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Why should we be concerned about loss of biodiversity

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ABSTRACT

Over the past century, documented extinctions in well-studied taxonomic groups have been at rates one hundred-fold to one thousand-fold above the average extinction rates seen over the half billion year sweep of the fossil record. But for most groups, particularly invertebrates, we are very uncertain how many species there are on Earth today, much less rates of extinction.

This article will begin by documenting these claims. I will then survey the reasons – some practical and self-interested, others more broadly ethical – why we should worry about the impending threats to our planet's biological diversity.

1. Introduction

This article, which aims to set the stage for the following detailed papers, begins with a discussion of how little we know about the number of distinct eukaryotic species alive on earth today. It next discusses what we know – and do not know – about current rates of species extinction. In conclusion, I outline some of the reasons why we should be concerned about such losses, at rates orders of magnitude above the average seen over the fossil record. These reasons range from the ethical to the very practical.

2. How many species?

How many distinct life forms – species – exists on our planet today? Our embarrassing lack of accurate answer to this question is partly because the first stirrings of systematic interest in cataloguing the diversity of other living things with which humans share the planet came a full century after the foundation of the French Academy of Sciences and the Royal Society of London around the middle of the Seventeenth Century, and the subsequent fundamental understanding of the laws of motion, along with the inverse square law of gravitational attraction. The corresponding date for Linnaeus' binary codification in *De Rerum Naturae* (which recognised a global total of around 9,000 species of plants and animals) is 1758. In many ways the legacy of this century-long lag still lingers.

Today the global total number of distinct species of eukaryotes (never mind the viruses and bacteria, where there are essential differences in the definition of "species") that have been named and recorded is probably around 1.6–1.7 million, with roughly 15,000 being added each year [1]. Part of the uncertainty derives from lack of synoptic databases for many groups, which compounds difficulties in resolving synonyms – the same species independently found, and then named and recorded, in two or more different places by different people. Today's true total of distinct eukaryotic species is usually estimated to lie in the range 3–10 million, with figures as low as 2 million or as high as 100 million being defensible. Possible the best recent estimate is by Hamilton et al. [2], which refines a chain of argument and observation first put forward by Erwin [3], to arrive at an estimated total number of tropical arthropod species roughly in the range 2.5–3.7 million. This implies a current overall total number of plant and animal species of around 3–5 million.

These lamentable uncertainties result partly from what a management consultant would call inefficiencies in the

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distribution of the relevant workforce. Although the taxonomy of taxonomists is itself poorly documented, rough estimates suggest it is approximately evenly divided among vertebrates, plants and invertebrates [4]. But there are around 10 plant species and at least 100 invertebrate species (possibly more than 1,000) for each vertebrate species. The labour force is even more inefficiently divided if one considers the research literature on conservation biology. Here an analysis of the 2,700 papers published in *Conservation Biology* and *Biological Conservation* between 1979 and 1998 showed 69% devoted to vertebrates, 20% to plants, and 11% to all invertebrates (with half of these being lepidoptera, which appear to have the status of honorary birds) [5]. And conservation action, as indicated for example by WWF's Annual Report, is almost wholly devoted to charismatic megavertebrates. This is understandable in view of public attitudes, but arguably unfortunate in terms of preserving ecosystem functioning; the argument that protecting vertebrate biodiversity will more-or-less automatically also preserve invertebrate biodiversity does not survive close examination [6].

3. Extinction rates

The pressures currently being inflicted on natural communities of plants and animals are huge, and increasing. Since Darwin published the *Origin of Species* roughly 150 years ago, human numbers have increased sevenfold, and the energy use per person has increased by a similar factor, resulting in a fifty-fold increase in our overall impact on our planet's ecosystems. Vitousek et al.'s [7] estimate that humanity takes to itself, directly or indirectly, roughly 40% of terrestrial net primary productivity has recently been validated by satellite images of the land area modified by us [8]. Even more extraordinary, of all the atmospheric nitrogen fixed in 2008, 55% came from the Harber-Bosch chemical process rather then the natural biogeochemical processes which created, and which struggle to maintain, the biosphere [8].

