Comment on “Extinction Debt and Windows of Conservation Opportunity in the Brazilian Amazon”

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A paper by Wearn et al. (Reports, 13 July 2012, p. 228) yields new insights on extinction debt. However, it leaves out the area dependence of the relaxation process. We show that this is not warranted on theoretical or observational grounds and that it may lead to erroneous conservation recommendations.

The Report by Wearn et al. (1) yields new insights into the field of extinction debt, such as how the debt can define the window of conservation action. At the scale of the Amazon, the authors predict extinction debt, and that it may lead to erroneous conservation situations.

The prediction made by Wearn et al. relies on their finding that relaxation rate has a half-life of about 57 years and is independent of area except for very small patches (which implies that extinction debt will be virtually independent of the degree of fragmentation). However, several studies have reported much slower relaxation and strong area dependence. For example, according to Diamond (2), half-life lies in the range 3,000–18,000 years for avifaunas of islands and increases with island area. Similar dependence on area has been demonstrated by others (3–6). Figure 1 shows the distribution of half-life for the data for bird communities based on data assembled in Halley and Iwasa (6). The area dependence of these rates is manifest with \( R^2 = 0.9 \) for the power law \( t_h = c a^\beta \) (where \( a \) is area and \( c \) and \( \beta \) are fitted constants), and there is no indication of any break-point. Theoretical studies also foresee strong area dependence of \( t_h \) on the basis of competition (3), neutrality (6, 7), and island biogeography (8). Thus, from empirical and theoretical considerations, \( t_h \) should depend on area.

Wearn et al. base their predictions on stratified bootstrap means of relaxation rates reported in previous studies. As they only use a mean for half-life, does it still matter if \( t_h \) increases with area? The answer is yes. For a bootstrapped average to predict accurately the global mean of \( t_h \) for some assembly of habitat patches, the distribution of patch sizes in studies should match that in the target region. Suppose a region retains \( A_j \) of its habitat, leaving \( n \) patches, each of area \( A_j/n \), and that the half-life depends on area as \( t_h = c A_j^\beta \), as in Fig. 1. The average value of half-life is thus \( c \\times (A_j/n)^\beta \), which clearly depends on fragmentation. The same is true for more realistic models with a spread of sizes. For example, suppose the remaining habitat area \( A_j \) is divided into fragments of various sizes, with the largest having area \( a_0 \), followed by two of area \( p a_0 \) and so on, so that there are \( 2^j \) of area \( p^j a_0 \) in the size class \( j \). The constant \( p < 1/2 \) is the measure of fragmentation. The probability that a randomly chosen unit of area of remaining habitat belongs to a fragment in size class \( j \) is \( p_j = (a_0/A_j)^{2^j} \).

The expected half-life for this unit of area is

\[
E(t_h) = \frac{1 - 2p}{1 - 2p^{1+1/p}} t_h^0
\]

where \( t_h^0 \) is the half-life of the largest patch, \( t_h^0 = c a_0^\beta \). Figure 2 shows how the expected half-life for this model depends on the degree of fragmentation, \( p \), with more fragmented ones (small patches) relaxing more quickly. This is unlikely to coincide with the mean found by bootstrapping from the sample set.

If there is an area dependence of relaxation rate, which is supported by both empirical and theoretical considerations, predictions of extinction debt that ignore area will not be accurate and will run the risk of inappropriate conservation recommendations. Thus, by failing to discern differences in fragmentation—for instance, among regions with similar total area and losses—decision-makers could fail to foresee the more rapid relaxation in the highly fragmented regions and end up wrongly assigning lower priority.

References
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Fig. 1. Observed relaxation times as a function of area. Values are based on the methods in Halley and Iwasa (6) showing the strong power-law dependence (exponent \( \beta = 0.652 \)). If we use an exponential model after Wearn et al., rather than the hyperbolic model of Halley and Iwasa, the area dependence still exists (\( \beta = 0.544 \)).

Fig. 2. Expected relaxation time associated with a randomly chosen unit of habitat in a system of habitat fragments of total area 40 km² that remained out of 2500 km². The three curves correspond to three different degrees of area dependence (after Fig. 1; \( c = 4.34 \)).
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