rapidly (eg: forgotten after a ten-minute delay) (Dror et al 2021).

Dror et al (2021) studied experimentally six border collies proven to know the name of objects by Fugazza et al (2021b). The dogs had learned between eleven to 37 new toys over a three-month period. The average was 26 names of objects. The dogs had been recruited via the "Genius Dog Challenge" on social media [4].

Experiment 1 - Owners were given six new dog toys and one week to teach the names. The amount and form of teaching was left to the owners.

The testing involved sixteen toys (ten old and the six new) on the floor in a separate room (monitored by video camera). The owner and the dog began in another room, then the owner told the dog to retrieve a certain new toy.

Four dogs retrieved all six new toys correctly, and two dogs five out of 6. The average correct for the group was thus 85% (significantly above chance).

Experiment 2 - Carried out 2-3 weeks later, this was the same as Experiment 1 but with twelve new toys. The testing involved twenty toys (including the twelve new ones). Four dogs retrieved 11 of 12 toys correctly, and two dogs all twelve (group mean 87%).

Experiment 3 - One month later, six of the new toys from Experiment 2 were placed in a group of fourteen toys for testing. Only one dog did not retrieve all six toys

[4] See http://geniusdogchallenge.com/.

correctly, and they retrieved three out of six (not significantly above chance). The overall group average was 61%, which was significant.

Experiment 4 - The same as Experiment 3 performed two months after Experiment 2. Three dogs scored six out of six correct, one dog 5 out of 6, and the other two dogs not above chance. The overall group mean was 57% (which was statistically significant).

Dror et al (2021) summed up: "Our findings show that the GWL dogs tested here were not only able to learn up to 12 new object names in one week, a learning rate which is comparable to early word acquisition in infants at the beginning of the vocabulary spurt but most of them also maintained a long-term memory of the object names for at least two months" (p5).

Methodological evaluation:

i) The experiments took place in the owners' homes around the world, but were conducted via live video streaming. "To control for the clever Hans effect [5], the owners were sitting in one room while the toys were placed in another room, out of view from them. A camera positioned in each room broadcasted the experiment so that the experimenters could always see both the owner and the dog in real-time" (Dror et al 2021 p2).

ii) Other experimental controls included the experimenters randomly choosing the toy for the owner to tell the dog to retrieve, and the dogs were given two opportunities to correctly retrieve each toy.

iii) The teaching of the names of the toys varied between owners. Dror et al (2021) stated: "This study... did not limit the owners' interaction, and we, therefore, cannot estimate the minimal amount of exposure that the dogs would have needed to learn. We suggest that future studies should systematically manipulate the learning conditions to estimate the exact amount of exposure dogs need to form and retain long-term memory of object name pairings" (p6).

iv) A larger sample than previous studies, which had

[5] This refers to a horse who appeared to be able to count and do simple sums ("Clever Hans"), but the owner was unconsciously cueing the animal to the correct answer.

involved one or two dogs. Dror et al (2021), however, admitted: "Although this sample is a significant increase compared to previous reports, we acknowledge that it is still relatively low" (p6).

v) The participants were dogs already with knowledge of names of objects whose owners had volunteered after a social media campaign. Dror et al (2021) again admitted: "Surprisingly, although the campaign received major coverage over popular international media channels, it still resulted in the recruitment of a small group of only about 15 GWL dogs" (p6).

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6. MISCELLANEOUS AND UNUSUAL

6.1. GIRAFFES AND LIGHTNING

Lightning strikes kill around 20-30 people in a year in the USA, but the mortality of non-humans is unknown (Scheijen et al 2020).

Lightning can kill in four ways (Scheijen et al 2020):

i) Direct strike.

ii) Side flashes - the victim is near an object hit by lightning.

iii) Step potential - "a discharge of lightning into the surface of the ground that happens if two parts of the body are in contact with the ground align in the direction of the electric ground current" (Scheijen et al 2020 p860).

iv) Touch potential - "when the upper body makes contact with higher elevation of the stricken object while another part of the body is still in contact with the ground" (Scheijen et al 2020 p860).

Tall things are particularly vulnerable, which led Scheijen et al (2020) to consider giraffes. Observational data were collected in Rockwood (private reserve), near Kimberley, South Africa, which housed eight giraffes. Two of them were found dead in early March 2020 after a thunderstorm. Injuries to the two animals suggested that one killed by a direct lightning strike (eg: particular damage to the skull), and the other "died likely either from a side flash or step potential" (Scheijen et al 2020 p862). The bodies were found in open grassland.

