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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. TOURISM IN THE FUTURE

Tourism is "recognised as one of 12 key global-scale geophysical forces reshaping the earth for human purposes" (Holden et al 2022 p424).

Holden et al (2022) explained: "Given its carbon-centric mobility demands, its exponential growth, a historical expediency of resource usage to secure short-term economic and financial gains, as well as the incremental and cumulative character of environmental impacts accompanying its geographical expansion, combined with the nebulous and fragmented structure of the industry that makes its regulation problematic, tourism is a voracious consumer of nature" (pp424-425) [1]. Furthermore, tourism is not equally accessible to all on the planet. Pirie (2008) described this inequality as an issue of "mobility morality", "necessitating a reconceptualisation of tourism mobility in terms of fairness, equity, environmental justice, and human rights" (Holden et al 2022 p425).

Holden et al (2022) outlined the main issues around the future of tourism in terms of climate change:

1. The impact of mass mobility - eg: economic, environmental, cultural, and social.

The prime impact is through the carbon-centric energy of mobility. Around 10% of global greenhouse gas (GHG) emissions have been attributed to tourism (with about half of that coming from aviation) (Holden et al 2022).

But, as mentioned previously, tourism in unevenly distributed and so is the responsibility for the GHG emissions (eg: 15% of the population took 70% of the flights in the UK in 2018; Holden et al 2022).

An example of inequality in resource use linked to tourism can be seen with water. This is "not infrequently a scarce resource in places with tourism-dependent economies, where the industry may use excessive amounts of water to the detriment of local inhabitants who experience rising prices, water shortage, and increased hardships... For example, the development of golf courses in parts of South-east Asia has been criticised for excessive water usage and their encroachment into protected forest areas, farmlands, and Indigenous territories. The consequential displacement of peoples for tourism development and the denial of people access

[1] Fisher (2023) described societies as "time-blinkered". This is "worse than simple short-termism: it is a present-focused view so embedded that it goes unnoticed" (Fisher 2023 p47).

to traditional natural and cultural resources raise political and ethical issues of the rights of local citizens and Indigenous peoples in the face of development" (Holden et al 2022 p429).

Then there is "over-tourism", which describes the situation "where destinations are overrun by mass numbers of visitors, resulting in the depletion of natural ecological goods, the destruction of cultural attractions, and negative social and economic impacts in the destination" (Holden et al 2022 p430). The reaction from some local populations has been anti-tourism and anti-tourist (Holden et al 2022).

2. Changing tourism - Put simply, tourism needs to become carbon-neutral, and environment-friendly. "Central to tourism is the tourist and the willingness to adapt behaviour to reduce tourism's carbon footprint will be essential for achieving this goal. However, individual concern for the environment tends to be unrelated to holiday behaviour, suggesting either an unawareness of tourism's environmental impacts or the non-acceptance of it as a cause of climate change. Buckley [2011] suggests a state of cognitive dissonance exists, manifesting itself in a justification of holiday enjoyment even if aware that the environment is being damaged by tourism" (Holden et al 2022 p433).

This latter is seen in "last-chance tourism" (LCT), where visitors travel to environmentally highly vulnerable areas like the Arctic and Antarctica. "The desire for LCT seemingly supports Weaver's [2011] observation that the norms of tourism mobility developed in recent decades will not change through some groundswell of voluntary social change but, instead, require coercion. With specific reference to flying, it appears the personal benefits outweigh the nebulous societal cost of climate change, with evidence suggesting that many travellers place responsibility for reducing GHG emissions on the industry and government" (Holden et al 2022 p433).

Suggestions for improvement include the application of the "circular economy" to tourism, and the connection of people to nature in "sustainable tourism" or "nature-positive tourism". "The creation of nature-positive tourism has to meet the challenges of being able to fulfil a universal right to tourism within environmental and social limits according to principles of social justice and equity. The fulfilment of this challenge will permit a sustainable future for tourists and those whose livelihoods are economically dependent on the sector while ensuring ecosystem and biodiversity conservation. This requires rethinking what 'we' as a global society aim to achieve through tourism and the values that determine the evaluation of the success of its development" (Holden et al 2022 p436).

Holden et al (2022) ended with this example: "Environmental consciousness could also be raised through government legislation requiring clearer messages about how our choice of travel and accommodation purchases influence GHG emissions. For example, it could be made compulsory for aviation advertising to exhibit warning messages about the contribution of GHG emissions from your chosen flight to global warming. This would follow a similar principle to the way cigarette packs are required to provide public health warnings of how smoking may cause cancer, for example, 'Your flight from Madrid to San Francisco contributes as much to global warming as heating your house for a year and a half'" (p440).

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2. ASSESSING BIODIVERSITY CHANGE

2.1. INTRODUCTION

Tekwa et al (2023a) observed that "biodiversity change is implicated in the sustainability of food provision, ecosystem regulation, habitat protection, carbon sequestration, cultural identity and tourism" (p1). But how to assess that change?

There are challenges: "Designing sampling protocols, identifying metrics, correcting estimation bias, quantifying uncertainties, attributing causes, projecting future pathways and designing policies are components that contain major and often underappreciated knowledge gaps" (Tekwa et al 2023a p2).

Tekwa et al (2023a) noted four major themes in assessing biodiversity change:

i) Policy motivation and scientific frameworks - eg: the need for formal standards for detecting and attributing change.

ii) Observation networks - eg: camera trap surveys to provide knowledge about changes within and between species.

iii) Statistical estimation - eg: developing models based on actual data and/or because of lack of data.

iv) Attribution and projection - eg: how species will adapt to biodiversity changes.

Dasgupta and Levin (2023) criticised the economic model of global capitalism in relation to biodiversity loss. They stated: "Contemporary economic thinking does not acknowledge that the human economy is embedded in Nature; it instead treats humanity as a customer that draws on Nature" (Dasgupta and Levin 2023 p1). These researchers wanted to reject Gross Domestic Product (GDP) as the dominant measure of income and wealth, and replace it with "inclusive wealth". This idea includes humans as embedded in Nature, and the recognition of the cost of the "free services" of the environment. This requires use to "develop an affection for Nature's workings, an appreciation of the infinite complexity and mystery of what goes on in the world around us" (Dasgupta and Levin 2023 p11).

2.2. POLICY MOTIVATION AND SCIENTIFIC FRAMEWORKS

Gonzalez et al (2023) observed: "While the magnitudes and even directions of biodiversity change are varying from place to place, there is considerable evidence that multiple dimensions of biodiversity are changing rapidly in many places, including genetic diversity, population abundances, range sizes and distribution, turnover in community composition and global species number" (p1). Humans have caused some of the changes as well as natural (non-human) factors, and the interaction between the two.

Formalising assessment of such changes is important. "For example, statements that the current rate of extinction is 10–100 times the background rate in the fossil record involves the detection of a significant increase in estimated extinction rate. However, this estimate has high uncertainty because of incomplete knowledge of past and current extinction rates estimates for known and unknown taxa" (Gonzalez et al 2023 p2). The requirement is for a "detection and attribution" (D&A) framework.

In relation to climate change, the Inter-governmental Panel on Climate Change (IPCC) has such a framework - "the first objective is to assess the evidence that some aspect of climate (eg: extreme weather), and/or a system affected by climate (eg: ocean chemistry as indicated by pH), has changed over time (detection). The second objective is then to evaluate the contributions of multiple potential drivers of this change (attribution)" (Gonzalez et al 2023 p2).

Gonzalez et al (2023) introduced such a framework for biodiversity change and ecosystem impacts. Firstly, they defined the terms. Detection is "the process of demonstrating that a measure of biodiversity has changed relative to a baseline or reference distribution characterising undisturbed variation (counter-factual state), or an appropriate model-derived null expectation of biodiversity change in the absence of a human driver(s). A clear statement of statistical confidence should be given" (Gonzalez et al 2023 p3). Attribution is defined as "the process of evaluating the relative contributions of multiple potentially causal factors to detected biodiversity change with an assignment of statistical confidence to the causal models used to estimate these effects" (Gonzalez et al 2023 p3).

Gonzalez et al (2023) described five steps in their D&A framework:

i) Causal models - hypothetical models to explain potential biodiversity changes.

ii) Observation - the collection of data in the real world.

iii) Estimation - "the process of combining observations into statistical estimates of metrics quantifying aspects of biodiversity, including the use of measures of uncertainty and replication" (Gonzalez et al 2023 p4).

iv) Detection - the assessment of change in relation to a baseline or reference point.

v) Attribution - to estimate the causal effect of potential drivers of change. This process has "three key ingredients":

a) Evidence of consistency - whether the detected change is consistent with known facts (eg: species richness is greater in areas isolated from humans).

b) Evidence of inconsistency - change in unexpected directions which highlight previously unknown or unexpected factors, and prevent confirmation bias; "(ie: the tendency to favour information that confirms existing preconceptions or hypotheses). Similarly, we want to avoid biased interpretation (ie: where some hypotheses are not confronted with high standards of evidence)" (Gonzalez et al 2023 p8).

c) Statement of confidence - the degree of confidence in the conclusions.

