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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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CONTENTS

1. ECO-ANXIETY

Current and future threats from climate change (CC) can create feelings of fear and anxiety. The term "psychoterratic" syndromes (Albrecht 2011) has been used to describe "mental health impacts as a result of negative emotions caused by perceived environmental and CC" (Boluda-Verdu et al 2022 p2). "Eco-anxiety" is an example. Though there is no standard definition, it "could be categorised as people's reactions of worry and anxiety in view of global CC threats and concurrent environmental degradation" (Boluda-Verdu et al 2022 p2). Other terms used include "CC anxiety", "CC worry", "environmental distress", and "ecological grief" (Boluda-Verdu et al 2022).

Boluda-Verdu et al (2022) undertook a systematic review of the relationship between eco-anxiety and health. Twelve relevant articles were found. Boluda-Verdu et al (2022) explained their findings: "Our results have to be interpreted with caution since the methodological quality of the studies was limited, most studies were cross-sectional and the sample size of the systematic review was small. Data suggests a relation between eco-anxiety and symptoms of depression, anxiety, stress, insomnia, cognitive-emotional and functional impairment, and reluctance to have children, mainly, in younger generations, women, and poorer countries. On the other hand, these results suggest that eco-anxiety may be associated to pro-environmental behaviour, which could buffer its negative health impacts" (p15).

Here are some the main issues with the studies:

i) Design - All but one were cross-sectional, "which does not allow conclusions to be drawn about the causal nature of the association between eco-anxiety and health outcomes. Cross-sectional studies are prone to reverse causality because temporal ordering of exposure and outcome cannot be established, making impossible to establish the independent contribution of eco-anxiety" (Boluda-Verdu et al 2022 p14).

ii) Samples - Limited in different ways, for example, by younger age group (5 studies in with participants in their 20s), students (three studies), more females than males (all but two studies), size (from 24 to 11 158), and country (mostly in the USA).

iii) Little or no information about non-responders to studies. "On the one hand, it is likely that those who were more concerned or worried about CC were most likely to participate and answer the on-line surveys, which was the most frequent mode of data collection in 9/12 studies... On the other hand, it is also likely that those from vulnerable groups - poorer, younger, rural populations and those more exposed to extreme weather events - were less likely to have access to the internet and to answer an on-line survey. People exposed to a direct acute CC event have been observed as having more intense negative emotions toward CC" (Boluda-Verdu et al 2022 p15).

iv) Data collection by survey mostly (ie: quantitative).

v) Varied definitions of eco-anxiety - eg: terms like "feeling of being worried", "feeling tense", "grieved", "guilty". "Moreover, sometimes eco-anxiety was defined as one... or two... emotions, at other times it was defined as deriving from various emotions" (Boluda-Verdu et al 2022 p13).

vi) Controlling confounders - eg: general anxiety; personal experience of consequences of CC; beliefs about CC; engagement with political issues.

vii) Measures of eco-anxiety varied - eg: the validated Climate Change Anxiety Scale (CCAS) (Clayton and Karazsia 2020; appendix 1A) or a general anxiety measure, as well as the outcomes (eg: depression; psychological well-being; life satisfaction; optimism).

One problem generally about CC anxiety is that people can respond either positively or negatively. "For some people, climate anxiety promotes positive environmental attitudes, a green self-identity, and determination to work towards pro-environmental solutions... For others, climate anxiety corresponds with lower mental health... and greater anxiety" (Cruz and High 2022 p5). Understanding the "when, why, and for whom climate anxiety exerts positive or negative outcomes" (Cruz and High 2022 p5) would be useful.

APPENDIX 1A - CLIMATE CHANGE ANXIETY SCALE

The CCAS has thirteen items covering two sub-scales

- cognitive-emotional impairment, and functional impairment (table 1.1). "The two types of impairment are conceptualised as two separate factors that combine to make up the overall experience of climate anxiety" (Cruz and High 2022 p2). However, CC anxiety as a unidimensional concept is the alternative, and the work of Clayton and Karazsia (2020) was not replicated in the Italian and German (ie: non-English) versions of the CCAS (Cruz and High 2022). "The reason for these different findings is unclear. It is possible the untranslated version performs differently than the translated versions or that the factor structure differs between US and European samples" (Cruz and High 2022 p2).

In their study, Cruz and High (2022) found that the CCAS is "generally valid and reliable, but there is some ambiguity about its factor structure. Specifically, although the results clarify that the two sub-scales cannot be treated as two separate constructs, they do not rule out either a first-order unidimensional model or a second-order unidimensional model. Continued conceptual and item development would be of practical and theoretical value" (p1). Over 500 US participants recruited online completed the CCAS, as well as general measures of depression, and anxiety, in this study.

Note that Cruz and High (2022) used a seven-point response scale as opposed to the five-point scale in the Clayton and Karazsia (2020) study.

Cognitive-emotional impairment:

- "Thinking about climate change makes it difficult for me to concentrate".
- "I think, 'why can't I handle climate change better?'".

Functional impairment:

- "I have problems balancing my concerns about sustainability with the needs of my family".
- "My friends say I think about climate change too much".

Each item scored as "never" (1) to "almost always" (5).

(Source: Table 2 Cruz and High 2022)

Table 1.1 - Example of CCAS items.

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2. INFECTIOUS DISEASES IN A CHANGING WORLD

Climate change has already had and will further have an impact on infectious diseases, both in terms of the evolution of the pathogens and the capacity of the hosts to react. "Indeed, the covid-19 pandemic has emphasised how quickly infectious diseases can evolve and spread — with consequences for transmission, virulence and evasion of host defences — and that disease dynamics will play out differently across regions of the globe" (King et al 2023 p1).

In understanding infectious diseases in this context, King et al (2023) outlined three key themes of the research:

1. "Climate change and infection outcomes" - eg: change in temperature.