The researchers drew out two points:

a) It appears that the victims had not modified their movement in response to the storm. "Given that lightning bolts tend to hit tall objects, especially in open areas, the height of giraffes may make them particularly vulnerable to fatal electrocution. However, they may have behavioural adaptations to reducing chances of mortality from lightning, for example seeking shelter during a thunderstorm or moving to thickly vegetated areas" (Scheijen et al 2020 p860).

b) This is an example of what Darwin (1859) called "fortuitous destruction". "His reasoning was that some organisms could be 'the best adapted to their conditions... [but] destroyed by accidental causes', such that 'natural selection will be powerless' in these instances. Stochastic factors, such as extreme weather events, can cause fatalities to individuals otherwise well-adapted to their environment" (Scheijen et al 2020 p860).

6.2. BORNEAN TUFTED GROUND SQUIRREL

The Bornean tufted ground squirrel (Rheithrosciurus macrotis) is relatively little researched, but it was given the moniker "vampire squirrel" in 2014 after local tales of the killing of deer (Marshall et al 2020).

Marshall et al (2020) argued that this animal is unusual in many ways, but not for this moniker. Its origin in Borneo is unclear, it has unusual incisor teeth, and "the largest tail relative to body size of all mammal species" (Marshall et al 2020 p3).

Marshall et al (2020) provided long-term feeding data from West Kalimantan, Indonesia on a number of resident vertebrates as well as the squirrel. Specifically, 79 feeding observations were made of the squirrel, and it was found to be "a dedicated seed predator" (p1) feeding on a smaller set of plants than other vertebrates. In particular, plants bearing extremely hard seeds, which could explain the unusual teeth.

6.3. MOUSE MATING MOTIVATION

Increased dopamine in an area of the hypothalamus motivates a male mouse to mate. The dopamine is triggered by the presence of a receptive female, and declines after successful mating (satiety). But stimulation of the particular neurons in the hypothalamus motivates the mouse to mate after sexual satiety (Zhang et al et al 2021).

Mating behaviour motivation and satiety were measured by a standardised procedure. A female mouse in oestrus is introduced into the home cage of a male mouse, and two measures were recorded - the amount of time the male spent sniffing the female during the first five minutes, and the time to mounting within fifteen minutes. Males isolated from females for five days spent 75% of the time sniffing, and 90% of them mounted the females. After successful mating, a new female is introduced, and the sniffing is reduced to 10% of the time and 0% mounting (Zhang et al 2021).

6.4. UNUSUAL OBSERVATIONS

6.4.1. Locomotion

Locomotion through aquatic environments is usually through swimming, propulsion, or flotation, but there is also walking on submerged structures. "Unlike terrestrial walking where gravity is the main and dominant horizontal destabilising force, animals that move under the water are required to counter the strong destabilising horizontal and vertical hydrodynamic forces of drag, lift, and acceleration which can force them to detach from substrates... This has resulted in the evolution of many different attachment mechanisms among animals, including adhesive pads, liquid secretions, friction, suction, and hooks, to better adhere to substrates underwater... Even some terrestrial animals, such as beetles, have been found to use air bubbles trapped securely between their feet to better allow their adhesive setae to stick to underwater substrates" (Gould and Valdez 2021 pp669-670).

There are a very limited number of animals that walk on the water surface. Best known is the water strider. "Their long, hydrophobic legs prevent them from breaching the water's surface which, along with their lightweight, allows them to remain afloat above the water even at rest and almost entirely through the surface tension forces of the water... To achieve forward motion, water striders sweep their legs backwards like oars, allowing them to row across it without getting wet" (Gould and Valdez 2021 p670).

Gould and Valdez (2021) reported a unique observation in Australia of walking on the underside of the water's surface by an unidentified beetle. "Evidently, this beetle has been able to use the underside of the water's surface as a substrate to push forward against to walk forward" (Gould and Valdez 2021 p670). There was a layer of trapped air around the beetle which helped with buoyancy.

The researchers speculated on the advantages of this behaviour: "Although the surface of open water provides little protection from aquatic predators, locomotion at this location may serve as an anti-predator behaviour by allowing the beetle to avoid ambush predators that wait along submerged substrates or the bottom of the waterbody... Indeed, the lack of apparent rippling as the beetle moved across the surface would likely minimise detection from predators in the water column that rely on vibrations to hunt... Moving on the underside of the surface is also likely to reduce detection or availability to aerial predators compared to movement above the surface" (p671).