The researchers hoped that a D&A framework would lead to biodiversity indices, for example, could help in policy decision-making and goal setting. They stated: "This framework could strengthen the bridge between biodiversity science and policy and support effective actions to halt biodiversity loss and the impacts this has on ecosystems" (Gonzalez et al 2023 p1).

Biodiversity science is reflecting on the systems of power, equity and justice that underlie it. "At the heart of these introspections are questions surrounding the worldviews and associated values that motivate science, influence environmental decision making, and ultimately, determine who benefits and how" (Salomon et al 2023 p2).

That is, the values behind it. "Yet, values are often unstated, unrecognised, assumed or overlooked. For example, the sciences that seek to quantify and understand biodiversity tend to be predicated on Eurocentric values, voices, and knowledge systems where people are considered external disruptors to and beneficiaries of biodiversity, rather than prominent components of it. Moreover, the management of biodiversity on land and in the sea tends to reflect individualistic and instrumentalist values such that populations of non-human species are termed 'stocks' or 'natural resources' available primarily for exploitation" (Salomon et al 2023 p2).

Indigenous and First Nations peoples have different values ans views, and Salomon et al (2023) outlined the principles of seventeen Indigenous Nations from the North-West coast of North America. These authors stated: "To enhance environmental sustainability, resilience and social justice amid today's crises, we need to broaden who benefits from and participates in the sciences of biodiversity by expanding the values and methodologies that shape such initiatives. In practice, biodiversity conservation and natural resource management need to shift from centralised, siloed approaches to those that can accommodate plurality in values, objectives, governance systems, legal traditions and ways of knowing. In doing so, developing solutions to our planetary crises becomes a shared responsibility" (Salomon et al 2023 p2).

The principles include respect, responsibility, reciprocity (ie: giving back to nature), accountability (making things right), interconnectedness, balance, and stewardship/caretaking (Salomon et al 2023).

2.3. OBSERVATION NETWORKS

Automated and continuous audio and visual sensors (eg: camera traps; CTs) "have the capability to provide novel characterisations of natural systems, as they facilitate data collection at larger spatio-temporal scales than what is possible using traditional data collection techniques, such as point counts and sign surveys" (Oliver et al 2023 p2). But they produce vast amounts of data which requires artificial intelligence (AI) systems to help in analysis.

CTs have three main advantages over traditional human observation (Oliver et al 2023):

i) Non-stop recording vs selective sampling of humans.

ii) They "collect information on many species, so that, in a given location, CT data may observe a larger proportion of species expected to occur there compared to other data collection techniques, especially difficult to detect or elusive species" (Oliver et al 2023 pp2-3).

iii) Easier to deploy in remote locations, and "therefore may provide information about portions of species' ranges not covered by other data sources" (Oliver et al 2023 p3).

Oliver et al (2023) provided evidence for these advantages with data from the "Global Biodiversity Information Facility" (GBIF) [2], which provides publicly available CT data, and "Wildlife Insights" (WI) [3], which uses AI for species identification. Data for 1st January 2022 and 26th November 2022 were downloaded.

CTs recorded species, particularly mammals, not documented by other sources (eg: mass observation projects). Comparing bird and mammal species recorded, Oliver et al (2023) stated: "In general, camera trapping studies tend to be more focused towards mammal species than birds. Additionally, the majority of studies deploy cameras near the ground, where relatively fewer bird species are active, and with settings and placement of the devices aimed at detecting large-bodied species" (p8).

The researchers further pointed out: "Although CTs may be deployed to monitor a specific species, they record information of all species for which they capture an image. Cameras may also be less obtrusive than other data collection techniques and thus better able to detect elusive species. CT studies provided much more consistent sampling in the locations where they were deployed" (Oliver et al 2023 p6).

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[2] See https://www.gbif.org/.

[3] See https://www.wildlifeinsights.org/.

Platforms, like GBIF and WI, that collect CT (or any) data depend on the willingness of providers to share data. For example, only a quarter of WI data are publicly available (Oliver et al 2023).

The advantages of CTs outlined above, fit with Mori et al (2023) observation that "biodiversity inventories are typically more comprehensive near locations that offer convenient access, infrastructure and logistics" (p2). Furthermore, they pointed out that "extensive infrastructure is often required for observations that cannot be systematically established and maintained in many locations. Finally, it is difficult to establish a global systematic network of monitoring across sectors and countries with different economic and cultural status, requiring an equitable solution" (Mori et al 2023 p2).

New techniques in monitoring include space-borne monitoring, environmental DNA (eDNA) (extracting the DNA left in the environment by animals - eg: in seawater), and "citizen science" or public involvement. Mori et al (2023) speculated that, for example, "tourists could be trained to collect data on wildlife sightings, water quality, or other ecological indicators, which could then be used for research and monitoring purposes" (p11).

2.4. STATISTICAL ESTIMATION

It is is crucial to know how many species there are and how the numbers are changing. It is not possible to observe all animals, so estimations will be made based on statistical models from actual data. These are called "species richness estimators" (Tekwa et al 2023b) (appendices 2A and 2B).

"Commonly, biodiversity observations include individual counts identified to the species level. One obvious way to improve biodiversity observation is to increase sampling effort, but this is costly and not possible for some taxa, habitats and historical samples. Insufficient sampling effort can increase bias, reduce estimation precision (repeatability) and undermine efforts to detect change over time, but a robust, unbiased estimator can recover missing observations to some extent" (Tekwa et al 2023b p2).

Tekwa et al (2023b) listed some technical problems with estimates, including the fraction of the total number of individuals observed by researchers that is the basis of estimations, and the number of areas (patches) sampled.

Climate change is producing two key observed changes in animals - distribution shifts (ie: where they live), and population abundances (ie: their total numbers) (Malchow et al 2023). Statistical modelling could help in understanding these changes and predicting the future.

Malchow et al (2023) presented an example based in Swiss birds. In the European Alps, different species live at different elevations, but warming is and will change their distribution. For example, if it becomes too hot at lower levels, a species may move upwards, and this will impact the residents at that elevation.

Data for the modelling included the Swiss breeding bird survey 1999-2019, and climatic information focused on five variables. The most influential climatic factors impacting bird populations were found to be mean breeding-season temperature (April-July), and total winter precipitation (December-February) (as opposed to total precipitation during the breeding season, and mean temperature in autumn or winter). There were some differences between the nine species focused upon (eg: bullfinch; dunnock; common linnet).

2.5. ATTRIBUTION AND PROJECTION

The collection of data will help in attribution and projection of biodiversity change. But, based on a study of European birds, Gregory et al (2023) warned that "changes in biodiversity cannot be captured easily by a single number; care is required when measuring and interpreting biodiversity change given that different metrics can provide very different insights" (p1).

The concept of "essential biodiversity variables" (EBVs) is used in studies. It refers to "derived measurements required to study, report and manage biodiversity change, which focus on describing the status and trends in specific elements of biodiversity" (Gregory et al 2023 p2). Gregory et al (2023) focused on two EBVs in their research - namely, species abundance, and biomass - using two datasets in European birds (from the UK Avian Population Estimates Panel, and the EU Birds Directive). The UK data covered 1966-2018, while the EU-level data came from 1980 to 2017.

The total number of breeding birds ("total abundance") in the UK was estimated to have declined by 19% in the study period, and by 17% in the EU.

"Population losses were skewed towards a small number of the most abundant bird species in the UK and EU. House sparrow (Passer domesticus), tree sparrow (Passer montanus), common starling (Sturnus vulgaris), willow warbler (Phylloscopus trochilus) and Eurasian skylark (Alauda arvensis) were common to both sets" (Gregory et al 2023 p5).

Change in total abundance was linked to habitat use, with the "largest absolute declines occurred in those species associated with human-modified habitat (including intensive agriculture, urban landscapes and gardens...). Birds associated with grassland have also declined... Forest-associated birds in the UK were increasing to a small degree..., but stable in the EU..., whereas woodland/parkland-associated bird species were increasing modestly in both the UK and the EU, but with high uncertainty. Wetland breeding birds show declines in the UK... and the EU..., as do riverine birds..." (Gregory et al 2023 p6). Long-distance migrants showed a larger decline than residents (ie: non-migratory species).

