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Global biodiversity gain is concurrent with declining population sizes

John C. Briggs

Oregon State University, Department of Fisheries and Wildlife, Corvallis, OR 97333, U.S.A; e-mail: clingfishes@yahoo.com
Current address: 2320 Guerneville Rd., Santa Rosa, CA 95403, U.S.A.

ABSTRACT Many authorities believe that the world's foremost conservation problem is biodiversity loss caused by the extinctions of thousands of species per year. Estimates of huge losses are based on indirect evidence such as the amount of habitat destroyed, pollution, or overexploitation. But, we now have documented records of species extinctions that provide direct instead of indirect information about diversity loss. By using extinction records for well-known animal groups plus surrogate data, I show there is no evidence for an unusually high rate of extinction, a mass extinction is not yet underway, and there are indications of a continued biodiversity gain. On the other hand, there is ample evidence to demonstrate the persistence of numerous small populations that are the remnants of once widespread and productive species. These populations represent an extinction debt that will be paid unless they are rescued through present day conservation activity. They constitute the world's true biodiversity problem.

KEY WORDS biodiversity gain; biodiversity loss; conservation; extinction debt; speciation.

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INTRODUCTION

As new portions of terrestrial wilderness continue to be utilized or modified by human activity, wildlife has less territory, individual species are crowded into smaller spaces, and many of them lose population size until their existence becomes precarious. Overexploitation by hunting and trapping directly affect populations of birds and mammals. In the oceans, there is loss of natural habitat over large areas of sea bottom through the action of commercial trawlers, and by the degradation of coral reefs by human use and global warming. Along shorelines, construction and pollution have impacted much of the shallow marine habitat. The direct effect of overfishing has resulted in hundreds of species being reduced to remnants of their original population sizes. These kinds of impacts are assumed to have contributed to a global biodiversity loss of several thousand species each year, an apparent crisis that has been called the world's greatest conservation problem.

The reactions of conservation societies and government agencies to the foregoing problems have tended in two directions: (1) trying to stem the perceived loss of biodiversity due to species extinction, and (2) paying attention to the plight of species that are threatened by extinction. This brings up the question, should we continue to concentrate on overall biodiversity loss or should we devote more resources to the needs of individual species? One might say that both conservation approaches are important, but is this really true? Let us first consider biodiversity loss.

BIODIVERSITY LOSS?

Global and local losses of biodiversity have been a major focus of conservation action for 40 years. Anguish over the apparent, continuing extinction of large numbers of species has been expressed in numerous scientific papers, newspaper and magazine articles, and on the internet. As E.O. Wilson (1993) has noted, biodiversity, as a term and a concept, has been a remarkable event in recent cultural history. It was born as "BioDiversity" during the National Forum on BioDiversity held in Washington, D.C., in September, 1986. Prior to that time, Norman Myer's (1979) book had caused considerable excitement when it predicted the extinction of one million species between 1975 and 2000.

By the 1990s, numerous books and articles had described biodiversity loss in terms of thousands of species that disappeared each year. Among the most notable, were Al Gore's (1992) book which estimated that 40,000 species were disappearing each year, and E.O. Wilson's (1993) prediction of about 27,000 rain forest extinctions per year. Other huge species loss estimations (Briggs, 2014) were soon followed by declarations that the Earth had started to undergo its sixth great mass extinction (Ceballos et al., 2010; Kolbert, 2014).

In retrospect, biodiversity loss became rapidly established as a scientific revelation and there were few questions about sources of the information. But, such concepts or theories need to be supported by facts and, in this case, the facts were few and the theory was so captivating that it survived even with little support for 40 years. The beginning can be traced back to an influential work on island biogeography by MacArthur & Wilson (1967). The authors found that on small islands, species diversity was determined by island size, i.e., the larger the size, the greater the diversity. Also, they found a constant turnover whereby the numbers of invading species were balanced by the native species that were lost. In subsequent years, more research was done on islands and other small habitats and these two discoveries were generally substantiated.

The relationship between area size and species diversity became important to many ecologists who were convinced that, if a given amount of habitat was destroyed, a certain number of species must be lost. That idea was converted to a "rule of thumb" which stated that when a habitat is reduced to one tenth its original size, the number of species eventually drops to one half (Wilson, 1993). This species-area rule (SAR) become well accepted and began to be applied to locations ranging from small islands to large continental areas. However, prohibitive difficulties became apparent when the SAR was applied to areas larger than small, isolated islands. As noted by Whittaker et al. (2001), the problem with such data is one of scale. When small scale data are applied to very large scale areas, the results are apt to become meaningless. Furthermore, there has been constructive criticism about the usefulness of the SAR (He & Hubbell, 2011). To avoid the SAR problem, as well as to depend on direct instead of theoretical data, it is preferable to utilize information from documented extinctions. More recently, various statistical methods have been used to manipulate the theoretical extinction data in order to prove large annual losses (for example Pimm et al., 2014), but they unnecessarily complicate what is actually a simple problem. By utilizing information from recorded extinctions, together with data from well-known surrogate taxa, I show that rate of recent extinctions has been very low.