If we do not know how many species have been identified – much less their functional roles in ecosystems – to within 10%, nor the overall species total to within an order-of-magnitude, we clearly cannot say much about how many species are likely to become extinct this century. We can note that the IUCN Red Data Books in 2004, using specific and sensible criteria, estimate 20% of recorded mammal species are threatened with extinction, and likewise 12% of birds, 4% of reptiles, 31% of amphibians, 3% of fish, and 31% of the 980 known species of gymnosperms [9]. However, when these figures are re-expressed in terms of the number of species whose status has been evaluated (as distinct from dividing the number known to be threatened by the total number known – however slightly – to science), the corresponding numbers are 23, 12, 61, 31, 26, 34% respectively. This says a lot about how much attention reptiles and fish have received.

The corresponding figures for the majority of plant species, dicotyledons and monocotyledons, are respectively 4 and 1% of those known, versus 74 and 68% of those evaluated. Most telling are the two numbers for the most numerous group, insects: 0.06% of all known species are threatened, compared with 73% of those actually evaluated. The same pattern holds true for other invertebrate groups. For these small things, which arguably run the world, we know too little to make any rough estimate of the proportions that have either become extinct, or are threatened with it.

Perhaps surprisingly, we can nevertheless say some relatively precise things about current and likely future *rates* of extinction in relation to the average rates seen over the roughly 550 million years sweep of the fossil record [1,10]. For bird and mammal species (a total of approximately 14,000), there has been an average of about one certified extinction per year over the past century. This is a very conservative estimate of the true extinction rate, because many species receive little attention even in this unusually well-studied group. Such a rate, if continued, translates into an average "species' life expectancy" of the order of 10,000 years. By contrast, the average life expectancy – from origination to extinction – of a species in the fossil record lies in the general range 1–10 million years, albeit with great variation both within and among groups [1].

So, if birds and mammals are typical – and there is no good reason to assume they are not – extinction rates in the twentieth century were higher, by a factor of 100 to 1,000, than the fossil record's average background rates. And four different lines of argument suggest a further tenfold speeding up over the coming century [10]. Such acceleration in extinction rates is of the magnitude which characterised the Big Five mass extinction events in the fossil record [11,12]. These Big Five are used to mark changes from one geological epoch to the next. Although there is much need for further work to refine estimates of this kind, it does seem likely that we are standing on the breaking tip of a Sixth great wave of mass extinctions. These facts and estimates are set out schematically in Fig. 1 [13].

The crucial difference between the impending Sixth Wave of mass extinction and the previous Big Five is that the earlier ones stemmed from external environmental events. The sixth, set to unfold over the next several centuries – seemingly long to us, but a blink of the eye in geological terms – derives directly from human impacts.

4. Reasons for concern

Why should we worry about this accelerating loss of biological diversity? I think the reasons can be broadly grouped under three headings: narrowly utilitarian; broadly utilitarian; and ethical.

4.1. Narrowly utilitarian considerations

It has been argued that plant and animal species – both known and yet-undiscovered – are a precious resource of genetic novelties. They may well be the raw stuff of tomorrow's biotech revolution, producing new pharmaceutical products, new foodstuffs, and other products for the global economy. So let us not burn the books before we have read them.

I understand such efforts to move biological diversity into the ambit of conventional economics, if only to

