

Essay

Species, extinct before we know them?

Species are going extinct rapidly, while taxonomic catalogues are still incomplete for even the best-known taxa. Intensive fieldwork is finding species so rare and threatened that some become extinct within years of discovery. Recent bird extinctions in Brazil's coastal forests suggest that some species may have gone extinct before we knew of their existence.

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Taxonomists are still describing new species of birds, mammals and amphibians, even though these taxa have the most complete taxonomic lists. From these groups, we are losing species at a rate of hundreds of extinctions per million species per year [1]. This is a thousand times faster than the natural background rate of extinction of about 0.1 extinctions per million species per year [1,2]. (Catastrophic events such as that at the end of the Cretaceous are understood to be exceptional.) This comparison raises several questions: how many recent extinctions might we have overlooked because species disappeared before we could discover them? How fast will extinctions happen in the near future and, in particular, does habitat destruction precipitate extinctions at the rates theory predicts? New studies from coastal Brazil provide some answers to these questions.

The common, widespread species were discovered long ago. Newly discovered species typically have very small geographical ranges and tend to be very rare within those ranges or located in remote regions [1]. The same will be true for as-yet undiscovered species. So, how fast do the 'very rare' species succumb to extinction? The IUCN ranks species into those that are of Least Concern, then Near Threatened, followed by the progressively more severely threatened species in the categories Vulnerable, Endangered and Critically Endangered [3]. This latter group is of special concern. Many species are not only naturally rare but occur in places with extreme habitat destruction and degradation, where they survive, if at all, in remnants of once extensive habitats. These species are presumed to go extinct quickly, unless we make extraordinary efforts to save them. Might we discover new species only to

watch them go extinct soon thereafter? If this situation were common, we would also expect to have lost some species before taxonomists could name them.

Birds in Atlantic Brazil

We here consider the Brazil's Atlantic Forest or Mata Atlântica — a coastal wet forest. It has the highest concentration of threatened vertebrates in the Americas [1], due to its exceptionally high numbers of small-ranged species coupled with very high levels of habitat loss. This forest once covered 1.2 million km². Now only ~12% of it remains (Figure 1). A quarter of the remaining forest is found in fragments that are likely to be too small to hold viable populations of most vertebrates [4,5]. To answer our questions, we must understand the timelines of both habitat destruction and human efforts to catalogue the region's biodiversity.

We first consider the region's ecological history [6]. Before European contact, the native indigenous peoples, the Tupi and Guarani, were forest dwellers. They hunted mammals and birds for food and feathers, and jaguars (*Panther onca*) for their skins, and they cleared and burned the forest — actions typical of indigenous forest dwellers in the Amazon today. As Dean [6] put it "one wonders [...] what was the impact upon the [forest] of the continued extermination of thousands of its largest predators."

For the purpose of this essay, we concentrate on birds. By the end of the 18th century, taxonomists had described 17% of the approximately 10,000 bird species known today. Globally, there were 27 bird extinctions from 1500 to 1800 traced from sub-fossil bones, skins and a variety of other sources. The most famous of these is the dodo (*Raphus cucullatus*). This list continues to grow. The recent update of the IUCN Red List has identified 13 more bird species that went extinct after 1500, but

before taxonomists could describe them [7]. All of these were island species. We are still documenting the impacts of European explorers — and the rats and cats that came with them — that began centuries ago. We know about some early extinctions from anecdotal evidence, such as eyewitness accounts and drawings. They include the inferred extinction of several species of large Caribbean macaw [8]. Parrots fascinated both the Tupi and early visitors to the New World and they were valuable items for trade [6]. Martin Waldseemüller's map of 1507 shows a 'red parrot' — possibly a macaw — just above the word 'America', famously used here for the first time. Northeast Brazil has a similar, albeit less certain example: multiple travellers reported an all-black parrot, but no specimen exists [6].

