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# To the Ark, and Back Again? Using the Marsupial Fossil Record to Investigate the Post-Flood Boundary: A Comment

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**Abstract**

Arment's paper on the marsupial fossil record and the post-Flood boundary contains a major statistical error, which impacts the ability to quantitatively consider the implications of the fossil data in context of the various Flood boundary proposals he considers. Specifically, he considers arrivals of each boundary crossing taxon to be statistically independent. This assumption alone is responsible for the eyebrow-raising magnitude of the final probabilities (for all boundary positions). The Law of Total Probability should have been used to produce much more realistic probability estimates. An updated estimate of the probabilities for Australian marsupials is equivalent to calling 22 coin flips, rather than Arment's 68 dice rolls.

**Keywords:** conditional probability, Bayes' Theorem, marsupials, post-Flood Boundary, biogeography

## Unwarranted Assumption of Statistical Independence

Arment's paper titled "To the Ark, and Back Again? Using the Marsupial Fossil Record to Investigate the Post-Flood Boundary" (Arment 2020) is a thorough and well-researched contribution to the Flood/post-Flood boundary debate. However, it suffers from a significant flaw in its usage of statistics in that it assumes without justification and contrary to current biogeographic knowledge that the location where genera, particularly those of marsupials, can be found are independent of each other. Statistical independence is not a neutral starting assumption, and is rarely satisfied in real world scenarios.

To assume statistical independence is to make a positive assertion that there are *no* systematic or confounding variables reflected in the data. Standard statistical practice is to either test for independence or to justify the assumption of independence, understanding that deviation from that assumption would invalidate the statistical model (Wasserman 2013). Systematic factors that are known to influence animal distribution include: climate and climate change (McCarty 2001; Walther et al. 2002), food availability (Kavanagh and Lambert 1990), predator preference and prey avoidance (Davidson et al. 2012; Laundré, Hernández, and Ripple 2010; McGregor et al. 2015; Thaker et al. 2011; ), geology (Bailey 2009; Clements et al. 2006), geography and altitude (Körner 2007), mutualism (Bronstein 1994), species dispersal modes (Pearson and Dawson 2003), and filter-bridges (Simpson 1940). Potential confounding factors should be addressed in the context of the unique conditions following the Flood and on likely migration pathways from the Ararat region. It may be that the marsupial taxa that Arment worked with are uniquely not affected by these or any other systematic factors. It may be that there are groupings of marsupial taxa by niche, diet, or habit (for example, fossorial, arboreal, predators, browsers, grazers, etc.) which are subject to the same external forcings, but can be considered as independent classes with respect to other groupings. Failing to consider the Law of Total Probability by accounting for the possibility of any coprobabilities is a significant mathematical conceptual oversight, and Arment should supply the biological justification for his chosen statistical model.

However, given the coincidence of high degrees of both diversity and endemism of marsupials, statistical independence is a highly unlikely assumption, particularly in the case of Australian marsupials (Lavery and Leung 2023). In some sense, it is Arment's goal to show by contradiction that the biogeography is *not* random. This is a strong argumentation technique, but as will be shown, the assumption of statistically independent arrivals of each taxon is so extreme as to not be representative of any of the proposals that Arment is attempting to test. Arment also inconsistently fails to apply the same assumptions to his preferred conclusions, which are also negatively impacted by his chosen statistical model (elaborated below). Others have taken his probability calculations as well established and are incorporating them into arguments regarding the Flood/post-Flood boundary (M. Ross, personal communication, 2023-07-18).

## Example Calculation with Proper Statistical Structure

The core quantity that Arment is trying to calculate is the probability of genus 1 and genus 2 and genus 3, etc. being found on a continent post-Flood that members of the same genera are buried in during the Flood. This can be represented mathematically as the probability of the intersection for all events, defined as a genus crossing a particular location, the total number of which is taken to be *x*:

$$P\left(\bigcap_{n=1}^{x} g_n\right).$$

From the Law of Total Probability (also known as Bayes' Theorem) the probability of both events occurring is written as: (Dekking et al. 2005),

$$P(g_2 \cap g_1) = P(g_2 \mid g_1)P(g_1).$$

This can be continued for another event:

$$P(g_3 \cap (g_2 \cap g_1)) = P(g_3 \mid g_2 \cap g_1)P(g_2 \mid g_1)P(g_1).$$

Continuing the trend leads to the following generalization for the value we are interested in

$$P\left(\bigcap_{n=1}^{x} g_n\right) = P(g_1)\Pi_{n=2}^{x} P\left(g_n \mid \bigcap_{m=1}^{n-1} g_m\right).$$