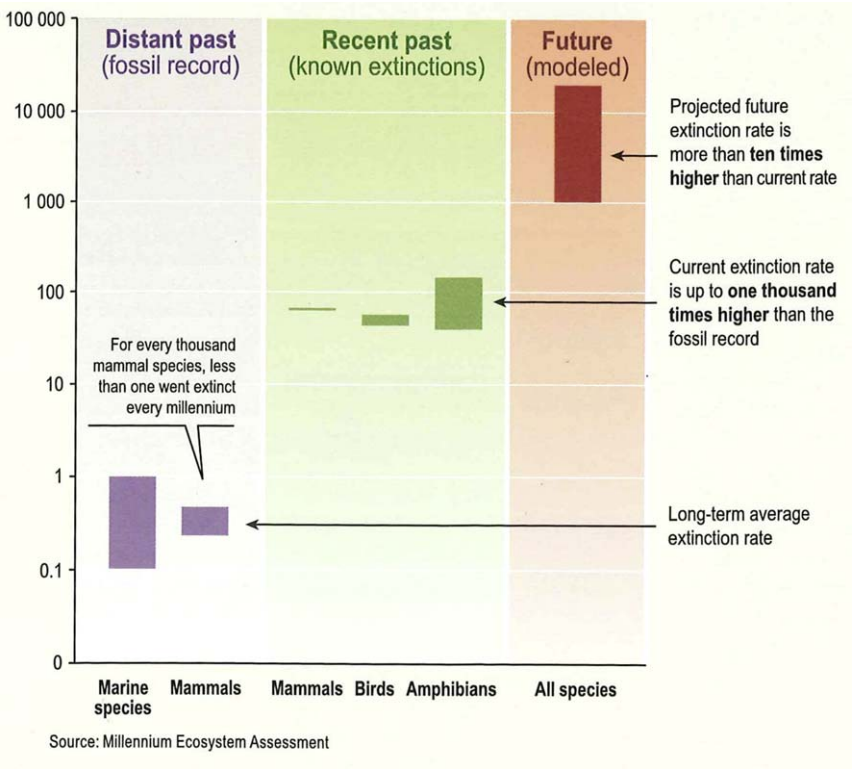

Fig. 1. Extinctions per thousand species per millennium.

motivate political concern. But I am sceptical of this argument. I think it more likely, with the pace of advances in understanding the molecular machinery of living things, that tomorrow's medicines will be designed from the molecules up, rather than emerging from high-tech bioprospecting.

4.2. Broadly utilitarian considerations

More generally, and arguably more importantly, we do not yet know enough about the structure and function of ecosystems to be able to predict how much disturbance and species loss they can suffer yet still deliver ecosystem services upon which we depend.

I began by showing just how little we know about how many species of animals, plants and microbes are present on Earth today. Additionally, for most of those species which have been named and recorded – the majority of which are invertebrates – we know little or nothing about the roles they play in maintaining the ecosystems of which they are part. One estimate is that we have information about the behaviour and ecology of fewer than 5% of all identified animal species [14]. It is therefore not surprising that we are not yet very good at predicting the effects upon local or regional ecosystems of the loss of species as a consequence of habitat disturbance, or over-exploitation, or introduction of alien species, or combinations of these extinction-causing perturbations.

The Millennium Ecosystem Assessment, sponsored by the United Nations, involved some 1360 scientists from 95 countries, and was the first global assessment of the world's ecosystems [13]. Despite many uncertainties, it gives a comprehensive appraisal of the condition of, and trends in, the world's ecosystems. These services are the benefit provided to humans as a result of species' interactions within the system. Some of these services are local (e. g., provision of pollinators for crops), others regional (e.g., flood control or water purification), and yet others global (e.g., climate regulation). In its massive report, the MEA identifies 24 categories of such ecosystem services, broadly grouped under three headings: provisioning, regulating, and cultural.

Table 1 summarises these 24 categories of services, along with indications of whether the service is being enhanced or degraded. Note that of the 24 categories of ecosystem services examined by the MEA, 15 – roughly two-thirds – are being degraded or used unsustainably. Whilst 15 have suffered in this way, only four have been enhanced in the past 50 years, of which three involve food production: crops, livestock, and aquaculture. The status of the remaining five is equivocal or uncertain, as indicated in the Table 1's notes.

The way economists conventionally calculate Gross Domestic Product (GDP) takes little or no account of the role of ecosystem services. For example, an oil tanker going aground, and wreaking havoc on the region's biota, will

Table 1
Global status of ecosystem services (Millennium Ecosystem Assessment [13]).