"Temperature has been shown to alter the encounter rates between host and parasites, host susceptibility and tolerance to infection and, finally, the infectivity and virulence of parasites. There is a common prediction of increased pathogen development and replication rates as well as enhanced parasite transmission under elevated temperatures (ie: 'warmer hence sicker world' scenario..." (King et al 2023 pp1-2). The expansion of the range of vectors, like mosquitoes, is another issue.

At the same time, "[A] warmer or heavily modified world is not always sicker. Temperature affects each component of host-pathogen interactions in unique ways, from host demography to within-host pathogen burden, making simple generalisations difficult" (King et al 2023 p3). For example, parasite spores exposed to higher temperatures experimentally are impaired in terms of attaching to hosts (and thus causing infection) (King et al 2023).

In experimental work with water fleas and their parasites that varied the environmental temperature, Sun et al (2023) found that as the temperature rose, the fleas changed - thicker guts developed (beneficial) but with dampened cellular immune responses (weakness).

Many parasites are exposed to environmental factors as they wait for a host, and this survival time is sensitive to temperature and humidity. "Longer survival ability in the external environment is clearly an advantage, as the chances for transmission increase. Indeed, many parasites have evolved specialised structures to resist drying, heating or freezing. Under natural conditions, the well-protected eggs of tapeworms (genus Taenia) were reported to survive for up to 12 months" (Marcus et al 2023 p2).

Using the Pasteuria ramosa (parasite) and Daphna magna (host) interaction, Marcus et al (2023) studied the "off-host" stage of the parasite's lifecycle. P. ramosa from seven different habitats (in terms of wet and dry, and temperature) were studied. Infectivity of host declined as the environmental temperature rose from 20-60 °C. Specifically, P. ramosa spores resting at temperatures of 40 °C and above could not infest hosts. "Long heatwaves and harsh summers, which are becoming more frequent owing to recent climate changes, may therefore pose a problem for parasite survival" (Marcus et al 2023 p1).

Infection can increase the sensitivity of hosts to heat. "Exposure to parasites in combination with rapid heating may propel many species to the brink of extinction" (Hector et al 2023 p4). Infected individuals can have an increased metabolic rate (eg: double an uninfected individual in a crab infected by rhizocephalan parasites) (Hector et al 2023).

Increased environmental temperature can reduce immune system effectiveness. "For example, in an abalone and shrimp, there was a rapid decline in immune response at or above 32°C, making the host most susceptible to vibrio [bacterial] infections at high temperature" (Hector et al 2023 p9).

But increased temperature will also limit the parasites that depend on transmission between living hosts. "Disproportionate declines in the number of infected hosts due to heat stress, alongside the death of a portion of the susceptible host population, will shrink the susceptible and infected population sizes. As a result of extensive host mortality, the parasite population size (ie: infected hosts) will also contract. Ongoing transmission following an extreme heat event could therefore be limited by both small host and parasite population sizes" (Hector et al 2023 pp9-10).

Warming temperatures risk increasing the range of mosquitoes, who are the main vectors of infectious diseases like malaria, dengue fever, Zika, chikungunya, and yellow fever. Alternatively, higher temperatures may exceed thermal limits, and deaths may ensue (Ware-Gilmore et al 2023).

Mosquitoes are sensitive to temperature changes, being ecotherms, and having aquatic and terrestrial stages in their lifecycle. "Mosquitoes may respond to environmental warming through short-term coping and avoidance mechanisms supported through phenotypic plasticity, including changes in behavioural regulation (ie: shifts in resting and biting behaviour), quiescence, use of micro-habitats, and differential oviposition site selection. In the long term, mosquitoes may cope with climate change through adaptive evolutionary change, which could result in shifts in their thermal tolerance (ie: the ability to survive a potentially lethal exposure to extreme thermal stress)" (Ware-Gilmore et al 2023 p2).

It is the latter that is concerning. Thermal tolerance is a heritable trait, and Ware-Gilmore et al (2023) investigated the genes involved. "At the molecular level, stressful temperatures can disrupt protein function, which can lead to impairment of cell function. To cope with thermal and other stresses (eg: infection, UV, desiccation, oxidative stress), cells induce a 'heat shock response' (HSR). The HSR is a series of cellular responses to physiological and environmental stressors that result in the production of heat shock proteins (HSPs)" (Ware-Gilmore et al 2023 p2). Hsp gene expression was the focus of this experimental work with the yellow fever mosquito (Aedes aegypti). The experiments were carried out at 42 °C, which is beyond the upper thermal limit, and time to immobility was measured. The Hsp gene expression was then compared for the two extremes - shortest and longest time to immobility individuals. Contrary to expectations, there was little difference between the two groups (even after allowing them to breed). So, HSP appears not to be involved in adaptation to increasing temperatures. Leaving aside other mean and factors in adaptation, Ware-Gilmore et al (2023) explained that their "data suggest that given exposure to thermal extremes, our population would not likely survive by 'evolutionary rescue' and would, instead, go locally extinct" (p6).

Note that this study used a specific inbred population with a unique genetic composition.

Studies with fruit flies have found that "at a high concentration HSPs are toxic, as they can interfere with cellular function, and the synthesis and degradation of these also serve as an energetic drain for cellular reserves. Furthermore, the accumulation of HSP's has been associated with long-term harm to organismal growth, development, and fecundity" (Ware-Gilmore et al 2023 p6).

2. "Underlying host-pathogen interactions in dynamic environments".

Rising temperature, for instance, is not linear, but fluctuations occur at a daily or seasonal level, say. How do these fluctuations affect host-pathogen interactions?

Greater seasonal fluctuations in temperature, for instance, is predicted to lead to "higher virulence (table 2.1) in parasites and lower avoidance in hosts, suggesting environments with greater fluctuations may be expected to lead to more prevalent, severe infections" (Best and Ashby 2023 p8), according to mathematical modelling.

- The virulence of a parasite is the harm it causes a host during infection, which varies from little to death. "Parasites are often dependent on their host for survival, but to be successful, parasites must transmit between new hosts. For parasites, a trade-off is predicted to occur between within-host replication and between-host transmission. To replicate, parasites consume host resources, which increases the harm caused to the host, reduces the host's lifespan and increases the risk of host mortality. The increased host mortality associated with replication is hypothesised to decrease parasite transmission, resulting in conflict between within-host growth and between-host transmission" (Hector et al 2023 p4).

