Appendix 6.6

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1 Human contribution to extinction

The influence of a species in contributing to extinction is another aspect of species-level involvement in ecosystems that may be measured. We are far from developing information on the limits to natural variation for extinction rates caused by individual species to see any pattern(s) among species. Nevertheless, an initial assessment of human contribution to worldwide extinction can be achieved through comparison with average rates of extinction caused by other species—rates that can be estimated in very rough approximations. An analogous exercise at the population level would be the mortality (e.g., murder, or cannibalism, for humans) caused by a specific individual compared to that caused by other members of the same species.

Mathematically, we can represent the current crude extinction rate (extinctions per year) by E, the current instantaneous extinction rate by ε', the background extinction rate (normal overall extinction rate) by ε, and the current number of species (total for the earth) by N_o. The ratio of ε' to ε (a measure of departure from normal) can be represented by m. Thus, an estimate of ε' is

$$\varepsilon' = \ln((N_o - E)/N_o)$$

and ε'/m is an estimate for ε in situations where we have information on the value of m.

If extinctions were caused exclusively by biotic causes (which they are not), the mean contribution by each individual species to the total background extinction rate ε, would then be estimated by ε/N_o. The total background extinction rate, ε, would be the sum of the individual contributions by each species none of which would necessarily be equivalent to the mean (ε/N_o). If the current excess of extinctions is due to human activities (Diamond 1989, Ehrlich and Ehrlich 1981, Ehrlich and Wilson 1991, Hern 1993, Kerr and Currie 1995, Raup 1984, Simberloff 1986a, Stanley 1985), then the human contribution can be estimated by ($\varepsilon'-\varepsilon$) or $\varepsilon(m-1)$. From this we can calculate a ratio of human caused extinction to that which is the mean contribution of other individual species:

$$(\varepsilon(m-1))/(\varepsilon/N_o) = N_o(m-1)$$

If every species showed such effects on their environment (i.e., if the total effect of all species were N_o times as large as the effect of humans), life as we know it would disappear quite rapidly. We can estimate how rapidly by multiplying the human contribution by N_o then using

$$t = -(\ln(1/N_o))/(N_o(\varepsilon'-\varepsilon))$$

to find an estimate of the time to achieve a reduction of species numbers to one final species.

The average duration of existence for an individual species under background conditions would be approximated by $1/\varepsilon$.

From May *et al.* (1995), the extinction rate among mammals and birds is two to four orders of magnitude higher than "background" rates (normal or average extinction rates, see also Wilson 1985a). The current (or soon to be realized) rates of extinction are estimated at levels from 1000 to 100,000 species per year (Ehrlich 1988, Janzen 1986, Myers 1989, Pimentel, Stachow *et al.* 1992, Simberloff 1986b). Ehrlich and Wilson (1991) estimate that in excess of 4000 species per year are going extinct.

Based on this information, Appendix Table 6.6.1 shows: (1) estimated time to achieve extinction to

Appendix Table 6.6.1 Implications of the current rates of extinction (species per year), estimates of total numbers of species on earth, and the current extinction rate expressed as a multiple of the background rate (implied temporal average for long geological time scales)

Current extinction rate (species per year)	Ratio[1]	Total number of species (millions)		
		10	30	50
Days until one species remains[2]				
10		594.25	634.76	653.59
100		59.43	63.48	65.36
1000		5.94	6.35	6.54
10,000		0.59	0.63	0.65
Human influence expressed as billion-fold that for the mean of other individual species[3]				
	100	0.99	2.97	4.95
	1000	9.99	29.97	49.95
	10,000	99.99	299.97	499.95
Mean duration of individual species (million years) at implied background rate[4]				
10	100	100.00	300.00	500.00
	1000	1000.00	3000.00	5000.00
	10,000	10,000.00	29,999.99	50,000.00
100	100	10.00	30.00	50.00
	1000	100.00	300.00	500.00
	10,000	1000.00	3000.00	5000.00
1000	100	1.00	3.00	5.00
	1000	10.00	30.00	50.00
	10,000	100.00	300.00	500.00
10000	100	0.10	0.30	0.50
	1000	1.00	3.00	5.00
	10,000	9.99	30.00	50.00

The three panels of this table show the time expected until the demise of all except the last species (in days) if all species had effects comparable to humans (top panel), human influence expressed as a multiple of the mean effect of other species (billion-fold, middle panel), and the average duration of a species expected from the implied background extinction rate (expressed in millions of years, bottom panel).