Service	Status	Notes
Provisioning services		
Food		
Crops	+	Substantial production increase
Livestock	+	Substantial production increase
Capture fisheries	–	Declining production due to overharvest
Aquaculture	+	Substantial production increase
Wild foods	–	Declining production
Fibre		
Timber	+/–	Forest loss in some regions, growth in others
Cotton, hemp, silk	+/–	Declining production of some fibres, growth in others
Wood fuel	–	Declining production
Genetic resources	–	Lost through extinction and crop genetic resource loss
Biochemicals, natural medicines, pharmaceuticals	–	Lost through extinction, overharvest
Fresh water	–	Unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating services		
Air quality regulation	–	Decline in ability of atmosphere to cleanse itself
Climate regulation:		
Global	+	Net source of carbon sequestration since mid-century
Regional and local	–	Preponderance of negative impacts
Water regulation	+/–	Varies depending on ecosystem change and location
Erosion regulation	–	Increased soil degradation
Water purification and waste treatment	–	Declining water quality
Disease regulation	+/–	Varies depending on ecosystem change
Pest regulation	–	Natural control degraded through pesticide use
Pollination	–	Apparent global decline in abundance of pollinators
Natural hazard regulation	–	Loss of natural buffers (wetlands, mangroves)
Cultural services		
Spiritual and religious values	–	Rapid decline in sacred groves and species
Aesthetic values	–	Decline in quantity and quality of natural lands
Recreation and ecotourism	+/–	More areas accessible but many degraded

+: enhanced; –: degraded, in the senses defined in the main text. The evaluation here is of "low to medium certainty"; all other trends are "medium to high certainty".

typically make a positive contribution to conventional GDP because cleanup costs are a plus whilst environmental damage is deemed not assessable. Constanza et al. [15] have attempted to assess the "GDP-equivalent" of the totality of the planet's ecosystem services. Their guesstimate is that such services have a value roughly equal to global GDP as conventionally assessed. Any calculation of this kind necessarily has many uncertainties, and some would argue that you simply cannot put a price upon a service which is essential to life. But I think it is helpfully indicative.

In essence, the broadly utilitarian argument recognises that we do not know how much biological diversity we can lose, yet still keep ecosystem services upon which humans depend. In this situation, as emphasised by one of the founders of the Conservation Movement, Aldo Leopold, "the first rule of intelligent tinkering is to keep all the pieces". But maybe we could be clever enough to survive in a greatly biologically-impoverished world. It would, very likely, be a world akin to that of the cult movie *Blade Runner*. The question arises, who would want to live in such a world? This takes us to the third argument.

4.3. Ethical consideration

The ethical argument is simply put: we have a responsibility to hand on to future generations a planet as rich in natural wonders as the one we inherited. Narrowly utilitarian considerations urge us to preserve individual species, many of them not yet recorded much less studied, because tomorrow's biotechnology may find their genes useful. Broadly utilitarian considerations worry about preserving ecosystems because we depend upon them. Some would say ethical considerations are more vague, but I find them more compelling.

Some of the complexities of the ethical responsibilities of human stewardship were set out eloquently by Aldo Leopold. Mourning the death in the Cincinnati Zoo in 1917 of Martha, the last passenger pigeon, he wrote: "We grieve because no living man will see again the onrushing phalanx of victorious birds sweeping a path for Spring across the March skies, chasing the defeated winter from all the woods and prairies... Our grandfathers, who saw the glory of the fluttering hosts, were less well-housed, well-fed, well-clothed than we are. The strivings by which they bettered our lot are also those which deprived us of pigeons. Perhaps we now grieve because we are not sure, in our hearts, that we have gained by the exchange... The truth is our grandfathers, who did the actual killing, were our agents. They were our agents in the sense they shared the conviction, which we have only now begun to doubt, that it is more important to multiply people and comforts than to cherish the beauty of the land in which they live."

This not only gives poetic expression to how many of us feel, but I think it also raises the question of whether I would feel the same way if I were a poor farmer in a drought-stricken developing country, striving to feed my family.

Conflict of interest statement

The author has no conflict of interest.

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