- Obligate killer parasites, however, depend upon host mortality for their transmission. For example, the bacterial parasite Pasteuria ramosa and the Daphnia magna host. Hector et al (2023) described the process: "Pasteuria spores exist in the environment and are picked up by the host during filter feeding. After entering a host, P. ramosa replicates, manipulates host physiology (causing castration and gigantism), reduces host fecundity and eventually causes early host death. At the point of host death, millions of parasite transmission spores are released into the environment where they can persist until they reach the next host" (p6).

Table 2.1 - Virulence.

3. "Outbreaks and pathogens evolution in human-altered ecosystems".

Certain human activities have a direct impact on host-pathogen interactions (eg: deforestation; human migration; pollution).

However, "[N]ot all populations will be equally impacted by change. Host and pathogen populations should be expected to be adapted to their local environment, and disease outcomes will likely vary with latitude, altitude, water depth (in the case of aquatic organisms), or prior exposure to human activity" (King et al 2023 p3).

One growing group of chemical pollutants produced by humans is pharmaceuticals, and over 600 different products have been detected globally in waterways, lakes and rivers (Aulsebrook et al 2023).

A global survey of waterways (Wilkinson et al 2022) [1] found four compounds in every continent (except Antarctica) - caffeine, nicotine, paracetamol (acetaminophen in the USA), and continine (produced by the body after exposure to nicotine). Another fourteen compounds including anti-histamines, anti-depressants, and anti-biotics were also found to be widespread (Thompson 2022).

Pharmaceuticals are typically excreted after consumption, and enter the water system this way while still being bioactive. "Evidence suggests that many pharmaceutical pollutants are slow to degrade and can bioaccumulate, with potentially dire consequences for exposed organisms, from feminisation of male fish to death in vultures. With the exception of anti-microbials such as anti-biotics, however, and in contrast to what is known about toxicants such as pesticides and heavy metals, the impact of pharmaceutical pollutants on disease dynamics remains largely unknown" (Aulsebrook et al 2023 p2) [2].

Aulsebrook et al (2023) concentrated on the serotonin-targeting anti-depressant fluoxetine (known most commonly by the brand name "Prozac"), which has a half life of 68 days, and the impact on the bacterial pathogen Pasteuria ramosa and crustacean Daphnia magna interactions. Experimentally different doses of the drug were placed in the water tanks. Over a life span it was calculated that the pharmaceutical pollution gave rise to complex interactions that impacted the host and pathogen, which are unlike to pesticide or heavy metal that tend to be lethal. The effect of fluoxetine on the host also varied depending on the presence or absence of a pathogen.

Aulsebrook et al (2023) made two points: "Firstly, pharmaceutical pollutants frequently exert non-monotonic responses, where lower doses can have larger effects than higher doses. This may be because these drugs are designed to act effectively at selective low doses, and

[1] The study sampled 258 rivers in 104 countries for 61 different chemicals and involved 127 scientists (Thompson 2022).

[2] Sampling waste water for signs of population infections as well as for drugs is now part of "waste water-based epidemiology". An early study in Italy in 2005 found waste that would be produced by four kilogrammes of cocaine each day, which was calculated as 40 000 users (Ainsworth 2022).

their intended receptors become desensitised at higher doses. Secondly, since pharmaceuticals are typically designed to have therapeutic benefits, it is possible that exposure of non-target organisms to these pollutants could even have positive effects on fitness, such as growth and reproduction. By contrast, traditional forms of chemical pollution such as pesticides and heavy metals typically reduce individual health and performance" (p2).

Plastic contamination is another issue, particularly the breaking down of plastic products into smaller pieces - micro-plastics (MPs; less than 5 mm) and nanoplastics (NPs; less 100 nm). "Current sewage treatment methods cannot remove micro-plastics from wastewater and novel remediation techniques still require further development to ensure the proper clearing of contaminated sites. As such, increasing quantities of MPs accumulate in soil and aquatic compartments... NPs can accumulate within living tissues, leading to their trophic transfer up the food chain. Due to their small size, these can also penetrate living cell membranes, with the potential to disturb intra-cellular functions" (Manzi et al 2023 p1).

The water flea Daphnia magna is well studied here. For example, Manzi et al (2023) exposed this host to two different parasites (fungal and gut) in experimental environments that varied the NPs in the water (zero, low or high). The fleas were exposed to one parasite only or both together (or none in a control condition).

The presence of NPs (more so in the low condition) increased the proportion of hosts infested by the fungal parasite, but not the gut parasite. Exposure to both parasites together had a stronger negative impact than single exposure. The findings showed that infection is influenced by the presence of NPs in the environment.

Pollinating insects and their pathogens have been impacted by human land use (eg: agricultural intensification; loss of hedgerows). Manley et al (2023) showed an example of this with a study of pollinating insects in the UK. The number of flowers at selected sites were counted, and virus analysis was made from the five most common insect pollinators (eg: honeybees) (in total 5180 individuals).

There was great variety found, but flower species diversity was a key variable in reducing pathogens. "Polyfloral diets have been shown to reduce mortality of honeybee larvae when infected with various pathogens demonstrating the importance of plant biodiversity in resistance to infections. Additionally, several plant-specific phytochemicals also have anti-microbial activity when ingested by bees" (Manley et al 2023 p11).