The 1648 *Historia Naturalis Brasiliae* has more compelling evidence for historical extinctions [9]. This epic eight-volume treatise, a pioneering attempt to catalogue Brazil's vast biodiversity, was the product of fieldwork by the German and Dutch naturalists Georg Marcgrave and Willem Piso in the then Dutch-controlled Northeast. Most of the bird species depicted have been satisfactorily identified [10]. An exception is an illustration and description of what is evidently a curassow of the genus *Crax* with a yellow beak. Curassows are large terrestrial birds in four related genera. They are large and tasty and, consequently, of 16 species, the IUCN classifies 12 as threatened with extinction. Ornithologists have not recorded a species of *Crax* in the Northern Mata Atlântica [11]. Thus, the plate and other paintings from the same time (Figure 1), and oral testimonies from old hunters [11] are unambiguous evidence for either the historic disappearance of a disjunct population of the similar-looking bare-faced curassow (*Crax fasciolata*) or an undescribed species.

In the Mata Atlântica, species discovery had a slow start: taxonomists described only 14 of its 215 endemic birds before 1800 (Figure 2), but accelerated after 1815 when 111 new species were described in two

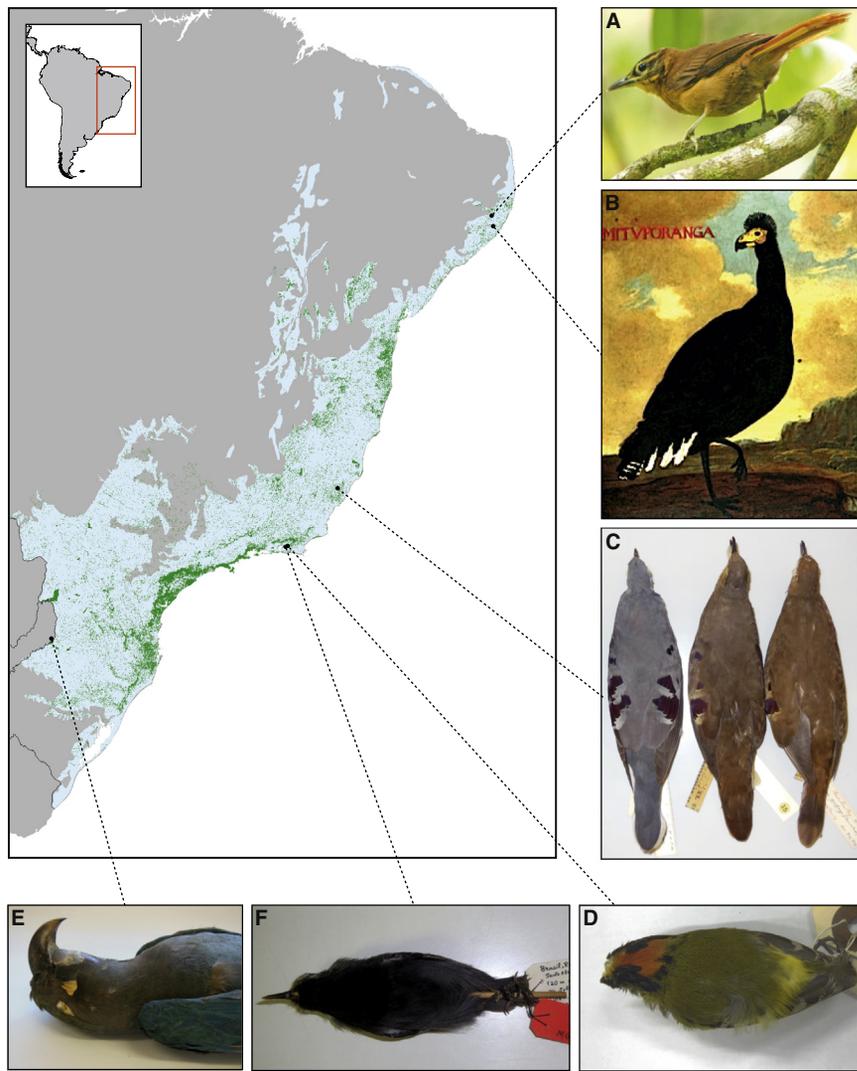


Figure 1. Candidate continental avian extinctions from the Atlantic Forest. Former limits of the Brazilian Atlantic Forest biome (light blue) with current forest remnants (green) and representative missing species. (A) The last known Alagoas Foliage Gleaner *Philydor novaesi* (C. Albano). (B) Purple-winged ground doves *Claravis geoffroyi* (A.C. Lees © Natural History Museum Tring). (C) 'Mituporanga' *Crax* sp. (photo D. Teixeira painting by Albert Eckhout ca. 1610–1666 from Wikipedia Commons). (D) Glaucous Macaw *Anodorhynchus glaucus* (A.C. Lees © Natural History Museum Tring). (E) Kinglet Calyptura *Calyptura cristata* (A.C. Lees © University Museum of Zoology, Cambridge). (F) The type specimen of Rio de Janeiro Antwren *Myrmotherula fluminensis*, the only evidence that this creature ever existed (A.C. Lees © Museu Paraense Emílio Goeldi).

decades. The problem is that by then this area had been under European influence for over three centuries. Most native peoples had been massacred, enslaved, or died from introduced diseases. Sugar cane — inevitably associated with enslaved Africans — may have consumed 7,500 km² by 1850, much of it in the Northeast [6]. Harder to assess were the impacts of gold and diamond mining and land tenure practices that encouraged burning then abandonment, resulting in the clearance of large areas. Land