[1]The ratio of total current rate of extinction to normal background rates of extinction.
[2]Time (days) to the obliteration of life (last species) if all species exhibited the same effects in causing extinction as do humans. It is independent of the ratio in the second column.
[3]Ratio of human caused extinction to mean species-by-species contribution to background rate of extinction (billion-fold). It is independent of the absolute current extinction rate.
[4]Average duration of species at implied normal background rates of extinction (million years) as dependent on current extinction rates, ratio of current to mean rates, and species numbers.

lose all but one species if other species were having the same impact as humans, (2) human-caused extinction as a multiple of extinction caused by the mean of other species under typical circumstances, and (3) the implied average duration of individual species under typical conditions. Within the range of rates represented in the literature as covered in this table, life would disappear in less than two years if other species, on the average, were having the impact that humans have.

The subsection of Appendix Table 6.6.1 devoted to species durations is closely approximated by $N_0 m/E$, and is shown because any information on average species duration helps narrow down the options being considered. For example, in combination with species numbers estimated at about 45 million, the average durations of 1–10 million years (based on marine invertebrates, Lawton and May 1995, Pimm *et al.* 1995, Stanley 1985), helps restrict realistic possibilities in this table to the lower right quadrant in each subsection of the table. This implies that human impact (middle section of the table) may be 10–12 orders of magnitude greater than normal (measured as the mean for other species).

These calculations are primitive and, in many ways, ignore a great deal of the complexity of reality. However, they do serve to provide first approximations helpful in assessing human impact. It should not be ignored that these estimates, as sobering as they may be, are probably conservative. For example, under circumstances free of such extensive human influence, some fraction of extinction is undoubtedly due to abiotic forces (Raup and Boyajian 1988) and not the impact of other species (i.e., not biotic [Vermeij 1987], thus reducing the contribution of individual nonhuman species and making human contributions even more atypical). Species turnover may occur at a much higher rate than indicated by data for marine invertebrates (owing to the rapid dynamics we might expect for the numerous terrestrial microorganisms, for example, thus emphasizing the focus on values in the lower right quadrants of the table). Finally, the mode of the species frequency distribution for species-specific contributions to extinction is probably less than the mean. If the mode is any indication of maximized sustainability, it would be maximized through minimized risk of extinction involving feedback from effects on supporting ecosystems.

This exercise also exposes potential oversimplicity (but serves to emphasize rather than detract from the intended message) in the *I=PAT* calculations (Ehrlich 1991, 1994, Ehrlich and Holdren 1974, Kummer and Turner 1994, Smith 1995; *I* is impact, *P* is population, *A* is a measure of affluence, and *T* is a measure of technology). If human-caused extinctions (one measure of human impact) are ten orders of magnitude larger than the mean of other species, there is much left to be accounted for. As pointed out in other parts of this chapter (and Fowler 2008), the human population may be three orders of magnitude beyond sustainable levels. If energy use is a measure of *AT* (affluence times technology), it may account for two more orders of magnitude. There remain four to five (maybe more) orders of magnitude! This implies that human impact (measured in terms of life destroying effects) is a nonlinear function of population multiplied by energy use, probably a power function of both. It undoubtedly involves synergism among the various factors associated with both population and energy use. This emphasizes the need to know if it is population (*P*) or amplification (*AT*) that is most nonlinear to prioritize management action (see Kerr and Currie 1995).

Furthermore, if extinction rates caused by humans are 5–10 billion times those of the mean rates caused by other species, this implies that the energy use and technological amplification of today's human society makes each individual human, on the average, roughly equivalent, in "toxic effects" at the ecosystem level, to that of the mean among other species *as entire species*! In other words, each human, on the average, would have an ecological influence (or extinction producing "footprint") roughly equivalent to an entire species among the nonhuman.

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