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3. FOREST LANDSCAPE RESTORATION

"Conservation and restoration of forests are at the centre of global efforts to mitigate climate change and prevent mass extinctions of biodiversity" (Marshall et al 2022 p1). But this is not easy, and deforestation still continues in some places. Forest landscape restoration (FLR) is a strategy that attempts to involve the active participation of local communities in forest conservation. Science has an important role to play, and Marshall et al (2022) outlined fifteen relevant issues and questions:

i) FLR with large, but realistic, goals.

ii) The socio-economic challenges of FLR - "At least 12% of the population in low-income countries live on forest restoration opportunity land and 1.2 billion people are directly dependent on nature for everyday life. While forest restoration can produce ecosystem services for these communities, it can also generate disservices (eg: negative health impacts from pathogens, crop damage by wildlife pests). These, in turn, may play an important role in stakeholder decision-making and may lead to misconceptions and opportunity costs, especially reduced agricultural land. Restoration planning, prioritisation modelling and mapping can therefore have substantial equity and justice implications" (Marshall et al 2022 p4).

iii) The governance of restoration sites - "FLR that does not secure local communities' consent and engagement, nor address potential negative social impacts, might lead to forced displacement, unjust climate mitigation and costly monitoring and regulation to prevent illegal, but often legitimate, activities" (Marshall et al 2022 p5).

Loveridge et al (2022) noted that "if conservation governance is perceived as being unfair, this could lead to conflicts and local resistance, as occurred in Kilimanjaro, Tanzania, where retaliatory killings of elephants have been recorded as a form of protest against PA [protected areas] conservation" (p2).

iv) The production of sustainable produce from restored forests that benefits the local community.

v) The interaction between what is best for the environment and what is best for the local community -

PAs have been set up over the years to protect and restore nature. "However, over the last 50 years the roles of PAs have expanded to include human well-being and equitable governance objectives. Some contend that these objectives are mutually supporting, with 'win-win' outcomes possible for people and nature. However, others consider these objectives to be competing" (Loveridge et al 2022 p1).

Loveridge et al (2022) reported the case study of a FLR project in Tanzania that showed "both win-win and trade-off pathways" (p6). Potential income from controlled timber sales which could be spent to benefit the whole community was a positive, whereas the conflict between restoration and agriculture was an example of a negative. As one community member said: "The government extended the national forest reserve boundary and so we have been left with a small area for farming. That land, it was very fertile, it was supporting us to have high production and we had a lot of food surplus. But now we have little food because we harvest very little" (p6).

Meeting multiple (or competing) objectives for FLR projects (and PAs) that include restoration and human well-being has "no simple solution", but "developing understanding of the pathways linking social and conservation outcomes can help identify opportunities to promote synergies and mitigate negative impacts to reconcile competing objectives" (Loveridge et al 2022 p1).

Landholders and land users can be encouraged to participate in FLR projects via incentive mechanisms (eg: direct payments for converting agricultural land into forest; funding for community development projects). In a survey of the literature, Tedesco et al (2022) found that "direct payments (eg: PES [Payment for Ecosystem Services]), financed mainly through government budgets, carbon offset mechanisms and funds and grants, were the most commonly described incentive mechanisms for forest restoration" (p6)

The amount, the length of the scheme, and the promptness of payment were all found to be important in developing engagement and trust of landholders (Tedesco et al 2022).

` Tedesco et al (2022) ended: "No incentive type is universally suitable for all socio-economic contexts; as such, mechanisms to promote restoration should be selected based on local needs and context" (p10).

vi) "Where should forests be restored?" (p6).

vii) The financing of FLR.

viii) Addressing the forest disturbances (eg: logging, mining, fire, flooding).

ix) The science of disturbances - "Ecosystem disturbance can impact soil through agricultural chemicals, machinery compaction, erosion and, in the most extreme circumstances (eg: mining), total removal or contamination. Accordingly, stabilisation of soil and maintaining or enhancing hydrological functions and quality are frequently cited within forest restoration objectives. Soils and below-ground processes are under-represented in the restoration science literature, with relatively limited knowledge on the impacts of disturbance, or the role of plant–soil interactions in ecosystem recovery" (Marshall et al 2022 p7).

x) FLR and the impact on water quantity and quality.

xi) The impacts on animals.

xii) The practicalities of tree-planting - "Tree-planting is central to most forest restoration projects and yet it remains controversial because of multiple past and ongoing widespread and large-scale mistakes and misclassifications, eg: planting monocultures, exotic/invasive species or ecologically inappropriate species, inappropriate locations and inadequate local input/collaboration" (Marshall et al 2022 p8).

xiii) Native vs exotic/invasive species and their management.

xiv) How to measure success in FLR?

xv) How to monitor progress?

Marshall et al (2022) summed up: "Clearly communicated scientific evidence for action at the outset of restoration planning will enable donors, decision makers and implementers to develop informed objectives, realistic targets and processes for accountability" (p1).

The growing visibility of "restoration science" in recent years has raised some issues. "Some are concerned that the potential of habitat restoration has led to a focus on tree planting rather than protecting existing forests. Others worry that restoration projects are being used as 'greenwash' by countries and companies to avoid reducing their fossil fuel emissions. Indeed, while some argue that a focus on ecosystem restoration is harnessing the power of nature to tackle societal problems, others claim that it is merely another tool being used to extend today's unsustainable and unjust status quo" (Lewis 2022 p1).

Lewis (2022) offered six recommendations for restoration scientists:

a) Do data-driven studies to show what interventions work.

b) Focus on meaningful results rather than "on getting a 'big number' published, which then generates widespread publicity" (Lewis 2022 p2).

c) Improve reproducibility of studies and findings.

d) Explain the context of findings.

e) Be aware of practicalities, like economics (ie: the cost of FLR).

f) Consider the social and environmental impact of research.

Seed dispersal by animals is an important part of "passive restoration" (ie: natural forest development). "Typically, small-seeded tree species dispersed by small birds, bats and wind colonise abandoned agricultural areas. These species form the canopy that encourages colonization by larger birds and mammals that bring in larger-seeded and later-successional tree species" (Estrada-Villegas et al 2022 p2).

Studying an area in Panama over twenty years, Estrada-Villegas et al (2022) found that dispersal by flightless mammals was crucial, while larger birds (compared to smaller ones) were more important as the forest aged.

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4. PSYCHOLOGICAL OWNERSHIP

Pro-environmental behaviour can be motivated by a feeling of "psychological ownership of nature (ie: the feeling that nature is 'mine/ours')" (Wang et al 2023 p1).