was cheap and Brazil kept slaves until 1888, keeping labour costs low. Dean [6] estimates that 18% of the province of Rio de Janeiro was cleared to grow coffee by 1888. As coffee planters supposed that only primary forest was suitable, much of the deforestation was in mountains, areas previously spared. Plantations exhausted the soils after twenty years and more forest was cleared; many of the abandoned farms became cattle pastures.

Rates of forest loss and degradation varied across the various discrete

biogeographic provinces of the Mata Atlântica. Worst affected were the forests in the northeast beyond the São Francisco River in the states of Alagoas, Pernambuco, Paraíba and Rio Grande do Norte. Today, almost half (48%) of the remaining forest cover there occurs in fragments smaller than 10 ha. Few patches exceed 1,000 ha, while just 3,731 ha are secured as strictly protected areas [4,5].

The pace of discovery and description of new species slowed after 1835: taxonomists described another 46 by the century's end, then only 16 in the next 60 years (Figure 2). The fate of the 192 species known before 1960 is that one, the Alagoas curassow (*Mitu mitu*), is extinct in the wild — it was last seen in the mid-1980s. Five more are Critically Endangered. One of these, the cherry-throated tanager (*Nemosia rourei*) occurs in just three forest patches and the Stresemann's bristlefront (*Merulaxis stresemanni*) is now known from only one. How certain can we be that the three remaining species will survive?

Conservation professionals are aware of the 'Romeo and Juliet' scenario — giving up on a species when it is not actually lost. The safe thing is never to abandon hope and to continue searching in case one discovers a few survivors. However, the intense interest rare birds generate sets bounds on such optimism.

No one has reported the glaucous macaw (*Anodorhynchus glaucus*), and purple-winged ground-dove (*Claravis geoffroyi*) in the wild since 1951 and 2007, respectively. The kinglet calyptura (*Calyptura cristata*) was seen, but not photographed, in 1996 after an absence of over 100 years. We have to go back far longer for unambiguous records of these species supported by physical evidence in the form of a specimen, sound-recording or photograph. The WikiAves [12] database provides interesting insights into the species recorded by the recently mobilized army of Brazilian birdwatchers. These three species have remained undocumented by the 20,112 participating bird photographers. That is a telling comment, given that the site hosts over one million images taken in the field in Brazil, a citizen science milestone worth mentioning, which has already produced some striking discoveries [13].

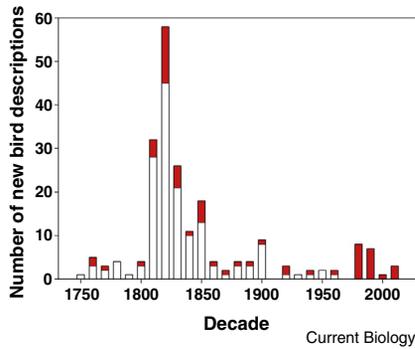


Figure 2. Decadal fluctuations in the description of new bird species and their threat status.