Using the measure of bird species biomass (ie: total weight), this had increased slightly in the UK, and remained stable in the EU over the study period. This was an unexpected finding. It suggested that "species with relatively larger mass were tending to increase in number, while smaller-bodied species were tending to decline" (Gregory et al 2023 p7). The researchers continued: "The six species declining at both a UK and EU level... are all less than 80 g in mass, most considerably less; those increasing at both scales include larger birds, amongst them wood pigeon and collared dove (Streptopelia decaocto), both greater than 200 g... This is a curious result, implying that total energy from primary production available to birds in Europe has remained roughly constant in recent decades, when one might expect it to have declined through increasing anthropogenic pressure. There is, however, considerable variation in the fortunes of individual species, with many falling in number but others booming... Compensatory mechanisms have long been recognised as the basis of community stability and ecosystem resilience and may explain the patterns we observe. Thus, bird communities in Europe are changing and presumably responding and taking advantage of changes in resource availability, which are themselves probably linked to land use and climatic change" (Gregory et al 2023 pp7-8).

The contradictions in two EBVs showed "the need for care in measuring and interpreting biodiversity change, given its multi-faceted nature and imperfect data" (Gregory et al 2023 p10). The researchers ended that "avian biomass has been roughly stable in Europe, while total abundance has declined, suggesting that bird community structure is changing" (Gregory et al 2023 p10).

The datasets were viewed as high quality, collated from multiple sources (eg: structured national breeding bird surveys).

Intense fishing of Atlantic cod (Gadus morhua) in the 20the century, for example, has produced selection pressure leading to "smaller size at maturity and lower age at reproduction" (Reid et al 2023 p2). This has been observed in two different populations in the Atlantic - in the north-west (Canada) and the north-east (Norway).

"Populations can adapt to novel selection pressures through dramatic frequency changes in a few genes of large effect or subtle shifts in many genes of small effect. The latter (polygenic adaptation) is expected to be the primary mode of evolution for many life-history traits but tends to be more difficult to detect than changes in genes of large effect" (Reid et al 2023 p1). Data, however, are available for the two populations of cod over one hundred years (Pinsky et al 2021). Reid et al (2023) used this dataset to simulate evolutionary pressures, and concluded that "the degree of covariance in allele frequency change observed in cod is unlikely to be explained by neutral processes or background selection" (p1). In other words, it can be attributed to human fishing - "fisheries-induced evolution" (Reid et al 2023 p6).

Thompson et al (2023) also analysed marine data. They stated: "In marine ecosystems, climate change is expected to result in warmer waters and reduced dissolved oxygen, both of which are likely to impact organismal performance, population growth rates and viability. There is evidence that marine species are more sensitive to temperature changes than terrestrial species, and many species are already shifting their distributions to track changing conditions. Therefore, we expect to see considerable reorganisation in the composition of marine communities as conditions continue to change" (Thompson et al 2023 p1).

The projection of the impact by these researchers covered 34 groundfish species in the north-eastern Pacific (off British Columbia, Canada, and Washington state, USA). "Many, but not all, species are projected to shift to deeper depths as conditions warm, but low oxygen will limit how deep they can go. Thus, biodiversity will likely decrease in the shallowest waters (less than 100 m), where warming will be greatest, increase at mid-depths (100–600 m) as shallow species shift deeper, and decrease at depths where oxygen is limited (greater than 600 m)" (Thompson et al 2023 p1). The data for the projection came from over 31 000 scientific research trawls since the 1980s, and the prediction related to mid-21st century onwards.

2.6. APPENDIX 2A - LONG-TERM STUDY OF RED DEER

"Field studies that track the complete lives of individuals can provide unique insights into the ecological and evolutionary processes that govern wild animal populations" (Pemberton et al 2022 p328). An example of such a study is of red deer (Cervus elephus) on the Isle of Rum, Scotland, which began in the early 1970s. Data on over 4000 individuals have been collected since 1972 (Pemberton et al 2022).

Females have well-defined home ranges and a dominance hierarchy, while males live in loose groups outside these ranges. In the breeding season ("the rut") (September), mature males move into female areas and defend harems. Roaring by males is a signal of quality, and roaring contests occur regularly during the rut. Occasionally escalating to fights. Females are fertile for around 24 hours (ie: in oestrus).

The long-term study was able to show that the cost of raising a calf was high for females. "In deer culled on Rum, mothers that rear calves in a given year enter the following winter at lower body weights than those that either fail to conceive or lose their calves shortly after birth... A mother that successfully rears a calf is more likely to die in the following winter... If she survives, she is less likely to bear a calf the following spring, and if she does breed the following year, she will, on average, give birth later and to a lighter calf" (Pemberton et al 2022 p331). Lifetime breeding success (LBS) (ie: number of offspring in a lifetime) and lifetime reproductive success (LRS) (ie: number of offspring that survive to two years old) appear to be linked to social rank (and consequent quality of home range), and environmental conditions in early life (Pemberton et al 2022).

Breeding success in males is associated with fighting success and body size. "The most successful males are those that are born early and heavy... Breeding competition is intense, and few individuals breed successfully until they are 7 or 8 years old. The average breeding success of males declines rapidly after approximately the age of eleven, with the result that the effective breeding lives of males are much shorter than those of females" (Pemberton et al 2022 p333).

The longevity of the study has revealed how fluctuations in weather conditions influence the population, particularly in spring when calves are born (ie: calving). In recent years, winters have become milder and wetter with increased grass growth. This had led to earlier dates (5-12 days) for key annual events - the start and end of the rut, oestrus, calving, and the development of male antlers (ie: appearance ("cleaning") and disappearance ("casting"). Antler size generally has also increased recently (Pemberton et al 2022).

Genetic data have been collected since 1982, and these showed "extensive low-level inbreeding" (Pemberton et al 2022 p336). First-degree relatives inbreeding (ie: father and daughter) was rare (eleven cases recorded). It has been calculated that a female mating with a half sibling (ie: 12.5% genetic similarity), say, has a 75% reduction in LBS and a 79% reduction in LRS compared to the average female, and a male a 95% reduction in LBS compared to the average. This is known as "inbreeding depression". Many species evolve strategies to avoid inbreeding. This may not be the case here because females change groups, and males have relatively short breeding life spans. "Given that many males never sire a calf despite surviving to adulthood, it is also likely that siring any offspring at all is more important to males than the low probability of mating with a close relative, and this is the main driver for male mating behaviour" (Pemberton et al 2022 p337).

2.7. APPENDIX 2B - PECCARY POPULATION

Population cycling has been observed in mammals, birds, fish, and invertebrates. This is the change in population size over time (with increases and decreases). Endogenous factors in this process include reproductive output, while interactions with predators, diseases, and food availability are examples of exogenous factors (Fragoso et al 2022).

The white-lipped peccary (WLP) (Tayassu pecari) (figure 2.1) is interesting here. "This is the only tropical forest ungulate that forms large, permanent, cohesive herds comprising hundreds of individuals. In the Amazon, the home range of a herd of about 400 animals may extend to 200 km^2. Considering an adult weight of 30 to 50 kg, such a herd represents 12,000 to 20,000 kg of biomass moving across the landscape, rooting up soils, consuming seeds, seedlings, plant parts and animal matter, dropping excreta, creating wallows, and providing abundant food for large cats, all processes that influence biotic communities and the carbon cycle" (Fragoso et al 2022 p2).

(Source: Whaldener Endo; public domain)

Figure 2.1 - A white-lipped peccary.

Entire populations have been documented as disappearing and later reappearing. "In the 1980s, researchers in the Amazon began to report occasional local disappearances of WLP populations, attributing them to migration and other large-scale movements, overhunting, or disease outbreaks" (Fragoso et al 2022 p3).

Fragoso et al (2022) investigated this topic using various data sources, including questionnaires to 58 wildlife researchers, and legal pelt trade records from 1932 to 1969. Forty-three disappearance events were analysed (figure 2.2) [4].

It was found that "the disappearances represent 7–12-year troughs in 20–30-year WLP population cycles occurring synchronously at regional and perhaps continent-wide spatial scales as large as 10,000–5 million km^2" (Fragoso et al 2022 p2).

The researchers considered the possible explanations, including hunting (but WLP live in low density human areas mostly), environmental stressors (eg: flooding), and disease. Fragoso et al (2022) suggested that these factors were exacerbated by "density-dependent overcompensation". WLP are highly reproductive (158 days of pregnancy; average litter on two young; first reproduction at 18 months old), which means that a population could easily become too large ("super-abundant"), and this triggers a population crash. "In this scenario, when WLP populations reach high numbers, food is less available per individual, female reproductive productivity decreases, and there is greater infant and adult mortality. The population goes into a fast retraction leading to declines and disappearances. External drivers, including a decline in food or habitat quality independent of population increase, are not necessary explanations in this scenario, but could play a role by depressing population recovery, as could disease affecting weakened animals or extreme drought, or habitat reduction with crowding in the remaining habitat due to flooding" (Fragoso et al 2022 p10).

[4] A disappearance event was defined as no more than twelve months between an observed normal or large (super-abundant) population and a low or absent one.