Work on the concept generally by Pierce and Jussila (2011), for example, suggested that psychological ownership develops from controlling the ownership object, knowing it intuitively, and investing in it (ie: not necessarily only financially) (Wang et al 2023).

Wang et al (2023) developed a scale to measure psychological ownership of nature (both at an individual and a group/collective level). Firstly, potential items were generated from the literature and experts, and nine were used. These items were presented online to Australian volunteers (427 who completed and individual version and 409 a group version). After analysis six items were retained (table 4.1).

- I feel like the natural environment in this place is *mine/ours*.
- Emotionally, I feel that nature in this place is *mine/ours*.
- When I visit this natural place, I feel as though it is *mine/ours*.
- I feel a sense of *personal/collective* ownership towards nature in this place.
- I feel that the natural environment in this place belongs to *me/us*.
- I have a sense of *personal/collective* ownership towards the plants and/or animals when I am in this natural place.

(Source: table 1 Wang et al 2023)

Table 4.1 - Items on psychological ownership of nature.

High scores were associated with pro-environmental behaviours, and environmental concern (as measured by other questionnaires) as expected, but also with "territoriality (ie: feelings that others should not use or visit that natural place), which could lead to interpersonal conflicts concerning the use of the place..." (Wang et al 2023 p8). This was stronger for the individual version of the scale. Also: "Individual (but not collective) psychological ownership was also linked to dominionistic beliefs toward nature, implying that when people feel that 'nature is mine', they might treat it as they please, thus potentially resulting in negative environmental outcomes (eg: nature exploitation)" (Wang et al 2023 p8). Pierce and Jussila (2011) had noted this "dark side" of psychological ownership.

Though there were some differences between the individual and group versions of the scale, the difference between individual and collective psychological ownership needs further research, Wang et al (2023) accepted. Also, although the sample was representative of the general population in Australia in certain ways, like age and gender, the survey was online in October 2020. Wang et al (2023) stated: "Collecting several rounds of data for scale testing and retesting would better inform our understanding of stability and generalisability of findings" (p9). Furthermore, participants were instructed to think about a special place in the natural environment before answering the questions rather than about nature and the environment generally. So, psychological ownership may be "place attachment" only here.

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5. ENVIRONMENTAL IMPACT OF COVID-19

The impact of covid-19 on the environment can be assessed in terms of three "time horizons" - during lockdowns, during the post-lockdown economic recovery, and after the economic recovery (Diffenbaugh 2022). "Likewise, there are at least three broadly identifiable degrees of causal linkage between the pandemic and environmental impacts: (a) primary impacts from the lockdowns, (b) secondary impacts from the lockdowns, and (c) impacts from cascading effects" (Diffenbaugh 2022 p68).

Writing in early 2022, Diffenbaugh (2022) outlined some known and potential impacts, including:

i) Short-term impacts:

a) Greenhouse gases - A reduction in emissions during lockdowns because of the limited amount of vehicle use (eg: an early estimate of a 7% decline in global CO_2 emissions in 2020; Diffenbaugh 2022).

b) Air quality - Early studies showed that lockdowns produced "substantially reduced air pollution" (Diffenbaugh 2022 p72).

c) Climate - "Changes in atmospheric composition due to covid-19 emissions reductions are not thought to have caused a detectable change in global temperature or rainfall in 2020" (Naik et al 2021 quoted in Diffenbaugh 2022).

d) Terrestrial ecosystems - For example, changes in the behaviour of animals as humans vacated areas during lockdowns, responses to reduced air and noise pollution, but increased plastic pollution from masks and PPE (personal protective equipment).

e) Marine ecosystems - eg: masks and PPE waste. "There is notable uncertainty about the lifetime of plastics in the ocean, and the input of masks and other PPE-related debris is likely to eventually decrease if prevalent and effective vaccination eventually makes widespread mask wearing less common. However, the environmental impacts of plastic debris are still likely to last past the period of widespread mask wearing" (Diffenbaugh 2022 p77).

ii) Potential long-term impacts:

a) Policies to reduce future pandemic risk - eg: control of the wildlife trade.

b) Post-pandemic economic stimulus - Economic stimulus policies will vary in impact depending on them being "green" (ie: environmentally-friendly policies) or "brown" (eg: use of fossil fuels).

c) Structural changes in society and behaviour - "For example, if comfort with remote work and/or discomfort with crowded work locations cause large fractions of the workforce to continue to work remotely or in a hybrid format after the pandemic recedes, the reduced commuting could alleviate congestion and associated air and noise pollution in urban areas. Similar transitions in recreation and entertainment (eg: away from crowded central locations and toward residences) could have similar local environmental impacts. However, it has been hypothesised that prolonged social distancing and fear of infection could strengthen individual preferences that contribute to aggregate environmental impacts, such as preference for personal vehicles over mass transit" (Diffenbaugh 2022 p81).

d) Poverty - "Although the relationships are complex, multiple lines of evidence identify poverty as a driver of environmental outcomes, including via the impacts of food and energy insecurity on resource extraction, habitat destruction, and local air and water pollution" (Diffenbaugh 2022 p82). For example, a reduction in income from tourism could lead to increasing poaching and illegal wildlife trading.

From the position of early 2022, Diffenbaugh (2022) concluded that "the balance of the literature suggests that the majority of the most lasting impacts are likely to result from social, political, economic, and behavioural cascades — and are likely to have negative environmental consequences. However, given the dynamic nature of both the pandemic and the literature, further research is clearly needed to fully understand the many dimensions of both short- and long-run impacts of the covid-19 pandemic. Indeed, it will likely be years before the totality of the environmental impact is comprehensively understood" (pp83-84).

THE FUTURE

MacAskill (2022a) argued for "longtermism", which is "the view that we should be doing much more to protect the interactions of generations to come" (MacAskill 2022b p27).

He proposed three reasons for such a view:

i) Future people matter in the sense that all individuals have moral worth.

ii) If humanity continues as a species, then there will be many more people. "This means we are probably at the very beginning of history. It is likely that the vast majority of people - real people, who are capable of joy and suffering just like us - are yet to come" (MacAskill 2022b p27).

iii) It is possible now to do things to improve the lives of people in the future.

