Balancing the Books on Biodiversity

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Humanity has induced pervasive negative impacts on the world's biodiversity (Smith et al. 1993; Morris 1995). Earth is accumulating an ecological deficit that, when the accounting is complete, will be written off by massive global extinctions (Tilman et al. 1994). But the evolutionary ledger has another side. Adversity for one group of species often represents opportunities for others. Despite repeated mass extinctions, the history of life reveals an impressive and consistent increase in biodiversity (Rosenzweig 1995). Each mass extinction is associated with adaptive radiation of the survivors.

We believe that human activities have placed us in the midst of one such major reorganization of life. We have, accordingly, searched a variety of sources in an attempt to identify the kinds and numbers of species flourishing under the current onslaught of human impacts.

Table 1 summarizes examples of taxa capitalizing on human-induced ecological opportunity and reveals several important lessons regarding the future of Earth's biodiversity: (1) human activities have provided new habitats and food sources to numerous species; (2) many of these species appear to be adapting to human-altered conditions; (3) adaptation to human-altered environments can occur rapidly; (4) most of the species are pests or pathogens of humans or their domesticated prey and mutualists.

Our list of taxa capitalizing on anthropogenic change represents a minimum estimate gleaned from a subset of taxa and geographical locales. We excluded introduced species so we could concentrate on those taxa that we know are exploiting anthropogenic environments without direct human assistance. Our errors of omission are counterbalanced to some degree by the inclusion of taxa that exploit anthropogenic environments as sink populations maintained only from sources in the native landscape (Pulliam 1988). We do not know how many taxa in our table fit the source-sink category. We include them because one cannot doubt their exposure to novel conditions that ultimately may lead to specialization in, and for those habitats (Rosenzweig 1995).

Perhaps the best evidence that large numbers of species can adapt to environmental change and altered biodiversity comes from the consistent species-area curves of novel pest species exploiting introduced crop plants (e.g., Strong 1974; Strong et al. 1977; Strong et al. 1984; Andow & Imura 1994). Many pest communities that have long associations with domestic plants appear to accept fewer host plants than those with shorter histories of co-occurrence (Andow & Imura 1994). Eventually, these taxa may undergo adaptive radiations that will replenish lost biodiversity, but there are several sobering corollaries: (1) the course of evolution is contingent on history and is easily deflected by the loss of taxonomic diversity (Gould 1989); (2) adaptive radiation of pests and pathogens paints a bleak future for humanity; (3) many of those pests and pathogens have cosmopolitan distributions that tend to homogenize global biodiversity; (4) the books don't balance—the number of species gained does not equal the number of species lost.

Worldwide, nearly 26,000 species are threatened with imminent extinction, including more than 2200 vertebrates (Smith et al. 1993; Morris 1995). Over a thousand species are known to have gone extinct in the last 400 years (Smith et al. 1993). Hundreds, if not thousands, of others have gone extinct without notice (Wilson 1992). It is thus difficult to judge the relative accuracy of our estimates of adaptive responses against those of species extinction. Our list of vertebrates, for example, is incomplete and comes from North America only. But the list of weeds is global and comprises about 3% of known plant diversity. The proportion of plants currently threatened with extinction is approximately three times as great (Smith et al. 1993; Morris 1995).

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Table 1. Examples of taxa capitalizing on anthropogenic change.

Taxa known to exploit anthropogenic habitats

Exploiting group	*Sample area*	*Species*	*Sources*
Weeds	Earth	8000	Ross & Lembi 1985
Major agricultural insect pests[a,b]	United States	365	Sailer 1983
Urban mammals and herptiles[a]	North America	38	Marsh 1986; Adams 1994

Native taxa known to exploit anthropogenic food sources

Exploiting group	*Food source*	*Species*	*Sources*
Phytophagous insects	35 nonnative plant species	7–1620 (median = 37)[c]	
Parasitoids	77 nonnative plant insect species	1–28 (median = 6)	Cornell & Hawkins 1993
New or emerging diseases[d]	*Humans*	*27*	T-W-Fiennes 1978; Shrag & Wiener 1995

Taxa known to have evolved[e] *in response to anthropogenic change*

Evolving group	*Evolutionary response*	*Taxa*[f]	*Sources*
Land plants	Metal tolerance	20	Antonovics et al. 1971
Aquatic organisms	Metal tolerance	31	Klerks & Weis 1987
Arthropods	Pesticide resistance	504	Georghiou & Lagunes-Tejeda 1991
Fungi[g]	Fungicide resistance	64	Eckert 1988
Nematodes[h]	Antihelmintic resistance	36	Condor & Campbell 1995
Vertebrates	Pesticide resistance	10	Ferguson & Bingham 1966; Georghiou 1986
Weeds	Herbicide resistance	81	LeBaron 1991
Human disease bacteria	Antibiotic resistance[i]	35	Abramowicz 1994

[a] *List includes native species only; the list for vertebrates is an underestimate because primary references occasionally group species into categories (e.g., shrews, moles, bats).*
[b] *Data extrapolated from estimate of 600 pests that "warrant control measures," 235 of which are exotic (approximately 9000 native insect species are classified as minor pests based on extrapolated data from estimate of 10,000 total pest species, minus 600 major pests and 630 exotic minor pests.*
[c] *Strong (1974); Strong et al. (1977); Strong et al. (1984); Wheeler & Mengel (1984); Goeden & Ricker (1986); Wilson et al. (1990); Ohmart & Edwards (1991); Wilson & Flanagan (1993); Andow & Imura (1994).*
[d] *New diseases are those organisms that have included humans as hosts since the agricultural revolution; emerging diseases are those currently spreading in human populations via anthropogenic activities.*
[e] *Includes increased incidence of expression as well as mutation but excludes selective breeding and genetic engineering by humans.*
[f] *Number of species for all cases except fungi and some disease bacteria (number of genera).*
[g] *Extrapolated from Fig. 2 in Eckert (1988).*
[h] *Nematodes causing infections of veterinary importance.*
[i] *Obtained from disease organisms that can exhibit resistance on treatment.*

If plants are roughly representative of other groups, Earth is losing biodiversity at a far greater rate than it is gaining species that exploit anthropogenic opportunities. The world's biodiversity, which nurtures human evolution, sustains our existence, and provides much of the pleasure of human experience, is disappearing at an alarming and accelerating rate. Evolutionary accountants, as sharp as their pencils may be, are unlikely to eliminate the accumulated debt of extinction for millions of years.

Those who are not concerned would do well to consider that adaptation is a compromised evolutionary response to environmental variation. Diminished biodiversity and homogenized habitats reduce that variation. Our pests and pathogens, free of many of the compromises, can now afford the specialization that will quickly make them even more formidable enemies. Our defense is simple: preserve as much biodiversity as possible.

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