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Article

Global biodiversity loss: Exaggerated versus realistic estimates

John C. Briggs
Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97333. USA. Present address: 2320 Guerneville Rd., Santa Rosa, CA 95403, USA. Telephone: 760-289-3193
E-mail: clingfishes@yahoo.com

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Abstract

For the past 50 years, the public has been made to feel guilty about the tragedy of human-caused biodiversity loss due to the extinction of hundreds or thousands of species every year. Numerous articles and books from the scientific and popular press and publicity on the internet have contributed to a propaganda wave about our grievous loss and the beginning of a sixth mass extinction. However, within the past few years, questions have arisen about the validity of the data which led to the doom scenario. Here I show that, for the past 500 years, terrestrial animals (insects and vertebrates) have been losing less than two species per year due to human causes. The majority of the extinctions have occurred on oceanic islands with little effect on continental ecology. In the marine environment, losses have also been very low. At the same time, speciation has continued to occur and biodiversity gain by this means may have equaled or even surpassed the losses. While species loss is not, so far, a global conservation problem, ongoing population declines within thousands of species that are at risk on land and in the sea constitute an extinction debt that will be paid unless those species can be rescued.

Keywords biodiversity loss; biodiversity gain; terrestrial; marine; islands; continents.

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1 Introduction

There has arisen a conflict between advocates of two kinds of data pertaining to the state of global biodiversity over the past 500 years. The first and most popular approach has been to use data on habitat destruction or exploitation together with statistical analyses to provide estimates of species extinction. Some of these authors may have been encouraged to inflate extinction rates with the hope of securing public support for conservation objectives. Leading conservation scientists such as Norman Myers have admitted exaggeration of extinctions in order to put them on scientific and political agenda (Ladle and Jepson, 2008). Others have publicly condoned misrepresentation if it gets the message across (Hannah and Phillips, 2004). The second approach has been to calculate the extinction rate by using data on documented extinctions in certain well-known animal groups that can serve as surrogates for larger, related groups (Briggs, 2015). In essence, the conflict amounts to using overexploitation, habitat destruction and statistics to generate exaggerated extinction numbers, versus using documented extinctions and surrogates to obtain a more realistic result.

2 Exaggerated Estimates

The exaggerated approach was started by publication of Norman Myers' (1979) book *The Sinking Ark* which predicted the extinction of one million species between the years 1975 and 2000. By the 1990s, numerous books and articles had called attention to the extinction of thousands of species per year. Among the most notable were Al Gore's (1992) book which estimated that 40,000 species were disappearing every year, and E.O. Wilson's (1992) prediction of about 27,000 rain forest extinctions per year. The 1992 books were followed by Leakey and Lewin's (1995) volume entitled *The Sixth Extinction* which estimated an annual extinction rate between 17,000 and 100,000 species. The exaggeration campaign continued until the present time, with frequent affirmative articles appearing in leading scientific journals (Briggs, 2014a). Most such articles used terrestrial vertebrates or angiosperm plants as examples, and largely based their predictions on the species-area relationship (SAR) whereby the species number is related to the size of the habitat; as the habitat becomes smaller, species are presumed to be lost.

More recent exaggeration articles attempted to compare contemporary extinction estimates with those found in the geologic record. Pimm et al. (1995) introduced a metric called the E/MSY (extinctions per million species-years). Using this method, background rates are estimated from fossil extinctions that took place in million-year-or-more time bins. For current rates, the proportion of species extinct in a short time (one to a few centuries) is extrapolated to predict what the rate would be over a million years. However, both theory and empirical data indicate that extinction rates will vary markedly depending on the time over which they are measured (Barnosky et al., 2011). MacLeod (2013) approached the problem of determining background extinction in a simpler, more straightforward manner. He utilized average longevities for different taxonomic groups as estimated from the fossil record. Based on these data, he estimated an average longevity for all species with a medium to high fossilization potential. This translated roughly to a historical, background extinction of about one species per year. A "very rough" rate of about one species per year had also been calculated by May et al. (1995).