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6. ANIMALS IN THE CHERNOBYL EXCLUSION ZONE

An accident at the Chernobyl Nuclear Power Plant (then in the Soviet Union, but now Ukraine) in 1986 left a large area of land (approximately 2000 km^2) contaminated, and thus uninhabited by humans. Studies have been undertaken on the impact on nature.

The first rigorous surveys of animals and plants in the Chernobyl Exclusion Zone (CEZ) occurred in the mid-2000s. "Up to that time, discussions of animal abundances had been largely qualitative and anecdotal. There was a notion in the popular media, perpetuated by a handful of scientists mostly without rigorous data, that many animals were thriving in the Chernobyl Exclusion Zone, presumably because of an absence of human predation. There was also a politically motivated undercurrent promoting the notion that what appeared to be a thriving ecosystem was evidence of the benign effects of low-dose radioactive contaminants" (Mousseau 2021 pp90-91).

A literature search by Mousseau (2021) found a limited number of studies on the ecology and evolution of Chernobyl organisms. He concentrated on the top twenty most impactful studies (based on number of citations).

The first rigorous test of genetic mutation due to radiation was of barn swallows (Ellegren et al 1997). Mutation rates were 2-10 times higher in offspring as compared to control populations in Ukraine and Italy. Moller and Mousseau (2006) found 33 similar studies that compared animals or plants in the CEZ with control populations. "There is considerable heterogeneity in the results, with 25 of the studies showing an increase in mutations or cytogenetic abnormalities. Several studies showed an increase in mutation rates for some loci but not for others" (Mousseau 2021 p96).

Moller and Mousseau (2015) performed a meta-analysis of forty-five studies covering ten species, and found "a very large overall effect size" (Mousseau 2021 p96) for radiation on offspring genetic diversity. The impact varied between species. "Overall, this study provides perhaps the strongest evidence compiled to date of the mutagenic consequences of chronic exposure to ionising radiation in natural populations" (Mousseau 2021 p96).

Looking at specifics, Moller et al (2005) found a frequency of abnormal sperm as ten times higher in barn swallows near Chernobyl than elsewhere, while Hermosell et al (2013) confirmed this difference for nine out of ten bird species. Other aspects of sperm have been reported as impacted in other studies (eg: sperm swimming behaviour) (Mousseau 2021). Similar findings with bank voles have been reported. While a study of 22 generations of voles found elevated rates of chromosomal abnormalities (Ryabokon and Goncharova 2006).

Sterility (or aspermy - ie: no viable sperm) has been found in 40% of 566 male birds examined in the most contaminated areas of the CEZ (Moller et al 2014).

Other changes in animals include partial albinos among barn swallows, shortened calling songs in cuckoos, and decreased brain size in birds and voles (Mousseau 2021).

Looking more widely at populations, fewer birds have been observed, with "a dose-response-like relationship, with approximately one-third as many birds and half as many species present in high contamination areas relative to the numbers predicted..." (Mousseau 2021 p99).

A comprehensive study of mammals (Moller and Mousseau 2013) found that "there were fewer animals in more radioactive areas but that there were significant differences among species in their response to radiation. In particular, predators were found to increase disproportionately with prey numbers at high radiation levels" (Mousseau 2021 p102). This study used footprints in 161 100 metre areas 1-2 days after fresh snow fall.

Other methods used include motion camera traps (which rely on animals passing, and depend on the time frame), and aerial (helicopter) surveys of tracks in the snow. "Aerial surveys capture only larger animals that are not afraid of the noise from the helicopters, and scented camera traps capture only animals that are drawn to the camera as a result of the smells. In addition, camera surveys, especially ones that capture only a few hundred images, likely do not have the statistical power to test for variation in abundance" (Mousseau 2021 p103).

Mousseau (2021) ended: "There is little doubt that even the relatively low levels of radiation experienced by most organisms inside the exclusion zone can generate significant genetic damage and elevated mutation rates" (p103).

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7. HUMAN-ANIMAL INTERACTIONS

7.1. URBAN PEREGRINE

"Urbanisation is generally associated with habitat degradation that makes human environments unsuitable for many sensitive raptor species, yet some populations manage to persist in cities... Others thrive, achieving high population densities or greater breeding success than conspecifics in more natural sites" (Mak et al 2023 p796). The availability of abundant food may over-ride the negative consequences of urbanisation. The food sources available include humans intentionally providing meat as part of religious ceremonies, roadkill, discarded food waste and litter to scavenge upon, or human pets (eg: racing pigeons). But the greatest food source may be prey species that live on food waste of humans (eg: feral pigeons; rats) (Mak et al 2023).

Raptors that depend directly or indirectly on anthropogenic food sources could be vulnerable to human behaviour changes. One case is the peregrine falcon (Falco peregrinus) in the UK during the covid-19 lockdowns.

Mak et al (2023) selected thirty-one sites of urban peregrine nests with online live streams between 2020 and 2022. Diet and breeding data were analysed, including from the online streams, for London (five sites) and elsewhere.

Three main groups of prey species were identified - starling, pigeon, and parakeet. The make-up of the peregrine diet significantly differed between lockdown and non-lockdown years. In London, less pigeons and more starlings were eaten, but elsewhere there was no change. However, during lockdowns outside London, more non-dominant prey (eg: waterbirds) was eaten. "Feral pigeons are known to depend on human food subsidies in urban areas (eg: litter around eating establishments, direct feeding) and the scarcity of such resources during the lockdown likely reduced their abundance at feeding hotspots... While starlings also take anthropogenic food, they may have been more resilient towards these shortages by being able to rapidly switch to remnant natural food sources (eg: at local green spaces) and were, thus, less vulnerable" (Mak et al 2023 p802). Outside London, it was assumed that pigeons could find alternative food sources.