The above is the general form of the probability equation that Arment should have used. The coprobability terms will only reduce to their individual probabilities if they can be shown to be independent of each other. Since marsupials most commonly live in environments where other marsupials live, the coprobability terms are very likely larger than 1/6. For extant marsupial genera (68 genera in Australasia, 18 in Central and South America, and 3 in North America), the *a posteriori* weights for the probability calculation are given in table 1. For the first term, the statistical question is, "What is the probability that this marsupial taxon arrived in Australia given there are no marsupials there already?" This is $\frac{1}{6}$ and the same probability that Arment applied to all taxa terms. For terms 1–3, the question is, "What is the probability that this marsupial taxon arrived in Australia given there are 1–3 marsupials there already?" The value of these terms are $\frac{1}{3}$ since only three continents have marsupials. By term 4 going through 18, there are only two continents that have sufficient marsupial diversity. All terms after the eighteenth are 1, and do not contribute additional information to the probability question asked. The revised probability calculation for the Australian marsupials using these *a posteriori* weights is $1.88 \cdot 10^{-7}$ rather than $4.42 \cdot 10^{-45}$. This corresponds to the equivalent of calling 22 coin flips, rather than 68 dice rolls. These coprobabilities are only an estimate based on the modern distribution of marsupial genera, and not necessarily those that would be applicable during migration from Ararat.

## Problems for Lower Flood Boundary Positions

Criticism of Arment's choice of statistical model is not a defense of any particular Flood/post-Flood boundary position. His assumption of statistical independence of migrating taxa causes problems for his own preferred boundary too. Considering the family to be an approximation of the biblical kind, there are 44 families and incertae sedis genera listed in Arment's tables 4 through 14 with extant or fossil members present in Australia in the Cenozoic. For this calculation, because we are only interested in the probability of the taxa winding up *together* rather than Australia specifically, the exponent used is one less than 44. So, using Arment's statistical assumptions, the probability of all of these kinds migrating to the same continent is: $(1/6)^{44-1} = 3.46 \cdot 10^{-34}$, which is a lower likelihood than two out of three of his higher boundary calculations for Australian marsupials. With his lowest estimate of the possible number of Australidelphia marsupial kinds, the probability is $(1/6)^{8-1} = 3.57 \cdot 10^{-6}$, which is still extremely unlikely.

Arment began to ask the question of how Australian marsupials could have all migrated to a single continent in his discussion, but did not apply his own statistical model to the earlier boundary position. Arment himself speculates on reasons why marsupials would be preferentially favored to migrate to Australia: "Either marsupials had certain characteristics that allowed them to take greater advantage of such a migration, or there was a barrier to placental mammalian migration that had little effect on marsupials" (Arment 2020, 4). This is directly contradictory to his chosen assumption of statistical independence.

**Table 1**. *A posteriori* probability terms for Australidelphia genera migrating to Australia. Partial probabilities in the last column are multiplied to get the total probability

| Terms | Count of Terms | Individual Term Probability | Total Contribution to Probability |
|---|---|---|---|
| 0 | 1 | 1/6 | 0.167 |
| 1–3 | 3 | 1/3 | 0.037 |
| 4–18 | 15 | 1/2 | 3.05E-5 |
| 19–68 | 50 | 1 | 1 |
| Product for Australia | | | 1.88E-7 |

Future studies in the mold of Arment's paper should make a positive biological case for assumed coprobabilities for statistical arguments to be valid, and to apply those assumptions consistently. Assumed independence is problematic since there are many potential reasons for animal distributions to be correlated, and not only due to radiation (for example, the TABs concept, Woodmorappe 1999). Arment's statistical model only serves to prove that marsupial biogeography is not statistically independent, which does not distinguish between any Flood boundary models.

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