(Source: Fragoso et al 2022 figure 1)

Figure 2.2 - Site of WLP disappearances.

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3. FLYING CREATURES

3.1. WINTER CYCLONES

Seabirds face a number of threats including habitat loss, invasive species, interactions with fisheries, and weather (Clairbaux et al 2021). Winter Atlantic cyclone-induced mortality is a particular concern. "During these, thousands of emaciated seabird carcasses are washed ashore along European and North American coasts. Winter cyclones can therefore shape seabird population dynamics by affecting survival rates as well as the body condition of surviving individuals and thus their future reproduction" (Clairbaux et al 2021 p3964).

Clairbaux et al (2021) concentrated on North Atlantic Ocean and adjacent seas winter cyclones (October-February) between 2000 and 2016). These "large-scale air masses that rotate around a centre of low atmospheric pressure" (Clairbaux et al 2021 p3965) were divided into four classes (table 3.1). Global location sensor (GLS) data were available on 1532 individual birds from five key species (Common guillemot (Uria aalge), Atlantic puffin (Fratercula arctica), Black-legged kittiwake (Rissa tridactyla), Little auk (Alle alle), and Brunnich's guillemot (Uria lornvia)) in 39 breeding colonies.

- 1 & 2 - Localised low-intensity, mainly in Baffin Bay, the Gulf of Maine, and the Mediterranean Sea regions.
- 3 - Widespread, mostly in October and November, in Baffin and Hudson Bays, the Davis Strait, the Labrador Sea, east off Newfoundland, around Iceland, and in the Barants Sea.
- 4 - All winter months off west Iceland, the Norwegian coast, and in the Barents Sea, and December-February in the Davis Strait and the Labrador Sea.

Table 3.1 - Four classes of cyclone (based on Dvorak storm classification).

Cyclones could lead to death from starvation due to increased energy requirements, unavailability of prey, and inability to feed. The data led to a rejection of the first possibility as "cyclonic conditions do not increase seabird energy requirements" (Clairbaux et al 2021 p3964). This was a "surprising conclusion" (p3966), but it did tally with a previous study of greater flamingos in Carmargue, France (Deville et al 2014). During cold spells, "thousands of flamingos died, not because of hypothermia but due to inaccessible food in frozen salt pans" (Clairbaux et al 2021 p3966). A previous modelling study (Fort et el 2009), however, did find contrary results to Clairbaux et al (2021).

Clairbaux et al (2021) stated: "What exactly prevents seabirds from feeding during cyclonic conditions remains unclear. One possibility is that cyclones may enhance water turbidity, decrease underwater light intensity, and perturb prey patches and vertical migration. Potentially disrupting water stratification, cyclones may modify prey aggregation and negatively impact seabird foraging efficiency" (p3966). This can be called a "washing-machine effect" (Clairbaux et al 2021).

The researchers admitted that "even if starvation may be the main driver of seabird winter wrecks, we cannot exclude other causes of mortality, such as drowning, collision with reefs and rocky coastlines..., or inland stranding" (Clairbaux et al 2021 p3967).

This study was a data modelling one, and it did not include any direct observations of seabirds. Such studies can provide knowledge about animals, but they are dependent on the data collected by others.

3.1.1. Direction of Flight

Studies that track seabirds, who are particularly exposed to tropical cyclones because hurricanes and typhoons develop over the oceans, find that adults fly around or above the most intense parts of the storm (eg: great frigatebirds flew 400-600 km from their usual foraging area during a cyclone; Weimerskirch and Prudor 2019) (Lempidakis et al 2023).

"Quantifying bird responses to extreme weather events remains challenging as they are, by definition, infrequent. Cyclones are also variable in terms of their intensity, spatial extent, movement speed, and trajectory. Understanding the behavioural rules that birds employ in an attempt to mitigate storm detriment therefore requires animals to be tracked during multiple, rare events" (Lempidakis et al 2023 p1). Lempidakis et al (2023) addressed this issue by tracking 400 adult streaked shearwaters (Calonectris leucomelas) on Awashima Island, Japan, over eleven years. Large and extreme typhoons are common in this area. GPS data were available on 75 birds who were exposed to storms.

The direction of the birds' flight was influenced by certain variables:

i) Wind speed – flying away from the eye of the storm in lighter winds and towards it in stronger winds.

ii) Wind direction - "birds being more likely to fly toward the eye when they experienced strong southerly winds, and away from the eye in strong northerly and easterly winds" (Lempidakis et al 2023 p2).

iii) Ahead of or behind the storm – flying away when ahead of the storm, and towards it when behind the storm.

Putting the information together, overall, "shearwaters flew toward the eye of multiple typhoons, a behaviour that was more likely as wind speed increased, with birds even moving toward the eye of the strongest typhoon in the study period" (Lempidakis et al 2023 p4). So, the birds were exposed to the strongest wind strengths. Why did they do this? Lempidakis et al (2023) offered these answers – the shearwaters' flying style (ie: "their use of dynamic soaring flight, which enables them to extract energy from the vertical wind gradient and fly at low metabolic cost"; p4), flying close to the water surface (where wind speeds are lower), and to avoid strong onshore winds (where there is a risk of collision and uncontrolled landings). Once grounded, the birds struggle to take-off again, and are susceptible to predators.

The birds need to know where the land is situated in order to avoid it, and this would suggest a "map sense", which juveniles do not have. They follow an innate compass bearing to migrate, and are more susceptible to being wrecked after storms (Lempidakis et al 2023).

3.2. NEW MIGRATION ROUTES

The impact of global warming on Arctic-breeding migratory animals can be seen in different ways, including changes in arrival and breeding times, expansion of breeding range or breeding in traditional wintering areas, and expansion of migratory routes. "Underlying mechanisms may be fast genetic adaptations, enhanced by assortative breeding, or phenotypic plasticity allowing for adjustments of behaviour. Herd or flock-forming species, where migration routes are learned and culturally transmitted, are particularly likely to rapidly adjust migratory behaviour" (Madsen et al 2023 p1162).

Madsen et al (2023) reported the example of the pink-footed goose (Anser brachyrhynchus) that has established a new breeding area and migratory route to it in a period of around ten years. A long-term monitored population of geese, that traditionally breeds in Svalbard and migrates south via Norway and Denmark to the Netherlands and Belgium, was studied. The new breeding ground was Novaya Zemlya, Russia (eastwards, around 1000 km away from Svalbard), and the new migration route was nearly a quarter longer. As well as increasing spring temperatures, changes in farming and habitat loss in the stopover areas seem to be important drivers of the new behaviour. Also interactions with other goose species that breed in this area may have been important, which would suggest the social transmission of information (Madsen et al 2023).

3.3. AVALANCHES

Avalanches impact high-elevation habitats. "Frequent avalanche activity can create semi-open habitats which are normally found at higher elevations in mountain landscapes (ie: the treeline ecotone), and may offer an appropriate habitat for high-elevation bird species" (Alba et al 2023 p378).

Alba et al (2023) studied the bird species in these areas in the western Italian Alps. Three different elevation belts were studied - mountain forest (1400-2200 m above sea level), treeline ecotone (2100-2500 m) and alpine grassland (2100-2500 m) - and two areas (one along the avalanche tracks and one undisturbed forest-alpine grassland). At 240 sites, in May-June 2021, ten-minute count periods were used to record all birds seen and heard within a 100 m radius of the researcher.

Overall, the most commonly observed birds were the Common Chaffinch, Rock Bunting, Tree Pipit, Common Linnet, and Eurasian Wren.

The bird assemblages differed significantly between the avalanche track areas and the undisturbed (control) areas. There were more species recorded in the avalanche areas (62 vs 55), and the difference was most pronounced at lower elevations. The open habitat created by the avalanches attracted a wider variety of birds, and appeared as "unique, harbouring a mixture of bird species from different habitats" (Alba et al 2023 p377).

Climate change will impact the frequency of avalanches, which, in turn, will have "consequences for mountain biodiversity" (Alba et al 2023 p377).

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4. HEAT

4.1. MARINE HEATWAVES

Smith et al (2023) began: "Living organisms function between certain temperature limits determined by the typical thermal conditions they have experienced over evolutionary timescales (ie: their thermal niche). Beyond these limits, performance declines, and without mitigating action, mortality may eventually occur. As Earth's atmosphere and oceans warm, organisms' upper temperature thresholds are being exceeded more frequently and by greater magnitudes" (p120).

These researchers concentrated on the "marine heatwave" (MHW), which is "a discrete period of unusually high seawater temperatures" (Smith et al 2023 p120). Practically, this is quantified as the temperature exceeding the 90th percentile of the local climate for five days or more. A number of such events have been reported in the last few years (eg: in the Coral Sea in 2016, 2017 and 2020) (Smith et al 2023) (appendix 4A).