Breeding data (ie: number of eggs, hatchlings, and fledglings) showed no significant difference between lockdown and non-lockdown years in any sites, which suggested that "urban peregrines may not have experienced food shortages amidst restrictions" (Mak et al 2023 p795). This was contrary to researcher expectations.

The researchers did not have pre-covid-19 data for comparison, and they were not able to show the longer term impact of lockdowns.

In conclusion, Mak et al (2023) felt that "human activity, while influential, is unlikely to be more important than other factors such as habitat availability determining the predation opportunities for the urban peregrines" (p802).

7.2. MIXED MESSAGES

Humans and animals can co-exist. In urban areas, for examples, animals become habituated to humans, especially when fed intentionally or unintentionally (eg: food waste left out) by humans. "Intentional feeding of wild animals is often discouraged as it changes natural behaviour patterns, but is popular in many parts of the world. In the United Kingdom, garden bird feeding is so prevalent that it has selected for longer bills in great tits (Parus major)" (Goumas et al 2022 p2).

Some species (eg: bears and foxes) receive "mixed messages" from human populations - provisioned by some individuals while hunted by others. The ability to recognise individuals who do the former has been observed (eg: feral pigeons; American crows; Eurasian jackdaws). For example, African elephants in Kenya's Amboseli National Park seem to be aware that it is Masai men who hunt elephants (Goumas et al 2022).

Goumas et al (2022) developed computer modelling of an animal's decision to "avoid encountering a human, or stay on their foraging ground and be subject to the human's actions whether dangerous, rewarding or neutral" (p2).

A number of points emerged, including:

i) Where all humans behave in the same way (attack or provision), one strategy works.

ii) In reality, a population will include a mixture of human behaviours, and so speed of learning, individual recognition (IR), and observational learning are key.

iii) Humans may be a lesser evil compared to other predators. "In some scenarios, 'prey' species such as deer may choose to stay close to areas with high human disturbance, as these areas are less commonly used by large carnivores" (Goumas et al 2022 p13).

iv) The frequency of encounters with humans.

Goumas et al (2022) concluded: "Animals are unlikely to use or require full IR, but some ability to discriminate among humans will always be beneficial when different, but repeatedly encountered, humans engage in contrasting behaviours" (p15).

7.3. URBAN EVOLUTION

"Urban evolution" is the study of the impact of cities on species' evolution. Diamond and Martin (2021) noted three "major research axes" - "investigating mechanisms (selection, gene flow, mutation, and drift), answering basic versus applied research questions, and using cities to isolate particular variables (eg: heat, aridity) versus examining pan-urban ["areas adjacent to the city footprint"] effects" (p520). Yet cities are "simply another ecotype or biome" (Diamond and Martin 2021 p521).

Diamond and Martin's (2021) review of the topic highlighted a number of issues and questions, including:

i) Evolutionary changes can occur within and between cities. "Cities can be used to isolate specific drivers; for example, urban heat island effects can be examined by selecting sites where variables other than surrounding imperviousness are similar. Or cities can be used to explore evolution in response to multiple stressors; for example, responses to heat island effects and pollutants can be examined by selecting sites with elevated imperviousness and proximity to chemical run-off" (Diamond and Martin 2021 p521).

ii) How do organisms come to be in the city? Did they move there, or did the city appear around them? "For example, cities might filter individuals of a particular species, leading to shifts in the genetic composition of populations, or entire species might be excluded based on trait characteristics, leading to shifts in biotic interactions and selection landscapes" (Diamond and Martin 2021 p523).

iii) Defining an urban environment.

iv) The negative aspects of cities (eg: pollution) and mutation rates (eg: higher in heavily industrialised areas in mice and European herring gulls; Diamond and Martin 2021).

v) Adaptation. "Assuming organisms are reasonably well adapted to their ancestral environments, populations are likely to be displaced from this fitness peak when confronted with novel urban environments. Whether and how populations are able to recover from this urban-associated maladaptation is thus a central question" (Diamond and Martin 2021 p525).

Is there a cost to adaptation to the urban environment in relation to the original habitat, especially if urban areas decline or "regreening" occurs?

vi) Dealing with contradictory and conflicting results. Many studies show local adaptation (eg: acorn ants and heat - Diamond et al 2018; moths' colouring and pollution - Kettlewell 1955), but a few studies show no adaptation, and others a complex or varied picture (Diamond and Martin 2021).

vii) The city as laboratory that allows researchers to study aspects of evolution, like the time course of change, to compare individual (eg: heat) and multiple (eg: heat and pollution) stressors, and to investigate parallel or convergent evolution. The latter idea is that different species independently evolve the same "solution" to the same selection pressures. One meta-analysis found parallel evolution in fourteen of eighteen species studied (Santangelo et al 2020).

viii) Sexual selection in the city. This has been most studied in terms of sexual signals (eg: male tungara frogs in the city produce more conspicuous calls than rural counterparts, and so attract more females; Halfwerk et al 2019).

ix) New and different species interactions in the city.

x) New species (speciation) - eg: London Underground mosquito (Culex molestus) from the surface-dwelling common house mosquito (Culex pipiens) (Diamond and Martin 2021).

xi) Disentangling plasticity (adaptive behaviours in a generation) and evolution. "Whether more plastic species are more successful at entering and persisting in the city compared with less plastic species, and subsequently, whether those species evolve in response to urbanisation (ie: plasticity-led evolution), has not yet been tested... Alternatively, if plasticity is, on its own, sufficient to buffer organisms against urban stressors, such variation might be shielded from selection, dampening evolutionary responses to urbanisation" (Diamond and Martin 2021 p534).

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8. INVASIVE SPECIES

8.1. TOADS AND SNAKES

Invasive species are known to impact ecosystems by bottom-up (prey limitation) and top-down (predator removal) effects (Licata et al 2022).

Licata et al (2022) studied the arrival of the (toxic) Asian common toad (Duttaphrynus melanostictus) in Madagascar (likely around 2010). The researchers studied an area of lowland humid forest (Analabe), known to have at least eighteen species of native amphibians and sixteen species of native reptiles, between November 2018 and February 2019, and April to May 2019. A key predator is the Malagasy cat-eyed snake (Madagascarophis colubrinus), and their monthly numbers were calculated by area sampling. Mortality from poisoning from the invasive toad was recorded.