Although the background rate of one species per year is a convenient reference, it must be used with caution. There is a background extinction gradient over geological time (MacLeod, 2013) so the rate will vary according to the stage selected. Upward through the Cenozoic, the rate has gradually become smaller and less variable. For the Pleistocene epoch, the extinction rate was less than any other time interval in the geological record (MacLeod, 2013). This became evident despite the well-publicized megafaunal extinctions on the continents and the slaughter of endemic, oceanic island species by the early explorers. For the purpose of comparing background extinction rates with those caused by humans, the Pleistocene is the closest time. How low was the rate for the past 2.5 million years? Judging from the graph published by MacLeod (2013, p. 47), a Pleistocene background extinction rate of about 0.5 species per year would be appropriate. This reduced background rate removes some of the incongruence that occurs when short-term extinctions are compared to the long-term rates in the geological record (Regan et al., 2001).

De Vos et al. (2014) also estimated the normal background rate of species extinction, as well as their rate of diversification. Their analyses of large sets of phylogenies found that average extinction rates are less than average diversification rates. But, using the E/MSY method, they concluded that human-caused extinction rates are 1,000 times higher than natural background rates of extinction, and future rates are likely to be 10,000 times higher. Those authors used an approximate benchmark of 0.1 extinctions per million species per year (E/MSY) for the background rate. This benchmark seems to be an awkward and questionable method of expressing extinction rate. If we accept a Pleistocene rate of 0.5 species per year, and extend it upward to the present time, we will have a background extinction rate to compare to extinctions caused by human activity. For the past 500 years, this would mean about 257 species became extinct due to non-human causes. The crucial question is, how do we determine the total number of species that became extinct over the past five centuries?

The most recent paper in the exaggeration category was published by Ceballos et al. (2015). The authors endeavored to demonstrate that species extinctions by humans have caused the world to enter into its sixth mass extinction. As evidence, they compared extinction rates, among terrestrial vertebrates for the past few centuries, to the historical rate from the geological record. However, the historical rate was calculated only from data on mammal extinctions. The authors assumed that the historical mammal rate could be applied to all the other vertebrates (birds, reptiles, amphibians, and fishes). Using the mammal data, the authors determined that, without human influence, only nine vertebrate extinctions would have been expected since the year 1900.

According to the IUCN Red List (2014), 198 extinctions were recorded for all terrestrial vertebrates since the year 1900. Compared to the expected nine extinctions during that time (Ceballos et al., 2015), an increase of 189 appears to indicate a significant human influence. Extending back to the year 1500, a total of 338 were documented by the Red List. The authors inflated that total by recognizing 279 more species under “extinct in the wild” and “possibly extinct” categories. These figures produced a grand total of 617 vertebrate species lost or presumed lost since 1500. This large number persuaded the authors to declare that the evidence is “incontrovertible”, that the recent extinction rates are unprecedented, and that the rate is highly unusual in Earth history. Therefore, they concluded that a mass extinction episode had been initiated.

The unfortunate aspect of this work is that no reference was made to estimates of global extinctions using other faunal groups, extinctions recorded in the marine environment were not considered, and no mention was made about concurrent gains in species diversity. About 90% of the terrestrial world’s species are insects. A recent review (Stork et al., 2015), utilizing new approaches to terrestrial arthropod estimates, has indicated a mean of 5.5 million species for all insects (range 2.6-7.8 million). Four insect groups (butterflies, tiger beetles, dragonflies, damselflies) have been of special interest to professional and amateur entomologists. Each is well known, has a worldwide distribution, and their species extinctions during the past 500 years have been documented. This makes it possible to use them as surrogates in order to obtain an approximation of extinctions among insects as a whole. Marine species extinctions have also been recorded (Dulvy et al., 2009). The contributions of the foregoing groups are considered in the following section (Realistic Estimates).

