Marine diversity. Sept. 27, 2005

Phanerozoic marine diversity

Plot of number of marine families known as fossils through the Phanerozoic: ("Sepkoski curve")

![Plot of number of marine families known as fossils through the Phanerozoic: ("Sepkoski curve")](image1)

Plot of number of marine genera known as fossils through the Phanerozoic: ("Sepkoski curve")

![Plot of number of marine genera known as fossils through the Phanerozoic: ("Sepkoski curve")](image2)

Total number of genera as a function of time during the Phanerozoic, in the classic database of Sepkoski (2, 3). The two dark blue regions indicate the time intervals studied in the new work by Alroy et al. Figure and caption from: Mark Newman, 2001. A new picture of life's history on Earth. Proceedings of the National Academy of Sciences 98: 5955-5956.
• The pattern: Rapid Cambrian-Ordovician increase, mid- to late Paleozoic plateau, Permo-Triassic crash (mass extinction), Mesozoic-Cenozoic increase (with small crash at K/T). Two rapid diversifications, one long plateau.

What could cause this pattern?

1. Pattern reflects the true history of the diversity of life. Rapid Cambrian-Ordovician diversification, mid- to late Paleozoic equilibrium, Permo-Triassic (mass extinction), Mesozoic-Cenozoic diversification (with small crash at K/T).

   Two rapid diversifications and one long plateau.

2. Pattern is a sampling artifact. The more rocks there are available to sample, the more different kinds of fossils one is likely to find. Perhaps the reason that fewer fossils are found in older rocks is that there are fewer older rocks to sample.

   The older rocks are more likely to have been metamorphosed, buried deeper or eroded away. In addition, the older the fossil, the more likely that it will be re-crystallized or altered in some way, making it more difficult to recognize.

   So, is the diversity curve a function of sampling? How could we tell?

- Histogram of geologic map area by time unit shows roughly the same pattern – fewer outcrops of older rocks than of Cretaceous and Cenozoic rocks. B in figure below.

- Histogram of rock volume by time units isn’t as similar as the species diversity pattern, but the thickness of rock units generally decreases with age. C in figure below.

- “Paleontologist interest units” - the number of paleontologists who have declared an interest in a particular time period shows a roughly similar pattern to that of the species diversity curve. But what’s the cause and effect here? Do more paleontologists cause more different kinds of fossils or do more different kinds of fossils attract more paleontologists? D in figure below.
Figure 8.18 (A) The empirical data of marine invertebrate diversity through time shows a Siluro-Devonian peak, and a rapid increase in the Cretaceous and Cenozoic. But the exposed area (B) and volume (C) of rocks is also biased toward the Siluro-Devonian, Cretaceous and Cenozoic, as is the research interest of paleontologists (D). (After Signor, 1985.)
A more sophisticated analysis of the rock volume issue is shown below. Plotting the number of genera of marine fossils on the same plot as the number of “sections” – exposures of rock sequences – in the US.

Global genus richness (black line) and rock quantity (shaded area) plotted at age of interval base. Genus data are from Sepkoski’s global compendium (24). Rock quantity is measured as the total number of sedimentary rock sections. Ordinate corresponds to eight times the number of sections. Note break in ordinate to accommodate Cenozoic increase in genus richness.

Figure and caption from: Shanan E. Peters, 2005. Geologic constraints on the macroevolutionary history of marine animals. Proceeding of the National Academy of Sciences 102: 12326-12331.

--Note that in this figure the match is pretty good until the Cretaceous, then the curves diverge. But overall, there’s an “r value” (a measure of how good the correlation is) of 0.41. This is a statistically significant value.

So it appears that sampling is at least part of the story of Phanerozoic diversity.

What about the Cretaceous and Cenozoic diversification?

**Could this increase be produced by “The Pull of the Recent”?**
Here’s how the Pull of the Recent works:
1. The best known fauna is the living fauna.
2. If the average duration of a species is about 5 million years, the farther back into the fossil record one samples, the less likely one is going to find that living species (or something very similar to it). In other words, the closer one gets to the Recent, the more likely it is that a fossil species will look like a living one and get assigned to the living species. That boas tends to “pull” the stratigraphic range of a fossil species toward the recent, increasing diversity toward the Recent.

Can this explain the Cretaceous and Cenozoic increase?

A test using marine bivalve mollusks. A group with a good fossil record. Jablonski et al. use only those species known as fossils. No Recent species counted. Curve only goes to Pleistocene.

Genus-level richness of marine bivalves with and without the Pull of the Recent (solid and dashed lines, respectively). The youngest time bin includes 958 extant taxa plus 92 extinct taxa. (A) Through the Phanerozoic. (B) Over the past 100 My. These data are available from the Paleobiology Database Web site (www.paleodb.org). Figure and caption from Jablonski, David, Roy, Kaustuv, Valentine, James W., Price, Rebecca M., Anderson, Philip S., 2003. The Impact of the Pull of the Recent on the History of Marine Diversity. Science 300: 1133-1135.
Jablonski et al.’s conclusion: Pull of the Recent explains only about 5% of the increase: the bias is real, but only has a minimal effect.

Message: The Cretaceous-Cenozoic increase in global diversity is real.

What about extinctions?

- The big five mass extinctions (end Ordovician, end Devonian, Permo-Triassic, end Triassic, end-Cretaceous.) More later when we discuss extinctions. Can sampling bias explain the mass extinctions? No. Because the actual species on either side of the boundary are different.

The three faunas:

Deconstructing Phanerozoic diversity: “Evolutionary faunas” -- Groups of animals that show the same pattern of diversity through time
- Cambrian fauna – inarticulate brachiopods, trilobites
- Paleozoic fauna – articulate brachiopods, crinoids, rugose and tabulate corals, cephalopods
- Modern fauna – bivalve and gastropod mollusks, crustaceans, fish, sharks

Why did one fauna follow the other? What prompted the changes? Extinctions?
Fig 13.3 The history of family diversity of the three great 'faunas' of marine animals, showing a Cambrian phase, a Palaeozoic phase, and a 'modern' phase. The three phases add together to produce the overall pattern of diversification in Figure 13.2(a).

Benton and Harper, 1997