Number of endemic bird species described from the Atlantic Forest biome per decade in the period 1750 to 2014. The number of threatened species (those in the IUCN categories Vulnerable, Endangered, Critically Endangered and Extinct in the Wild) is indicated in red.

Given the popularity of bird photography in Brazil and the fact that most of the Mata Atlântica and adjoining biomes are readily accessible, the best guess is that the macaw, dove, and calyptra are now extinct. These extinctions add to the increasingly well-documented prediction that extensive habitat loss causes species extinction [1].

Conservation efforts do save bird species from extinction, but extinction can happen before any effective measures, such as breeding in captivity, can be implemented. Hunters exterminated the Alagoas curassows in the wild in the 1980s. A few wild-caught birds at the end of the 1970s became the progenitors of a very successful captive breeding program, subject to intensive genetic management with plans for future reintroduction [14].

The purple-winged ground dove (Figure 1) was not so lucky. The last, undocumented report was made in 2007. It is one of the region's three species reliant on mass-seeding of bamboo [15]. The other two species are seedeaters of the genus *Sporophila* and the Red List considers them both Vulnerable. Periodic die-offs of bamboo occur over hundreds of square kilometres following such seeding events. Die-offs would not have posed a problem in pre-Colombian forest landscapes, where birds could disperse long-distances through extensive forests to find new flowering bamboo patches. In today's fragmented landscape, such nomadic behaviour is impossible [20].

This scenario recalls the nomadic passenger pigeon (*Ectopistes migratorius*), the last individual of which died in captivity 100 years ago. The last purple-winged ground dove may also have died in captivity. Several Brazilian bird breeders kept the species up until the 1980s but these populations were not maintained and died out [16].

New species

In the last few decades, the pace of taxonomic accumulation has quickened again as increasing numbers of ornithologists and birdwatchers have explored new areas armed with better knowledge of avian vocalisations and molecular analysis toolkits.

Taxonomists have described 17 species in the last three decades, three in the last year (Figure 2). Buzzetti *et al.* [17] described the São Paulo marsh antwren (*Formicivora paludicola*) from wetlands east of the city of São Paulo. Intensive conservation efforts hope to secure these wetlands from more damage by aggregate extractors, dam builders and reclamation. The Red List has not yet formally evaluated its status, but Buzzetti *et al.* [17] argue it should be classed as Critically Endangered.

The Bahian mouse-colored tapaculo (*Scytalopus gonzagai*) also made its debut in 2014 [18]. Tapaculos are small, unobtrusive and morphologically similar grey-brown birds. Novel vocal and molecular analyses allow better understanding of species limits across South America. Taxonomists described 9 of the 41 species of *Scytalopus* in the last two decades. This latest discovery came from the mountains of southern Bahia. Although the taxon also awaits formal evaluation, the authors propose that the species would easily qualify for Endangered status.

The last new species of 2014 was the cryptic treehunter (*Cichlocolaptes mazarbarnetti*). This bird is very similar to the Alagoas foliage-gleaner (*Philydor novaesi*; Figure 1), which occupied the same forests in northeast Brazil. Its discoverer, Juan Mazar Barnett, a brilliant Argentinian ornithologist, perceived vocal and structural differences amongst the few remaining Alagoas foliage-gleaners in their then last two forest fragment redoubts. A new species was hiding in plain sight. Serendipitously, Juan checked the six Alagoas foliage-gleaner specimens in the National Museum of Brazil and two collected in 1986 turned out to be misidentified specimens of

this new species of treehunter. This ornithological detective work finished in double tragedy. First, Juan died tragically young before seeing the description published. The species now bears his name [19]. Second, a recent assessment [20] of the threatened birds of the forests of the north-east failed to find evidence for the continued persistence of this new treehunter (last seen in 2007), the Alagoas Foliage-gleaner (*Philydor novaesi*; described in 1983, last seen in 2011) or the Pernambuco pygmy-owl (*Glaucidium mooreorum*; described in 2002, last seen in 2000). Conservationists working in north-east Brazil suspect that all three are now likely to be extinct, and if any individuals do persist their chance of long-term survival is remote.