Documented extinctions

Until recent years, there had not been sufficient data on species extinctions to provide an overall estimate of biodiversity loss over the past 500 years or more. But now, the availability of more data, based on contemporary and fossil extinctions, has made possible a new analysis. It is important to note that previous estimates were made primarily on life in the terrestrial and freshwater environments. Obviously, global predictions should also depend on information from the sea which covers about 71% of the Earth's surface. There is one significant difference between the data from land and sea. In the first instance, there have been, in the early years of island explorations by humans, thousands of extinctions of endemic species that were confined to very small spaces. But in the second case, recorded extinctions have been remarkably few.

Although attention has been called to marine biodiversity losses by Worm et al. (2006), that article was referring to decreases in population size rather than species extinction. The Holocene began about 12,000 years ago and a total of 20 marine extinctions were recorded by Dulvy et al. (2009). When the losses of the 20 marine species (4 mammals, 8 birds, 4 molluscs, 3 fishes, 1 alga) are compared to a total marine diversity of about 2.21 million eukaryotic species (Mora et al., 2011), the rate of extinction becomes vanishingly small. Although it is often assumed that invasive species are responsible for native extinctions, none of the 20 marine extinctions have been due to competition from exotic invaders (Briggs, 2007).

In fact, there is now good evidence that invasive species function to increase rather than decrease biodiversity. In locations where large numbers of exotic species are being introduced, such as the eastern Mediterranean Sea (Galil, 2007) and in many harbors and estuaries (Briggs, 2012), the invaders are accommodated by the native species resulting in local biodiversity increases. Information from Pliocene invasions demonstrates that a large fraction of invaders eventually speciate (Vermeij, 1991; 2005) thus adding to global bio diversity. It has been concluded that in the marine environment, invader species are a dynamic diversity-creation force with a circumglobal influence (Briggs & Bowen, 2013).

In the terrestrial environment, the birds and mammals are the best known vertebrates and their extinction rates have been recorded. The records and geographical locations of the extinctions, based on evidence in the IUCN Red List and the CREO List at the American Museum of Natural History, have been analyzed by Loehle & Eschenbach (2012). Extinctions during the past 500 years demonstrate an enormous difference between islands and continents. On all continents, only three mammals are recorded as having gone extinct. The remaining mammal extinctions (58 or 95%) took place on islands (Australia, due to its history of isolation, was classified as an island). Of 128 extinct bird species, 122 (95.3%) were island extinctions and only six were on continents. It has been observed that well-known surrogate taxa can be used as biodiversity indicators (Caro & O'Doherty, 1999). If we use the birds and mammals as surrogates for all the vertebrates, this suggests that extinction rates among the vertebrate animals of the world's continents have been very low. Another discovery (Loehle & Eschenbach, 2012) was that none of the bird and mammal extinctions were known to have occurred solely because of habitat reduction. For many years, habitat reduction, especially tropical deforestation, had been regarded as the primary cause of species loss. A recent study of the vertebrate species in the Brazilian Amazon by Wearn et al. (2012) demonstrated that extinctions have been minimal (1%) and that 80% of the losses predicted by habitat decline were yet to come.

For invertebrates, the Zoological Society of London has published the world's first study of global invertebrate biodiversity (Collen et al., 2012). This report, produced in conjunction with the IUCN and its Species Survival Commission, concluded that about 80% of the world's species were invertebrates and about 20% of them were threatened with extinction. Of the world's terrestrial invertebrates, about 90% are insects. This suggests if dependable information on insect extinction rates were available, it might yield an approximate rate for terrestrial invertebrates as a whole. Three orders of insects: butterflies, tiger beetles, and Odonata (dragonflies and damselflies), have been studied to the extent that almost all the species are well known. The world total of butterfly species is about 17,280 (Shields, 1989). Although three species are often listed as extinct (two in South Africa and one in the USA), the records are doubtful. Ehrlich (1995) found that there was no documented extinction of a continental butterfly species anywhere in the world. No island butterfly species has been recorded to be extinct.

There are about 2,300 species of tiger beetles (Pearson, 2001) and, although several are listed as endangered, none has become extinct. For the Odonata, a random sample of 1,500 of the 5,680 described species was assessed (Clausnitzer et al., 2009). Ten percent were found to be threatened but none of them had become extinct. In fact, there are only two documented extinctions, one from Maui in the Hawaiian Islands and the other from St. Helena, an isolated island in the South Atlantic. If the three insect orders can constitute a surrogate group for all insects, and if the lack of extinction among the insects (two out of 25,260) is indicative of the terrestrial invertebrates, the extinction rate has been exceedingly low.

The foregoing indications of very low extinction rates may be compared to data that show continuing gains in species diversity.