The attempt to forecast a global extinction on the basis of only terrestrial vertebrate animals (Ceballos et al., 2015), is unconvincing and the number of extinctions was exaggerated. As noted, the authors inflated the vertebrate total extinctions by adding 279 species to the IUCN Red List of documented losses, and they also failed to mention that the great majority of extinctions took place on oceanic islands. In regard to the mammals and birds, more than 95% of all extinctions during the past 500 years were island species (Loehle and Eschenbach, 2012). In their analysis, the authors considered Australia (a physiographic continent) to have functioned as a biogeographic island due to its separation from other parts of the world during the latter half of the Cenozoic. If we use the mammals and birds as surrogates for all the vertebrates, extinctions on the world’s continents must have been very few. For example, only three of the 61 mammal extinctions and only six of the 128 bird extinctions took place on continents. The loss of isolated, island species had little or no effect on continental ecology.

3 Realistic Estimates

A reassessment of earlier, extravagant global extinction rates was made by Stork (2010). He utilized records from actual extinctions and concluded that there were almost no empirical data to support estimates of current extinctions of 100 or even one species per day. In regard to plant species richness on regional, continental landscapes, Ellis et al. (2012) found an overall increase, mostly because species invasions tended to exceed native losses. But, Vellend et al. (2013) conducted a global analysis that revealed no net change in local-scale plant biodiversity over time. An important advance was made when Dornelas et al. (2014) published their assemblage time series study. They gathered data that represented 35,613 species from 100 individual time series. The data included marine, freshwater and terrestrial biomes from the poles to the tropics. Most of the time series were concentrated within the past 40 years. Their results did not indicate a negative trend in species richness.

There is a need for additional analyses of global biodiversity that include extinctions and originations on land and sea, as well as a time frame extending well into the past. It is important to contradict the extravagant claims of huge biodiversity losses by using accurate extinction data for well-known species groups so they can serve as surrogates to indicate extinctions in larger, related groups. Surrogates had not previously been used on such a large scale, but the technique had proven to be useful (Lewandowski et al., 2010). It is particularly important to obtain reliable information on insect extinctions. Considering that insects comprise about 90% of all terrestrial species, that group alone should powerfully reflect the rise or fall of overall species diversity.

In a paper published early in the year (Briggs, 2014a), I used two surrogate groups, butterflies and tiger beetles, to indicate the insect extinction rate for the past 500 years. The apparent loss of only three surrogate species out of 19,580 indicated an extremely low extinction rate. A follow-up paper, that included more information, was published later (Briggs, 2014b); it reinforced the data on documented insect extinctions by including the Odonata (the dragonflies and damselflies of the world), and eliminated three butterfly extinctions because of doubtful authenticity. Clausnitzer et al. (2009) used a random sample of 1,500 of the 5,680 described Odonata species and found that none had become extinct. Otherwise, only two extinctions had been noted, one from Maui in the Hawaiian Islands and the other from St. Helena, an isolated island in the south Atlantic. The addition of the Odonata made it possible to use four well-known insect groups (butterflies, tiger beetles, dragonflies and damselflies) as surrogates to provide an up-to-date indication of the extinction rate for all insects. The additional evidence showed only two recorded extinctions out of 25,260 species over the span of 500 years. But an extinct butterfly species was found that had been endemic to the Island of Mauritius (IUCN, 2014), bringing the insect total to three, all endemic to oceanic islands. This result accords with the work of Coope (2004) who noted a virtual absence of insect extinctions during the Pleistocene, indicating that the lack of recent extinctions may reflect an extinction resistance that has lasted for more than two million years.