In sum, recent publications allow us to consider the patterns of species discovery and ask whether we will find species before they go extinct or only afterwards. The simple message is that we are constantly adding to the totals of recently extinct species. As predicted from our knowledge of the effects of habitat destruction, the populations of species the IUCN deems to be Critically Endangered are often too small to be viable.

Less expected is that we are adding new species that, when discovered, are so threatened that they survive for only a few years. That we have these examples may be by good luck: we will surely have missed many others. This renders global estimates of extinction rates conservative [1]. The survival of these global rarities is dependent on the protection of remaining forests, a task no longer guaranteed amid the current climate of downgrading, downsizing and removing protection from existing protected areas in Brazil [21].

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Q & A

Patrick Bateson

As an undergraduate at Cambridge, Patrick Bateson worked on the Ivory Gull in Spitsbergen and was much influenced by Niko Tinbergen. After finishing a degree in Zoology, he did a PhD on behavioural imprinting under Robert Hinde. He spent two years in California as a Harkness Fellow with the neuropsychologist Karl Pribram, and then returned to Cambridge where he stayed until he retired. He was Director of the Sub-Department of Animal Behaviour and later became Provost of King’s College, Cambridge. He was the Biological Secretary and Vice-President of the Royal Society, and then President of the Zoological Society of London. His research has been focused on the development of behaviour. He has also been involved in improving the welfare of animals.

When did you first show interest in biology? From a very early age, I told anybody who asked that I wanted to be a ‘biologist’ without having any clear idea what that might entail. I had a very good teacher who gave me, as a five year old, a love of natural history. But another reason was that I had a kinsman who was an eminent biologist: William Bateson, who, as one of the champions of Gregor Mendel, coined the term ‘genetics’. He was a cousin of my grandfather and had died 12 years before I was born, but the family was evidently very proud of him and often referred to him.

In my teens, I spent several holidays at a bird observatory on the Northumberland coast which launched my interest in ornithology. I was told that I could go on to do something called a P H D involving the study of birds in depth. I had little idea of what that meant at that time, but it sounded like heaven and I set my heart on doing research on birds.

When interviewed for an undergraduate place at Cambridge, I was told briskly that birds only took up two weeks in the second year. However, I was admitted, read Natural Sciences and in my third year I specialized in Zoology. Finally I was doing what I wanted to do since I was a child. It was wonderful to be able to think critically and creatively about the

subject. That experience paved the way for a PhD in animal behaviour.

As a second generation ethologist did you know the Nobel laureates Niko Tinbergen and Konrad Lorenz?

When I was still an undergraduate, I went with three friends to the high Arctic to work on the rare Ivory Gull. Niko Tinbergen was working on a comparative survey of gulls at the time and wanted to come with us. He gave us a lot of help both in preparing our expedition and in writing up what we had discovered later. Sadly a serious ulcer prevented him from joining us. My initial plan was to work for a doctorate under Niko, but in the end I stayed on in Cambridge to work on behavioural imprinting in birds under the supervision of Robert Hinde.

As my doctoral research progressed, I became more and more convinced that imprinting shared many features with perceptual learning and that Konrad Lorenz’s claim that imprinting was a special form of learning was wrong. Still a graduate student, I described my experiments at an international conference in 1963. Lorenz was sitting in the front row of the audience. He became increasingly angry. At the end of my talk he got up and said “I’m going to direct my remarks not to you, but to Robert Hinde”.

Subsequently I was asked to give a plenary lecture at the Ethology conference in 1967. Konrad Lorenz was in the chair and was studiously polite. Although my relations with him never fully recovered after my talk four years before, it was obvious to me that he was a man of enormous charm and charisma. It is hard to believe that ethology would have achieved what it did without Konrad Lorenz or indeed Niko Tinbergen, who exerted a strong influence on me throughout my career. Nevertheless, the subject was moving into a much more rigorous phase than in its early days. Many of the classical examples that figured so strongly in the first text books on animal behaviour would not pass editorial scrutiny in the 21st century. Lorenz used to say: “If I have one good example, I don’t give a fig for statistics”. Small samples, non-independence of measurements (when measurements were made), naïve or improper use of statistics (when statistics were used), lack of adequate controls (when experiments were carried out), not conducting

Species, extinct before we know them?