The main research method is field-based observations, with the collection of time series data. "Where field observations benefit from realism, however, they may lack in mechanistic understanding. Marine ecosystems are highly variable and complex, and effects of MHWs are not observed in isolation. Other factors, such as nutrient, light, and oxygen availability; UV light; desiccation and turbidity stress; pollution; fishing pressure; and disease may interact additively, synergistically, or antagonistically with temperature to mediate MHW impacts... Similarly, species interactions are highly complex and prevalent in marine ecosystems, and responses of certain species can disproportionately influence community- and ecosystem-level effects" (Smith et al 2023 p134). Another problem is the establishing of baseline measures by which to detect changes.

Experimental work allows the inference of causation. "Controlled manipulations can be used to determine cause-effect relationships for single stressors (in this case, MHWs) in isolation, helping to disentangle their effects from those of other stressors in the marine environment. Characteristics of MHWs, such as intensity, duration, and return period, can be manipulated to gain a deeper understanding of their relative importance. Moreover, under controlled conditions, a wider range of response variables can be measured, particularly at the molecular and physiological levels, again offering insights into the mechanisms underlying observed responses" (Smith et al 2023 p134).

Computer modelling can be used to predict future changes and events. In Australia, for example, near-term (the next week) and seasonal MHW forecasts have been developed (Smith et al 2023).

The impact of a MHW on individuals varies from minor changes in physiology to mortality. "Under high thermal stress, the cellular stress response — a multi-system, graded, energetically expensive response — is activated to protect and repair the cellular macro-molecular systems (proteins, RNA, DNA, and lipoproteins)... In addition, individuals may make other physiological adjustments to depress their metabolism and conserve energy for cellular protection and repair... Consequently, energy deficits develop that generally increase with MHW intensity and duration. Where these debts are not matched by increased energy acquisition, other aspects of performance will be negatively impacted... In such cases, individuals may modify their behaviour, relocate, and/or adjust their physiology. However, if such buffering capacity is exceeded,MHWs can have severe consequences for individual performance" (Smith et al 2023 p122). Specifically, in terms of growth, and reproduction.

Stenotherms (ie: those animals with a narrow thermal niche) will be affected more than eurytherms (ie: a broader thermal tolerance).

At a species or population level, there may be local adaptation over generations, but if not, mass mortality events, reproductive failure, and range shifts are possibilities. Sedentary and immobile animals will have limited ability for the latter. Temporary and semi-permanent range shifts have been seen in mobile species (eg: fish). "However, unlike terrestrial and inter-tidal landscapes, which offer a mosaic of micro-climates, sub-tidal seascapes often lack local thermal refugia" ((Smith et al 2023 p123). Movement, though, means invasive species to another area, and the impact on natives there.

Mass mortality events have been reported for a number of species (eg: forty species of coral reef fish in the MHW in the Red Sea in 2017; Smith et al 2023). The risk being not just the heat, but also harmful algal blooms in some cases.

There are impacts of MHWs on flora (eg: kelp forests and seagrass meadows), and on humans (Smith et al 2023).

4.2. THERMOREGULATION

4.2.1. Behaviour

Hyperthermia, "a rise beyond the normal range of body temperature, can cause lasting damage to body tissues and organs, and severe cases can be lethal" (Chen-Kraus et al 2023 p179). Mammals can avoid this state with physiological responses like sweating, and panting, and with behaviours like retreating to shaded, cool places. Arboreal mammals have their options. "Some, like Prince Bernhard's titi monkey (Callicebus bernhardi), change their body posture to maximize exposed surface area, increasing opportunities for heat dissipation via convection or conduction... Hugging tree trunks, which tend to be cooler than other parts of the tree, has been predicted to allow substantial heat loss in koalas (Phasocolarctos cinereus), potentially reducing their need for evaporative cooling" (Chen-Kraus et al 2023 p179).

Chen-Kraus et al (2023) concentrated on Verreaux's sifakas (Propithecus verreauxi) in Madagascar that face summer temperatures in the 20s and 30s °C. They have few sweat glands, and rarely drink standing water, and so terrestrial tree hugging may be an option. "When sifakas engage in terrestrial tree hugging, they come down to the ground and sit with their arms and legs wrapped around the base of a tree, their bodies pressed against the trunk. This behaviour is unexpected because sifakas are primarily arboreal and rarely rest on the ground, where exposure to predators — including domestic dogs, fossa (Cryptoprocta ferox), and wildcats (Felis silvestris) — is higher" (Chen-Kraus et al 2023 pp180-181).

Data were collected in the form of 78 days of observation by two researchers of six named groups of sifakas at Beza Mahafaly Special Reserve in southwest Madagascar in June-October 2018. Event sampling was used. This involved the recording of all instances of terrestrial tree hugging observed, including the duration, the species of tree, and air temperature. Tree surface temperature was also measured.

Overall, sixty-four bouts of terrestrial tree hugging were observed, each lasting an average of 31 minutes, and the mean air temperature was 37.4 °C at the time. The temperature at the base of the tree (ie: the hugging point) was cooler by 3-5 °C on average. Chen-Kraus et al (2023) summed up: "Sifakas were significantly more likely to engage in tree hugging on days when ambient temperatures were high, and the bases of trees they hugged were significantly cooler than further up the trunk, the air, and ground. These results support our predictions and the hypothesis that tree hugging is a means of behavioural thermoregulation" (p186).

This type of tree hugging has previously been observed in koalas (Briscoe et al 2014). This study outlined four variables that influence the amount of heat conducted between the animal and the tree surface - "1) how much of the animal's surface area is in contact with the surface area of the tree, 2) the thickness of the animal's skin (and fur), 3) the temperature differential between the animal and the tree, and 4) the thermal conductivity constant of skin" (Chen-Kraus et al 2023 p186).

Chen-Kraus et al's (2023) dataset was quite small. The researchers explained: "Sifakas only hugged trees on days when temperatures were high, yet there were many hot days when they did not, and we never observed tree hugging in one study group (Elahavelo). Group Elahavelo was disturbed by livestock and dogs much more frequently than other groups... The presence of dogs, in particular, which are perceived by sifakas as a significant threat, may have changed the trade-off between predation risk and thermoregulatory advantage for this group, and made animals more hesitant to rest on the ground" (Chen-Kraus et al 2023 p187).

The temperature measures were taken 1.5 m from the animals to avoid disturbing them, and used infra-red thermometry, but actual measures of sifaka body temperature would have been ideal.

4.2.2. Morphology

Dealing with thermal stress has led to morphological adaptations like the large ears of the elephant or the featherless head patches of the Zebra Finch. "These structures effectively work as 'thermal radiators' emitting excess heat to the surrounding environment during hot conditions and reducing heat loss during cold conditions" (Svensson et al 2023 p3).

Body size is also a means of thermoregulation. "Large bodies can cause higher thermal inertia, and a slower rate of body temperature change, compared to small bodies. Thermal inertia can help maintain body temperatures during cold conditions, but can jeopardise survival and reproduction when extreme temperatures cause heat stress" (Svensson et al 2023 pp3-4).

Svensson et al (2023) showed that the featherless neck of the ostrich (Struthio camelus) was a "thermal radiator". Data were collected in Klein Karoo, South Africa, and included thermal imaging. The environmental temperature can vary from -5 to 45 °C. As air temperature increased, so did neck temperature beyond the head temperature, which suggested that the neck "may function as a thermal radiator to get rid of excess heat to protect the head and brain" (Svensson et al 2023 p5). There was a stronger effect for females, who have to incubate eggs during the hot afternoon.

There was a difference between three ostrich populations in Africa depending on the temperature fluctuations in the environment. "Ostriches from populations that experience greater temperature changes were also more efficient at dissipating heat through their necks" (Svensson et al 2023 p8).

Note that the long neck "probably serves multiple functions, including foraging, vigilance and amplification of male mating sounds, but currently it also functions in thermoregulation. There are signs that other such co-opted thermoregulatory traits are currently rapidly evolving, due to the increasing temperatures of recent and ongoing climate change, consistent with 'Allen's Rule' [5]. Specifically, the relative length of appendices and bird beaks that function as thermal radiators have increased during recent decades. Given these recent trends in other animals, it is possible that the neck length of the ostrich will increase in the future to improve the ability to get rid of excess heat" (Svensson et al 2023 p11).

4.3. APPENDIX 4A - RHYTHMS AND MARINE ORGANISMS

"The relative positions of the sun, the moon, and Earth result in cycles with a complexity of different period lengths, ranging from tidal periods in the range of 12 h to diel and monthly periods and annual/seasonal

[5] This is the idea that animals adapted to colder climates have thicker limbs and bodily appendages (Allen 1877).

cycles. Furthermore, these cycles differ depending on geographic location" (Hafker et al 2023 p510). Adaptation to such cycles is "likely been a fundamental aspect of survival" (Hafker et al 2023 p510). Biological rhythms are both endogenous (driven by internal "clocks") and exogenous (in response to environmental cycles).