Biodiversity gains

While global losses were evidently minimal during the past 400 to 500 years, there is evidence that concurrent gains have taken place. As noted for the marine environment, invasive species add to local biodiversity and many of them eventually speciate, thus increasing global diversity. 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, invertebrates, and vertebrates (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; furthermore, no general decreases in diversity have been known to occur at regional scales (Sax & Gaines, 2003).

In fact, human introductions for agricultural and ornamental purposes, along with natural invasions, have produced substantial gains in continental plant biodiversity (Ellis et al., 2012). These positive indications of biodiversity increase indicate that the Earth is still gaining biodiversity, just as it has been for the past 65 million years (MacLeod, 2013).

DISCUSSION

It is now possible to make a realistic assessment of recent global biodiversity trends without having to depend on estimates of habitat destruction, species invasions or other abstract and possibly subjective factors. For the past 500 years, there have been few documented extinctions in the oceans or on the continents, with the exceptions of some restricted freshwater habitats. In using these data, I do not imply an absence of unobserved extinctions among groups of lesser known organisms. Even when estimates of such extinctions are included, it has been found that contemporary extinctions could not have been as high as generally predicted (Costello et al., 2013), and that less than 1% of all organisms could have become extinct within the past 400 years (Stork, 2010). Global projections of biodiversity loss have generally included estimates of extinction due to invasive species (McGeoch et al., 2010). But, detailed studies have found no evidence that invasive species are implicated in the extinction of continental natives (Gurevitch & Padilla, 2004; Davis, 2009).

The losses of endemic species on islands and in freshwater lakes, while regrettable, took place on very small spots on the Earth's surface and their extinctions had little effect on the ecology of the mainland biotas. Those endemics are generally short-lived and tend to appear and disappear along with their habitats (Whittaker et al., 2008). Of course, there are the exceptions of a few ancient islands and lakes that demonstrate the effects of evolution and extinction over long time periods. Why do small places lose species to invaders while mainland habitats do not? The demise of almost all island/lake endemics has been due to humans and species they introduced (Blackburn et al., 2004). Extinctions resulting from natural (non-human) invaders have seldom been recorded. Despite the early losses of endemic species, oceanic islands have shown biodiversity gains in recent years (Sax & Gaines, 2003).

The world's greatest conservation problem is exemplified by the thousands of species that were once widespread but are now represented only by very small populations. They are the remnants of species that were almost destroyed by human overexploitation, habitat destruction and pollution. These populations are threatened because they have suffered genetic loss due to their reduced size, inbreeding, and depensation (Allee effect). Genetic loss reduces the ability to respond to environmental change such as continued global warming. Furthermore, small populations are often confined to restricted habitats, from which they would be unable to migrate in response to climatic change. Formerly abundant species that now exist in small numbers are considered to be evidence of an extinction debt, one that will be paid when environmental change proves too difficult for them to adapt (Kuussaari et al., 2009). If governments and conservation societies could be convinced to spend less effort on mythi-cal global biodiversity loss, and more on the needs of species that are at risk, the world would have a consolidated conservation goal that could produce better results. The conservation plan, initiated by the World Wildlife Fund, and supported by the Zoological Society of London, the Global Footprint Network, and the European Space Agency, is promising. Their Living Planet Index (2012) provided information on the status of 9,014 vertebrate populations belonging to 2,688 species. The Index reported that the population sizes had undergone a 28% global loss since 1970; the greatest decline was in the tropics where the loss was 60%. The Living Planet Index needs to be expanded to cover invertebrates and plants.

CONCLUSIONS

In regard to the question about the need for conservation measures to be applied to global biodiversity loss or to the precarious condition of species that have been reduced to small populations, there is no longer cause to be concerned about biodiversity loss because it is apparently not true. For the past 40 years, estimates of global loss, based on the extinction of thousands of species per year, have been a primary concern of ecologists and conservationists. These estimates, mainly due to belief in the utility of the SAR, are shown to be erroneous and the SAR is found to be applicable only to small islands, lakes, and other restricted habitats. On the other hand, we now have substantial evidence of gains in global species diversity. This should permit conservation societies, government entities, and interested individuals to concentrate on species that are at risk on the continents and in the oceans, as well as species confined to islands and smaller habitats. Species at risk comprise an extinction debt that will be paid unless they are rescued before global warming or other environmental change takes their toll. A conservation emphasis on critically endangered species does not mean that projects to preserve rain forests, coral reefs, and other natural habitats should be abandoned.

On the contrary, such high diversity areas are sources of biodiversity and are significant in an evolutionary sense. However, each species that is at risk must be considered in view of its own conservation problems that are often unrelated to habitat area. The current (2014) IUCN Red List identifies 4,286 species that are critically endangered and likely to become extinct due to global warming or the inherent risks of small population size. We need to be aware that many of those species can be rescued prior to the anticipated rise in extinctions.

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