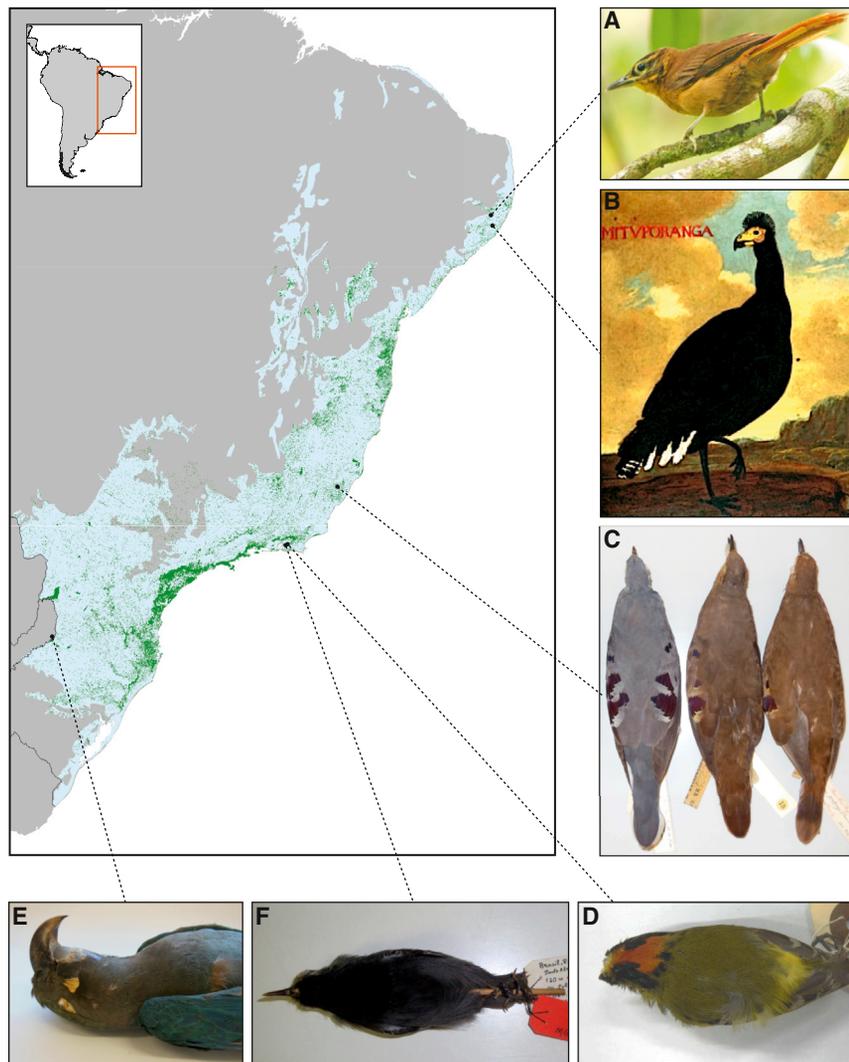
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Due to a production error, the legends for Figure 1 panels B and C in this Essay were reversed, as were the legends for Figure 1 panels D and E. The figure and its correct legends are shown here. The journal apologizes for the error.



Current Biology

Figure 1. Candidate Continental Avian Extinctions from the Atlantic Forest

Former limits of the Brazilian Atlantic Forest biome (light blue) with current forest remnants (green) and representative missing species.

(A) The last known Alagoas foliage-gleaner *Philydor novaesi* (C. Albano).

(B) “Mituporanga” *Crax* sp. (D. Teixeira photo of Albert Eckhout painting ca. 1610–1666; Wikimedia Commons).

(C) Purple-winged ground doves *Claravis geoffroyi* (A.C. Lees © Natural History Museum Tring).

(D) Kinglet calyptura *Calyptura cristata* (A.C. Lees © University Museum of Zoology, Cambridge).

(E) Glaucous macaw *Anodorhynchus glaucus* (A.C. Lees © Natural History Museum Tring).

(F) The type specimen of Rio de Janeiro antwren *Myrmotherula fluminensis*, the only evidence that this creature ever existed (A.C. Lees © Museu Paraense Emilio Goeldi).