During the study periods, 54 snakes were counted, and nine carcasses were found. "All carcasses lacked any evident external injuries or trauma. In four cases, dead toads were found almost intact in the stomach, mouth, or next to the body of the snakes. In addition, the observation of an adult toad with a clear snakebite mark on the head, suggests that toads can sometimes survive snake predation attempts, despite likely poisoning the snake" (Licata et al 2022 p1193). It was estimated that the monthly rate of snake mortality was at least 6%. If this estimate is correct, this is an annual mortality of 50% of the snake population in this area.

This is an example of a top-down effect of an invasive species. "Toad-induced decline of snakes in Madagascar can reduce predation pressure on rodents and insectivores and facilitate their expansion, especially if these species are not impacted by toad poisoning, such as the rat Rattus norvegicus... An increase of rats may result in reduced harvest yields and stored food quality..., and potentially increase the transmission rates of rodent-borne zoonotic diseases" (Licata et al 2022 p1195).

The estimates of snake numbers, and deaths were based on area sampling - eg: 150 m^2 areas visited daily during the observation periods. Standard methods of sampling were used by the researchers.

Invasive snakes are often a problem (eg: brown tree snake in Guam; Burmese python in Florida; horseshoe snake in the Balearic Islands) (Piquet and Lopez-Darias 2021).

Piquet and Lopez-Darias (2021) measured the impact of the California kingsnake (Lampropeltis californiae) on three species (herpetofauna) - Gran Canaria giant lizard (Gallotia stehlini), Gran Canaria skink (Chalcides sexlineatus), and Boettger's wall gecko (Tarentola boettgeri) in Gran Canaria (Canary Islands) in May-September 2018. North, east and south parts of the island have been colonised since the snake's arrival via the pet trade in 1998. A non-invaded area in the south was used as a comparison.

The three species of prey were significantly less dense in the invaded areas than the non-invaded one - 90% less of the lizard species, 80% less of the skink, and 50% less of the species of gecko studied. So, "considering that no snakes have ever naturally occurred on Gran Canaria, all endemic reptiles in this island are likely lacking anti-predator responses against L. californiae, as no co-evolutionary history exists between these taxa" (Piquet and Lopez-Darias 2021 p4).

8.1. FRESHWATER FISH

"The growth of global trade has resulted in the intentional and unintentional displacement of many species beyond their natural geographic ranges... From 1800 to 2000, new species introductions increased worldwide, and this trend is expected to continue over the next few decades... These new species introductions can lead to biological invasions, which are a major source of change and decline in global biodiversity" (Bernery et al 2022 p428) [3].

This type of invasion has five stages (Bernery et al 2022): the transport of a species beyond its natural range by humans, introduction into a new area, establishment (ie: a self-reproducing population), spread, and impacts.

Freshwater fish species is a prime example of this process, with over 500 non-native species established (Bernery et al 2022). The main pathways of introduction are aquaculture (ie: farming of fish), ornamental trade (eg: "pets"), release of bait for anglers, and biological control (eg: mosquitofish species to control mosquito populations). Human construction may interconnect waterways and fish species can move in this way (eg: the

[3] Elton (1958) produced the seminal work on invasions (Bernery et al 2022).

Panama Canal allowed movement from the Rio Chagres and the Rio Grande systems (Bernery et al 2022).

Not all invasive species survive and spread. Bernery et al (2022) outlined four key factors influencing invasion success:

i) Propagule pressure - "Propagule pressure (also termed 'introduction effort' [Blackburn and Duncan 2001]) is a composite measure of the number of individuals released into a region to which they are not native. It incorporates estimates of the absolute number of individuals involved in any one release event (propagule size) and the number of discrete release events (propagule number). As the number of releases and/or the number of individuals released increases, propagule pressure also increases" (Lockwood et al 2005 p223).

ii) Life history traits - eg: adaptability and plasticity of behaviours.

iii) Residence time - The time since the first recorded introduction.

iv) Characteristics of the invaded ecosystem - eg: similarity between original and new environments; diversity of native species; potential predators ("enemy release"). "The enemy release hypothesis [Torchin et al 2003] states that an introduced species often experiences a reduction in predators, parasites, or pathogens in its new ecosystem compared to its native range" (Bernery et al 2022 p437).

There is another concept known as "invasional meltdown" (Simberloff 2006). The presence of already established invasive species "may directly or indirectly increase the chances of success for new invasive species" (Bernery et al 2022 p437) [4].

In terms of the impact of invaders, the "Global Invasive Species Database" listed, in order, competition over resources (ie: outcompete native species), predation, hybridisation (ie: the mating of two genetically distinct populations), disease and parasite transmission, and impact on habitat (eg: burrowing or digging) (Bernery et al 2022) (table 8.1).

[4] Enders et al (2020) proposed 39 hypotheses about invasive success and impact (Bernery et al 2022).

IMPACT	EXAMPLES
Predation	* Peacock bass in Lake Gatum, Panama. * Nile perch in Lake Victoria.
Hybridisation	* Nearly half of crucian carp in the UK are hybrids with goldfish. * Sheepshead pupfish and Pecos pupfish in Pecos River, Texas.
Disease and parasite transmission	* Topmouth gudgeon carries rosette agent parasite without being affected by it. * Asian fish tapeworm carried by carps, guppies, and mosquitofish.

(Source: Bernery et al 2022)

Table 8.1 - Examples of impacts of invasive freshwater fish species.

The response to invasive species, particularly in relation to future events, include strategies like prevention (eg: legal restrictions on transporting fish species), containment, and eradication. "As long as the area of invasion is very limited, and the non-native population is small, eradication using several possible methods may be logistically and financially feasible. Chemical treatments such as rotenone have been widely used for years to eradicate species rapidly and efficiently, but they are also toxic to non-target species... and not well accepted by the public" (Bernery et al 2022 p442).

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