Rhythms in marine organisms are less studied than in land organisms. But there are distinct variables in the former case, including tides, depth of water, water temperature, salinity, and pressure and mechanical factors (Hafker et al 2023).

Hafker et al (2023) outlined some of the key research on rhythms and marine organisms:

i) Marine algae - Alga is used for a diverse range of aquatic photosynthetic species, while the molecular mechanisms of biological clocks were originally uncovered in Acetabuleria ("mermaid's wine glass").

Phytoplankton (micro-algae), for example, show vertical migration towards the light on a daily basis, while other species have moon-related cycles, and seasonal or longer ones.

ii) Diurnal vertical migration - Zooplankton, especially, but other organisms as well, move upwards towards sunlight. But alson in response to moonlight, and even "during the darkest part of the polar night... and in the deep sea..., suggesting the existence of an endogenous oscillator co-ordinating these migration events" (Hafker et al 2023 p517). Krill have been studied in detail in controlled environments. Kept under different light regimens, the clocks show flexibility as would be needed in long dark periods in polar regions (Hafker et al 2023).

iii) Rhythms in the deep sea - Low temperature, high pressure, internal tides, and differences in vertical water layers are particular variables here.

iv) Different rhythms - Short-term cycles including tidal (approximately 12.4 hours), diel (24 hours), and lunidian (approximately 24.8 hours). "Tidal variations at the coast cause remarkably regular but drastic changes in immersion, temperature, salt concentrations, oxygen and food availability, and so on. As it is of the utmost importance for organisms to not be surprised by those environmental changes, circa-tidal clock mechanisms to anticipate the imminent tidal variation provide a large adaptive advantage" (Hafker et al 2023 p519).

There are also circa-semi-lunar (semi-monthly) and circa-lunar (monthly) cycles (eg: molluscs, crustaceans), particularly important for the timing of reproduction as many species are external fertilisers.

v) Impact of climate change - For example, the warming of tropical waters impacts the timing of synchronised mass spawnings of corals. While ocean acidification, and oxygen concentration changes also impact marine rhythms.

Interspecies mismatches are a particular concern. The rhythms of different species are synchronised to occur at the same time, and climate change could alter the rhythms in different ways. "For example, the onset of the Arctic phytoplankton bloom is gradually shifting to earlier dates..., but seasonal reproduction of the copepod Calanus glacialis [small crustacean], which depends on the bloom as a food source, could not adapt to changed bloom timing, resulting in a seasonal mismatch with low copepod abundance" (Hafker et al 2023 p526).

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5. CHANGING ENVIRONMENTS

5.1. FORESTS

"Intact, high-integrity forests are important for conservation and planetary functioning" (Sze et al 2022 p4949). Intact forests can be defined as "seamless mosaics covering a minimum area of 500 km^2 with no remotely detected signs of human activity and bearing similarities to high-integrity forests, which conceptually refer to areas with minimal anthropogenic modifications to its structure, composition, and function" (Sze et al 2022 p4949).

Sze et al (2022) mapped such areas using various datasets, and, in particular, distinguishing between legally protected areas and/or indigenous lands, and non-protected areas. It was found that "high-integrity forests tend to be located within the overlap of protected areas and indigenous lands (protected-indigenous areas)" (Sze et al 2022 p4949).

The researchers used the "Forest Landscape Integrity" index (Grantham et al 2020), which scored an area from 0 (lowest integrity) to 10, based on three criteria - observed pressures on the forest (eg: human infrastructure, like roads; agriculture), the inferred pressures from those observed, and forest connectivity (eg: uninterrupted forest).

5.2. WILDFIRES

Wildfires may cause large carnivores to approach urban areas for food. Blakey et al (2022) studied such behaviour with data on seventeen GPS-collared mountain lions (Puma concolor) around Los Angeles (in the Santa Monica Mountains and Simi Hills).

In the fifteen months after the 2018 "Woolsey Fire", the mountain lions avoided burned areas, and showed a small increase in urban area use (from 4% to 5% of time) compared to the fifteen months before the wildfire. There was an increase in daytime activity (from 10% to 16% of 24-hour activity), and more crossing of major roads (from an average of three to five per month). "Mountain lions increased both their distance travelled and the amount of space used after the fire" (Blakey et al 2022 p4763) (from a mean of 250 to 390 km travelled per month).

The changes in the behaviour post-wildfire increased the risk of conflict and encounter with humans, as well as with male mountain lions. So, "after a severe wildfire, when space available for hunting and moving within cover is reduced, animals must trade-off energetic demand with perceived risk of encountering adult males, weighing behaviours that put them at greater risk of conflict against greater flexibility in space use and, potentially, diet" (Blakey et al 2022 p4764).

Mountain lions are ambush predators, and so require vegetation cover to stalk prey. Burned areas, even if patchily burned, would limit opportunities for cover. Blakey et al (2022) admitted that they "did not account for differences in burn severity across the landscape, which can be an important predictor of wildlife post-fire habitat use, because fires within Southern Californian shrubby vegetation tend to burn with uniformly high-intensity, stand-replacing fire" (p4764).

The researchers ended: "Greater risk-taking behaviours by carnivores living near urban areas could lead to increased mortality in populations already suffering from low genetic diversity, leading to increased extinction risk" (Blakey et al 2022 p4766).

5.3. FROGS AND AIRCRAFT NOISE

Human noise impacts animals, particularly auditory communication. "Wild animals have been found to use several strategies to reduce the influence of excess noise... Some species can increase their call amplitude in noisier environments and thus augment the transmission distance of sound signals... Another adaptive strategy is to adjust signal structures such as call frequency, call duration and call complexity" (Zhao et al 2021 pp9-10).

Zhao et al (2021) studied the calls of frogs living near an airport in China. Calls were recorded before, during, and after the passing of aircraft. Recordings were made of four species – spot-legged treefrog

(Polypedates megacephalus), pointed-tongue floating frog (Occidozyga lima), Guenther's frog (Hylarana guentheri), and ornamented pygmy frog (Microhyla fissipes).

An aeroplane passed every 4-5 minutes during recordings. Frog calling increased in noise amplitude when an aircraft passed overall, while the two frog species characterised by lower frequency calls increased them (spot-legged treefrog and Guenther's frog), and the three species with higher call rates reduced them (not Guenther's frog). This study showed that each species adapted their calling in some way in response to aircraft noise.

5.4. MERCURY POLLUTION

Mercury pollution from illegal (or artisanal) mining ("garimpos") in the Brazilian Amazon has been found in unsafe levels in fish. Mercury, which is toxic, is used to separate gold from sediment, and estimates of nearly half of that used by illegal miners is dumped in rivers (Taylor 2022).

Santiago de Vasconcellos et al (2021) explained: "Fish has an important role in food security, since 17% of all animal protein consumed in the world is provided by fish. In addition, fish consumption contributes to nutritional security, given its high content of essential nutrients (ie: vitamins and minerals) and polyunsaturated fatty acids (eg: omega-3 and omega-6). The food and nutritional security attributed to fish consumption is especially important for low-income populations in developing countries where over 90% of inland water caught fish are directed for local human consumption. Indeed, fish is often the only quality protein accessible to poor people" (pp1-2). Such is the situation for Indigenous groups in Amazonian.

One group is the Munduruku in the Middle-Tapajos Region of the state of Para in Brazil. It was estimated that their population was consuming mercury at levels 3-25 times greater than US recommended safe levels. This suggested that there was a "serious risk of harm as a result of ingestion of mercury-contaminated fish" (Santiago de Vasconcellos et al 2021 p1).

"The mercury used in garimpos is converted into methylmercury (MeHg), the most dangerous mercurial form to human health. Methylmercury undergoes bioaccumulation and biomagnification through aquatic trophic chains and, consequently, the consumption of contaminated fish and other organisms (eg: crabs, shrimp, turtle etc) provides the main route of human exposure to this persistent environmental contaminant. Ingested methylmercury is rapidly absorbed by the human gastro-intestinal tract, principally affecting the central nervous and cardio-vascular systems. This mercurial form is especially harmful to pregnant women because the foetal brain is more sensitive to the action of methylmercury, causing many neurodevelopment problems to occur, including mental retardation, learning delays, visual and auditory alterations, and other harmful effects" (Santiago de Vasconcellos et al 2021 p2).

Santiago de Vasconcellos et al (2021) made fish samplings between 8 am and noon on seven consecutive days between 29th October and 9th November 2019 in the Sawre Muybu Indigenous Land (also known as Pimental). Eighty-eight individual fishes were caught from seventeen species.

5.5. INVASIVE ANTS

The red imported fire ant (Solenopsis invicta) is classified as the fifth costliest invasive species worldwide with the impact on ecosystems, agriculture, and human health (Menchetti et al 2023).