6.4.2. Living in Trees

Adaptation of animals to their environments leads to unexpected and not before seen observations, like jaguars (Panthera onca) in the Amazon flooded forest living an arboreal and semi-aquatic existence for part of the year (Ramalho et al 2021). Elsewhere, large felids "commonly use trees for resting, hunting, avoiding predators or competitors..., and others may prey on arboreal, aquatic, and semi-aquatic species..." (Ramalho et al 2021 p1).

Three to four months per year the Amazon River system floods the varzea floodplain forests to depths of ten metres or more. Many animals migrate before the flooding.

In 2010, Ramalho et al (2021) placed a GPS collar on a pregnant female jaguar and monitored her for one year. The jaguar lived in the tree canopy, found food by swimming from tree to tree, and raised a cub.

Subsequently, eight more adults were monitored between 2010 and 2016, and all of them stayed in the flooded area. The data were collected in Mamiraua Sustainable Development Reserve in Amazonas state, Brazil.

Ramalho et al (2021) reported: "During our field observations, animals had good body condition throughout the year, even during flooding, which indicates that the abundance of arboreal animals in the varzea can sustain a healthy jaguar population during flooding" (p3).

The researchers ended: "The behavioural adaptation of a large felid to survive and reproduce while living an arboreal and semi-aquatic lifestyle in areas that are flooded for several months each year is new to science. Although arboreal lifestyles have been reported for smaller felids such as margay (Leopardus wiedii) and semi-aquatic lifestyles for medium mammalian carnivores such as the giant river otter (Pteronura brasiliensis), no combination of such lifestyles has been reported as an obligate life history pattern for populations of any large apex predators" (Ramalho et al 2021 p4).

6.4.3. Orca

An increasing number of recent attacks on boats by orcas in the Straits of Gibraltar have been reported (41 in July 2021 and 25 in August 2021) (Gabay 2021). The motivations for the attacks are not known.

6.4.4. Predation

Examples of invertebrates predating on vertebrates on land are "comparatively scarce" (Halpin et al 2021). Halpin et al (2021) reported the case of the ground dwelling Phillip Island centipede (Cormocephalus coynei) that predated reptiles, fishes, and seabirds. Phillip Island is a small uninhabited island in the South Pacific (south of Norfolk Island).

Over seventeen nights in February and March 2019, observations were made of the nocturnal centipedes. Nestlings of the black-winged petrel were the main prey focus. Tissue samples were taken from the two species.

From a total of 132 hours of observation, twenty-one feeding events by the centipedes were recorded. No feeding on birds was observed, but other vertebrates (reptiles and fishes) were seen. Crickets, however, were the main prey species. There was evidence in the petrel nests of centipede attacks in a small number of cases (10-20%). Halpin et al (2021) explained that "the conclusion that black-winged petrel nestlings were actively preyed on rather than scavenged is our observation that no white-necked petrel nestlings were consumed by Phillip Island centipedes during nest monitoring. White-necked petrel body mass is almost three times larger..., with their nestlings reaching a larger body mass more quickly than black-winged petrel nestlings, and presumably, nestlings are able to defend themselves from centipedes at a younger age. This accords with our observation that Phillip Island centipedes preyed predominantly on smaller-sized black-winged petrel nestlings" (p546).

A calculation was made that the centipedes consumed between 2 000 to 3 000 seabird nestlings per year (out of around 20 000 breeding pairs) (Halpin et al 2021).

6.5. MALE PREGNANT RAT

Zhang and Liu (2021) reported an experiment to impregnate castrated male rats conjoined with female rats. The elbows, knees and skins of pairs of rats were sewn together to join the blood supply. This is known as a parabiont (ie: shared blood supply) (and is used to blood infusion). The male rats received a transplant uterus (Mallapaty 2021).

In total, 842 embryos were introduced into forty-six conjoined pairs, and viable foetuses developed in one-third of the females and one-tenth of the males. Ten pups (4%) in the male rats survived to adulthood. Embryos did not mature in males attached to females without developing foetuses. So, the pregnant female's blood supply seems to be key (Mallapaty 2021).

Not surprisingly, such work has produced strong reactions. On the support side is the view that it will help to understand pregnancy in people of any sex. While the opposite view is that it offers few insights (Mallapaty 2021).

One of the authors reported on social media that the study was performed "for our personal interest and curiosity" (Mallapaty 2021).