4 Discussion

4.1 Species gained

Over the past 50 years, alarm over a present biodiversity crisis and the beginning of a sixth mass extinction has continued to be spread by many ecologists, while little attention was paid to the possibility that there might have been gains to offset the losses or to actually cause an overall increase. As noted for the marine environment (Briggs and Bowen, 2013), invader species are part of a worldwide, dynamic system that often serves to increase global diversity by speciation following successful invasion. Other paths to speciation have also become apparent. Molecular research has revealed numerous cases of rapid, adaptive divergence resulting in ecological speciation. Such cases have been demonstrated in plants, vertebrates, and invertebrates (Hendry et al., 2007). Specific examples have been reported in mammals (Rowe et al., 2011), echinoderms (Puritz et al., 2012), and plants (Foxe et al., 2009). Within the past few centuries, species diversity has increased on oceanic islands and in many continental regions; in addition, no general decreases in diversity have been known to occur at regional scales (Sax and Gaines, 2003). Human introductions for agricultural and ornamental purposes have produced substantial gains in continental plant diversity (Ellis et al., 2012). Furthermore, De Vos et al. (2014), who examined a series of individual phylogenies, found that average extinction rates were less than average diversification rates. For these reasons, and in view of minimal losses, except for species endemic to isolated islands, it appears that terrestrial biodiversity gain is concurrent with, and probably exceeds biodiversity loss.

4.2 Species lost

Previously, we posed the question: how many species were actually lost during the past 500 years? For the terrestrial environment, we can turn to the insects which comprise about 90% of all species. As noted, among the four well known groups of insects that include 25,260 species, only three species are known to have become extinct. Considering that about 5.5 million insects species exist (Stork et al., 2015), and an extinction ratio of 3 out of 25,260 is found in the surrogate groups, we can calculate-by using the same ratio-that about 653 of all insect species may have been lost. According to the IUCN Red List, 66 documented insect extinctions have taken place over the past 500 years. However, in this case the IUCN List is deficient because so few insects have been evaluated. The calculated figure of 653 total insect losses may be compared to the IUCN documented figure of 338 vertebrate extinctions over the same period.

4.3 Marine environment

In the marine environment, there are few recorded extinctions and they are scattered among five biotic groups. This means we have no reliable surrogate taxa that can be compared to larger, related entities. From the beginning of the Holocene about 12,000 years ago, Dulvy et al. (2009) recorded the losses of 20 species (4 mammals, 8 birds, 4 molluscs, 3 fishes, 1 alga). When these extinctions are compared to a total marine diversity of about 2.21 million eukaryotic species (Mora et al., 2011), the rate of extinction becomes exceedingly small. In regard to the three fishes, the New Zealand grayling needs to be excluded because it lived primarily in freshwater. Another fish species, the Mauritius green wrasse, has been taxonomically confused and is actually a species common throughout the Indo-West Pacific (Russell and Craig, 2013). This leaves only one marine fish species, the Galápagos damselfish, documented to be extinct.

There is a looming marine extinction which consists of a thousand or more small populations of fishes and invertebrates that are the collapsed remnants of species that have been overfished (Briggs, 2011). Some of them represent collapses that took place 30-50 years ago, yet they have still managed to avoid extinction (Roberts, 2007). Lotze and Worm (2009) investigated records of 256 exploited fish populations and found an 89% decline from known historic levels. Populations that have sustained losses of this magnitude are generally considered to have collapsed. A collapsed state means that the population has become so depressed that it no longer plays an effective role in the ecosystem (McCauley et al., 2015), and its chances of continued survival are greatly diminished.

A Living Blue Planet Report (2015) has been published by the World Wildlife Fund and the Zoological Society of London. The Report provides a global picture of 7,829 populations from 1,243 marine species of birds, mammals, reptiles, and fishes. An overall population decline of 49% was shown to take place between 1970 and 2012. For the same time, an index of 17 species of large pelagic fishes indicated a 74% decline, 2,501 reef fish populations demonstrated a 34% decline, and 350 fish populations in seagrass habitats suffered more than a 70% drop. These extensions of population studies into marine waters represent an important step forward in the monitoring of oceanic habitats.