Menchetti et al (2023) made the first report of a mature population in Europe, specifically in Sicily, Italy. Cases had been documented previously, but not settled, as in the eighty-eight nests found near the city of Syracuse by Menchetti et al (2023). The researchers noted: "Locals informed us of frequent ant stings in the area since at least 2019, suggesting a prolonged presence of S. invicta that is coherent with the large invaded area and high number of mature nests" (Menchetti et al 2023 pR896).

Originally from South America, this ant has spread northwards in the Americas as well as worldwide (eg: China, Australia), but now climate warming is making Europe suitable as a habitat (Menchetti et al 2023).

Commenting on their observations, Menchetti et al (2023) stated: "How the species reached this site is not clear, but no large landscaping or planting projects seem to have taken place over the last few years and it is highly unlikely that it represents the first arrival point and only location in the area. The proximity of one of the main cargo harbours of the island, the Augusta port (~13 km northward), may be relevant for its introduction" (pR896). Ant queens disperse aided by wind during nuptial flights.

5.6. OCEANS

5.6.1. Bycatch

Bycatch is a key problem for shark populations. Doherty et al (2022) reported the trialling of "SharkGuard", a shark bycatch mitigation device, with commercial longline blue tuna fishing. "SharkGuard creates a powerful, short-range, 3D pulsed electric field designed to overstimulate electro-receptors to reduce frequency of hook interaction" (Doherty et al 2022 pR1260). In studies in southern France in 2021, SharkGuard significantly reduced bycatch rates of blue sharks (and pelagic stingrays) (figure 5.1).

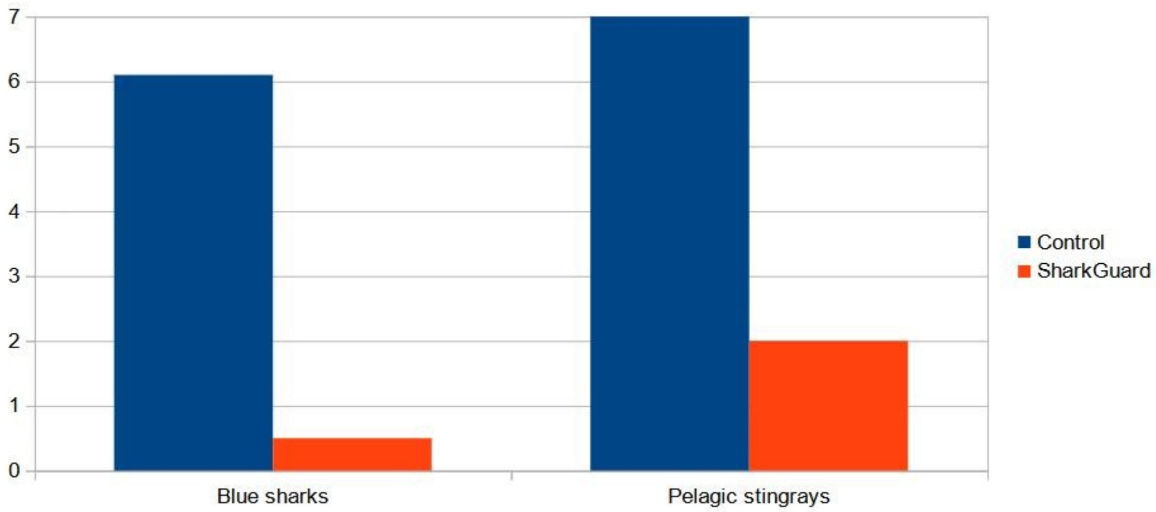


Figure 5.1 - Mean standardised bycatch per 1000 hooks.

5.6.2. Shark Depredation

Depredation by sharks occurs "where a predator partially or completely consumes an animal caught by fishing gear before it can be retrieved to the fishing vessel" (Mitchell et al 2018 p715). The estimated rate ranges from 0.9% to 26% of fish caught by commercial and recreational fishing (Mitchell et al 2020). "Depredation can cause injuries to sharks, loss of income for fishers and a reduction in the quality of the fishing experience" (Mitchell et al 2020 p2). For example, in a survey of over 600 grey nurse sharks in New South Wales, Australia, Bansemer and Bennett (2010) found that just under one-fifth had visible fishing hooks present.

"Depredation is similar to natural feeding behaviour where sharks opportunistically prey on injured or unhealthy fish, because a hooked fish is also restricted in its ability to escape and will be injured (or already dead in the case of some pelagic longline fisheries with long soak times). Depredating a hooked fish is beneficial to sharks because it is more energy efficient compared to locating, capturing and consuming healthy, free-swimming prey" (Mitchell et al 2018 p717).

Sharks can learn that fishing vessels are associated with easy prey, including when unwanted fish are thrown back into the sea. In other words, sharks are changing their behaviour.

Mitchell et al (2018) found sixty-one studies on shark depredation published between 1955 and 2018 (but over four-fifths were in the 21st century). Twenty-seven different shark species were documented. Little of the research covered recreational fisheries compared to commercial fisheries. There is also research fishing where shark depredation has been reported. This type of fishing is done by researchers (eg: to tag fish, count them, or study them in laboratory conditions).

The main impact of shark depredation is upon targeted fish species. "This is because fishers often aim to catch a particular volume of fish based on their allowed quota, daily bag limit or hold size. Therefore in order to reach the quota, more fish will be hooked overall to compensate for those depredated by sharks... This extra mortality may not be recorded in commercial fisheries logbooks, or accounted for by measures such as recreational daily bag limits. This is especially the case if the shark consumes the whole fish, leaving no sign of its original presence, which is a form of 'pre-catch loss' (Gilman et al 2013)" (Mitchell et al 2018 p732).

Mitchell et al (2020) investigated shark behaviour with the "Baited Remote Underwater Video" (BRUV) system (which is video cameras attached to a metal bar with bait placed at the bottom of the sea). The study took place in an area of the North West Cape of Western Australia. A site where recreational fishing takes place was compared to a no-fishing (marine reserve) site on six consecutive days in 2014. "A greater number of individuals from four carcharhinid species [eg: Blacktip/Australian blacktip shark; Sicklefin lemon shark] were observed at the fished site, compared to only three individuals from two species [eg: Tiger shark] in the no-take marine reserve"

(Mitchell et al 2020 p1) (in total 60 vs 3 individuals respectively). Sharks also arrived earlier in the day at the fished site.

This was a preliminary study using the BRUV system, but it showed evidence of sharks changing their behaviour in response to fishing vessels, possibly the sound of the engine creating the association with easy food.

5.7. IMPACT OF HUMAN HANDLING

"Bird ringing" is commonly used to monitor individuals by catching them in mist netting and then placing a coloured ring on the leg. "Several factors, such as the material and size of the mist net, weather conditions, number of birds caught and presence of predators of the trapped bird species..., as well as experience of the ringer..., can determine whether this practice is harmful to the birds' welfare. However, capture and subsequent ringing do not necessarily involve a risk for trapped birds" (Onate-Casado et al 2021 p19).

Studies have found no negative differences between handled and non-handled birds (eg: survival; territory maintenance) (eg: Petruskova et al 2021). But individuals learn from previous experiences, and research has shown that "previously captured individuals are more difficult to catch in subsequent attempts using the same technique than individuals never trapped before" (Onate-Casado et al 2021 p20) (eg: great tits; Seress et al 2017). One observation is that "the process in which bird ringers capture and release individuals might mirror events of a bird being caught by a predator with a subsequent escape" (Onate-Casado et al 2021 p20).

One impact of capture may be upon playback studies. Birds ringers often use playback recordings to attract birds into the nets. Onate-Casado et al (2021) investigated this with an intensively monitored population of tawny pipit (Anthus campestris) in the Czech Republic. A three-minute playback of the song of a male was played to individual territorial males in the breeding season from two groups - 29 previously captured in a mist nest (in the same breeding season or 2-5 years previously) ("experienced") and thirty-one never captured ("naive"). The behaviour of the territorial male in response to the playback mimicking a territorial invasion was categorised in three active territorial defence behaviours - "flyovers" (male flies over the area where the playback is coming from), "flight attacks" (male approaches the playback speaker in flight (within one metre)), and "physical contact" (with the playback speaker). The level of aggression is highest in the latter response. The same of response to the playback, and the male's song output were also measured.

All males responded to the playback (within an average of nine seconds). Experienced males reacted slightly later than naive ones, particularly individuals who had been captured recently.

There were differences in the aggression responses to the playback with experienced males being more cautious. Most males in both groups performed flyovers, but fewer experienced males performed flight attacks (14% vs 90% of naive males), and physical contact (3% vs 71% respectively). "All but three experienced males (ie: 90%) avoided approaching closer than 1 m to the speaker, and the remaining three did not spend more than 5 s in its vicinity. In contrast, all but three naive males (90%) approached closer than 1 m, and most of these spent substantially more time within 0.5 m of the speaker (median 19 s...)" (Onate-Casado et al 2021 p23).