6.6. SOCIAL ISOLATION

Human social isolation is associated with illness. The fruit fly has become in the 21st century a model to study this behaviour as flies are sensitive to their social context (Levine 2021). "Fruit flies are social animals, and exhibit dynamic social network structures and collective behaviours, which contribute to environmental sensing, foraging, feeding, fighting, mating, oviposition, circadian time setting and even the existence of 'culture'" (Li et al 2021 p239).

Li et al (2021) compared flies kept in groups (of 2, 5, 25 or 100) (control conditions), or alone for 1-3 days (acute isolation conditions) or 5-7 days (chronic isolation conditions). The latter group showed disrupted sleep patterns, and ate twice as much food. It was found that social isolation produced changes in certain genes linked to feeding. "Thus, in the fly, social isolation mimics starvation" (Levine 2021 p179).

6.7. BATEMAN'S PRINCIPLES

"Bateman's Principles" (Bateman 1948) on sexual selection came from experimental work on fruit flies. Simplistically, males have greater reproductive success with a large number of partners as compared to females.

The original work has subsequently been criticised for conformation bias, for example (Hoquet et al 2020). Patricia Gowaty has been especially critical (eg: Gowaty 2018; Gowaty et al 2012, 2013; Snyder and Gowaty 2007).

A reanalysis of the recently discovered original handwritten laboratory notes of Bateman by Hoquet et al (2020) did not support "Bateman's Principles". In other words, there was no advantage to males having multiple partners compared to females.

6.8. NAMING SPECIES

The naming of a new species follows the rules of the International Code of Zoological Nomenclature (ICZN), which specifies a unique Latin binomial. The second part allows taxonomists the opportunity for creativity and originality. "Taxonomists have used various sources of inspiration to name new species. These range from distinctive morphological features of the new species, to honouring eminent researchers or celebrities, with sometimes humorous results" (Poulin et al 2022 p1).

In the case of parasite species, the naming after a person has become fashionable (eg: avian louse Strigiphilus garylarsoni after the American cartoonist Gary Larson) (Poulin et al 2022).

Poulin et al (2022) analysed the naming of 2891 parasite species between 2000 and 2020 under five headings:

i) Based on morphology of the species (n = 601).

ii) Named after the host where the parasite found (n = 550).

iii) Named after the locality of the discovery (n = 616).

iv) Named after an eminent scientist (n = 596).

v) "Named for something else" (n = 528) (table 6.1).

Categories (i) to (iii) are more traditional naming practices. For category (iv), there were few women. "This gender bias is no different from the one documented with respect to which scientists receive major awards, funding and prestige" (Poulin et al 2022 p7).

Concerning category (v), "the tendency to name it after a mentor, close personal friend or relative has increased in the past two decades" (Poulin et al 2022 p7).

Poulin et al (2022) made the following recommendations with particular reference to categories (iv) and (v):

a) Aim for inclusivity and diversity if naming after an eminent scientist.

b) In relation category (v), "although it is not done often, naming new species after celebrities such as politicians, athletes or artists should be done with caution, if not avoided altogether. This practice can attract media coverage and draw public attention to the importance of species discovery and biodiversity. However, unlike scientists, celebrities already achieve fame and global recognition without their name being immortalised in a new species" (Poulin et al 2022 p8).

c) Similarly, "naming a new species after the child, spouse, parent or other family member of the authors, as well as naming it after a close friend with no connection to the discovery or description of the new species, should be discouraged. This practice is reminiscent of the favouritism granted to relatives (nepotism) or friends (cronyism) in other areas. Although not strictly disallowed by the ICZN, self-naming, ie: naming a species after oneself, would be so severely frowned upon that it is simply not done. Naming a species after a relative or close friend seems like only a small step away from self-naming, and should therefore be avoided" (Poulin et al 2022 p8).

Latin Name	Reason for Naming
Ruhnkecestus latipi	Captain Latip Sait of fishing vessel used in research
Pseudodactylogyrus kamegaii	Mr Shunya Kamegai, former Director of the Meguro Parasitological Museum, Tokyo, who had recently died
Constrictoanchoratus lemmyi	"Lemmy" Kilmister of "Motorhead", the favourite band of the lead researcher
Baracktrema abamai	US President Barak Obama
Rhabdias glaurungi	"Glaurung" in JRR Tolkien's "The Silmarillion"
Rhinebothrium carbatai	"Corbata", pet dog of researcher

(Source: table 1 Poulin et al 2022)

Table 6.1 - Examples of parasite species "named after something else".

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