4.4 Conservation implications

Almost all biodiversity estimates made for conservation purposes are based on species numbers, i.e., species richness or alpha diversity. But, occasionally beta diversity, which reflects the sizes of individual populations, is utilized. In an influential paper under the main title “Global Biodiversity”, Butchart et al. (2010) measured population trends in a variety of habitats over the past 40 years. In most cases, their data showed significant declines in population sizes. While their results were important, the title should have suggested declines in population sizes or beta diversity rather than global biodiversity, which usually means species diversity or richness. Even so, the article pointed to the greatest conservation need, which is to keep track of population sizes of species that have declined to the extent that their continued existence is in doubt.

The research reported by Butchart et al. (2010) was similar to that being carried on by the World Wildlife Fund, supported by the Zoological Society of London, the Global Footprint Network, and the Water Footprint Network. Their Living Planet Index (2014) provided information on the status of 10,380 vertebrate populations belonging to 3,038 species. The Index reported that population sizes had undergone a 52% global loss between 1970 and 2010. The greatest decline was in freshwaters where the loss was 76%. The Living Planet Index needs to be expanded to cover some groups of invertebrates and plants. Populations of rare animals and plants need to be monitored so that species in decline can be rescued before it is too late. As populations become very small, they suffer genetic loss due to their reduced size, inbreeding, and depensation (Allee effect). Genetic loss reduces their ability to respond to environmental change.

5 Conclusions

Documented extinctions, or those indicated by surrogates, have allowed a realistic estimate of global (alpha) biodiversity losses. During the past 500 years, the Earth has lost approximately 1009 species from three faunal groups: 338 terrestrial vertebrates (documented) 653 insects (based on surrogates), and 18 marine species (documented).The expected background loss of 257species (0.5 species per year), when subtracted from the 1009 total, leaves 752 extinctions, or a rate of 1.56 species per year, probably attributable to human-caused extinction. For the terrestrial world only (including oceanic islands), the figures on insects and the vertebrates minus the background loss, over the past 500 years, yield 734 extinctions, or 1.47 species per year. Is it reasonable to estimate global biodiversity loss from only insects, land vertebrates, and marine species? At present, these are the groups that yield the most dependable data. The calculated figures should be regarded as approximations that will change as new information on extinction or speciation becomes available. As noted in the abstract, it would be preferable to refer to a realistic terrestrial loss of less than two species per year instead of exactly 1.47. Accordingly, one can compare this realistic loss to the extinction of hundreds or thousands of species per year as claimed in the exaggeration literature.

The terrestrial data on insects and vertebrates should be viewed in context with the previously noted information on higher plants (Ellis et al., 2012; Velland et al., 2013) and on biomes across the world (Dornelas et al., 2014). None of these studies, conducted over time, revealed net losses in biodiversity. Overall, the information presented in this paper indicating few losses due to human influence, should help reduce public consternation over global biodiversity loss and the advent of a sixth mass extinction. It may permit more attention to the plight of individual species whose populations have suffered from human exploitation and habitat loss, the world’s greatest conservation problem. Is it ethical to keep publishing exaggerated extinction claims or to use alarming extinction numbers for terrestrial vertebrates without pointing out that the great majority of the losses took place among species confined to oceanic islands? Misleading the public is not an effective conservation strategy. The best way to keep track of biodiversity loss in the terrestrial world is to continue monitoring the well-known groups of insects and use them as surrogates to estimate the overall extinction rate. Of course, attention should still be paid to extinctions among the vertebrate animals and higher plants but their diversity is small compared to that of the insects. The recorded extinction rate in the marine environment seems suspiciously low, which indicates the need for long-term monitoring of familiar groups such as the corals and fishes. At the same time, attention needs to be paid to the rate of speciation. Are species being created at more or less than the extinction rate? There are indications that the buildup of species diversity, evident throughout the Cenozoic, is still continuing.

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