There was no difference in the song output of the two groups - an increase in song rate.

Onate-Casado et al (2021) summed up: "In this study, we demonstrated that male tawny pipits that had been lured to mist nests by playback recordings of conspecific songs before exposure to a new playback stimulus reacted less aggressively and more cautiously than naïve males without such an experience" (p24). this showed that long-lived birds remember capture (up to five years).

In similar research Budka et al (2019) had found that male chaffinches previously captured in the same breeding season sang fewer songs in response to a playback of a male territorial intrusion than non-captured males.

Onate-Casado et al (2021) commented that their observations and other research suggested that cautious behaviour after capture did not have a negative impact on long-term fitness of the individual. "Captured males did not leave their territories after handling, and successfully defended them during the whole season" (Onate-Casado et al 2021 p25).

5.8. MISCELLANEOUS

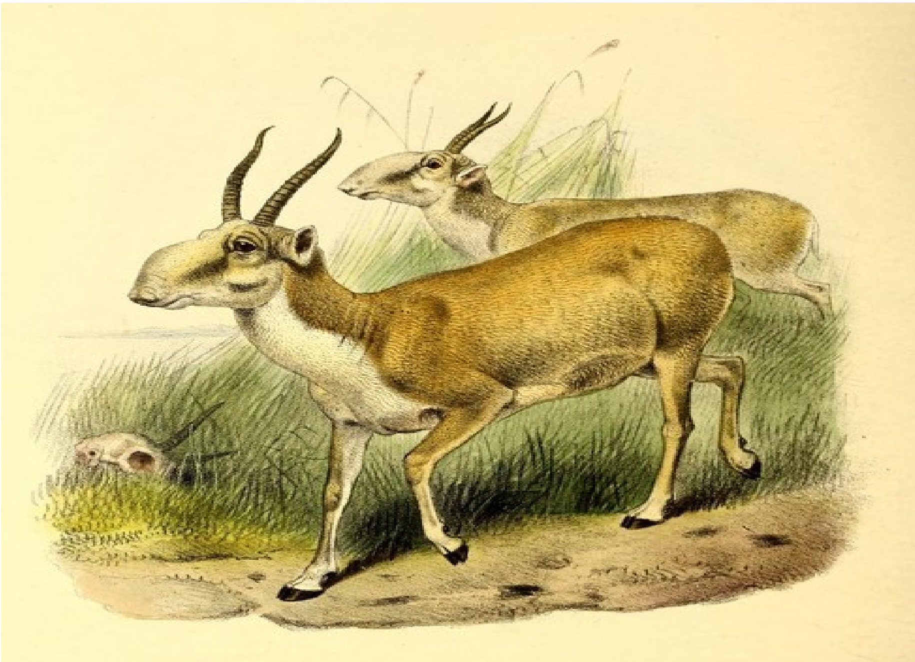
1. Daylight Saving Time

In the USA in November, clocks go back one hour (from daylight saving time to standard time), and this leads to an increase in the amount of driving during darkness hours (Sparkes 2022). Cunningham et al (2022) calculated the number of deer-vehicle collisions that would not happen if daylight saving time was permanent with over 36 500 less deer deaths per year. This estimate was based on data from car insurance companies in 23 US states between 1994 and 2021.

It was also estimated that 33 human lives per year would be saved in these collisions (Sparkes 2022).

2. Saiga Antelopes

Saiga antelopes (Saiga tatarica) (figure 5.2) were in rapid decline at the beginning of this century, but the numbers have rebounded now (eg: 40 000 in 2005 to 1.3 million now in Kazakhstan) (Wetzel 2022).



(Source: Sclater and Thomas 1894; public domain)

Figure 5.2 - Drawing of saiga antelopes.

Poaching for meat and horns were the main causes of the population decline, but these were reduced with land protection (eg: 5 million hectares in Kazakhstan) and hunting bans. The population of Kazakhstan also survived a fatal bacterial pathogen (Wetzel 2022).

Fortunately, females have multiple calves at once, and there are no predators. "Though saiga have been the poster child of Kazakh steppe restoration, their recovery is linked to the return of other species, like the ground-nesting steppe eagle. Because the eagles scavenge on meat, the abundance of saiga has meant more food for the birds" (Wetzel 2022 p11).

3. Mountain Species

Species tend to have a specific geographical range in which they thrive (ie: adapted for). For example, on tropical mountains this is a narrower range of altitude compared to the more broader elevational range on temperate mountains (Freeman et al 2022). But why is this so?

The two main explanations are due to climate (ie: adaptation to temperature range) (eg: Janzen 1967) or to species interactions and competition (eg: Diamond 1973) (Freeman et al 2022).

Freeman et all (2022) found support for the latter using data on forest bird species from thirty-one mountain ranges [6].

4. Subnivium

In Arctic regions, there is "a hidden ecosystem under the snow" (known as the subnivium): "It is found in a clandestine space between the snowpack and the soil beneath, which is sheltered from the bitter cold and is where some insects, spiders, frogs and even small mammals spend at least part of the winter" (Eberle 2022 p53).

For the subnivium to develop, there needs to be a minimum of 20 cm of snow which is not too dense (Eberle 2022). As the snow "settles on the ground, warmer air from the soil rises up, turning the snow at the bottom of the snowpack into water vapour. The resulting moisture condenses and refreezes on the cold layer above, creating a space above the soil that is usually a few centimetres high, with an icy ceiling" (Eberle 2022 p53). The temperature remains around 0 °C, though it is much colder above (Eberle 2022).

The subnivium is not an inevitability where there is snow, but it is influenced by the ambient temperature, snow characteristics, and land cover type. "For example,

[6] Citizen science data from "eBird" (https://ebird.org/home).

the amount of canopy cover and ground vegetation mediate the balance of incoming and reflected radiation, as well as wind speed, and generally result in subnivium conditions in wooded areas being warmer, in some cases by 4–6 °C, compared to open habitat types" (Petty et al 2015 p2). But the subnivium loses its insulating effect if the snow pack is shallow (eg: below 50 cm; Petty et al 2015). Climate change has a role to play too.

Petty et al (2015) compared snow depth and density on three land forms - a prairie, a deciduous forest, and a coniferous forest - in controlled environments, which altered the ambient temperature to be increased. Micro-greenhouses were placed at the different sites which raised the ambient temperature by 5 °C during the winter of 2013-14 in Wisconsin, USA.

Changes in ambient temperature impacted the subnivium in different ways depending on the land cover type. It was found that "the mean daily subnivium temperature was significantly colder in the deciduous cover type than the prairie cover type, and that prairie had higher maximum subnivium temperatures than both of the other cover types" (Petty et al 2015 p1). Higher ambient temperature reducing the depth of snow and so increased the temperature in the subnivium. "While the effects of climate change are likely to be less pronounced during the middle of winter when ambient temperatures are significantly below the 0 °C melting point, there may be more drastic effects during the early winter and late winter periods, when ambient temperatures are higher and more variable, and the snow is more vulnerable to melting" (Petty et al 2015 p9). This will impact species that survive in the subnivium over winter.

5. European Eels

The European eel (Anguilla anguilla) spend around a year travelling across the Atlantic Ocean westwards from Europe to the Sargasso Sea to mate and die. The larvae (known as leptocephali) are born in the Sargasso Sea and are carried eastwards by prevailing currents. During the journey they develop into glass eels, and then into elvers (moving into freshwater). Once settled they become yellow eels in the next stage of their life cycle. The final stage is the silver eel for returning to the Sargasso Sea (Lawton 2023).

The number of glass eels arriving in Europe (known as "recruitment") has fallen by 90% since 1980 (Lawton 2023). There are a number of possible reasons for this, including (Lawton 2023):

i) Climate change leading to changes in the ocean currents in the Atlantic, and in the nature of the Sargasso Sea.

ii) Human-erected river barriers, like dams, that inhibit the movement of the eels up and down rivers.

iii) Illegal fishing - eg: black market for eels in Asia.

6. Unusual Microbiomes

The kakapo in New Zealand is critically endangered with around 250 of these heavy parrots living on predator-free, managed islands (Evans 2023).

An analysis of their microbiome through the droppings found that it was almost entirely the bacteria Escherichia coli (West et al 2022). Usually, in other species, the microbiome has varied bacteria. "It's not yet clear if it's bad for kakapo, but a microbiome so homogeneous can be cause for concern because it may not carry out all the functions a species needs" (Evans 2023 pp11-12).

The unusual microbiome may be a product of the small population as well as contact with humans. Pandas in captivity in China, for example, have different microbes to wild pandas, in particular due to the difference in food (eg: Yao et al 2019). It takes a year in the wild for the microbiome to adapt (Evans 2023).

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