Fern Evolution Through Deep Time, Not Deep Water

Fern spore survival under prolonged saline inundation as a difficulty for a global year-long Flood

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ABSTRACT

The global Flood account requires that the present diversity of land plants re-established after roughly one year of inundation. Seed plants have an obvious survival route, since they can persist and travel as seeds, and the ark narrative concerns food, which Genesis elsewhere identifies with seed-bearing plants (Genesis 1:11-12; 1:29; 6:21). Ferns, however, are seedless. They reproduce through wind-dispersed spores and a small, free-living gametophyte, and if they were not carried as propagules in the manner of seed plants, their persistence through the Flood must have depended on spores surviving in the water column, in bottom sediments, or on floating debris. I examine this requirement against the only experimental study to test fern spore survival under prolonged saline and freshwater inundation (de Groot and During, 2013). That study found that immersion in freshwater alone was tolerated by most tested species, but that salt progressively reduced germination, and that gametophytes grown from spores held for a year in saline water were smaller and far less viable. Critically, real marine sediments yielded no viable fern spores, and freshwater sediments yielded only two gametophytes, both of which died before maturity. Because a global Flood would be predominantly marine and more saline than the conditions tested, and because it would leave no dry refugia from which fresh spores could re-seed the drained land, sediment-based fern survival appears far from optimal. I then set this against the paleobotanical record, which shows a long and continuous fern diversification with no signature of a recent global bottleneck. I conclude that the survival of ferns is a genuine difficulty for a literal global year-long Flood.

Keywords: *ferns, Pteridophyta, spore survival, salinity, global Flood, gametophyte, paleobotany, Philippine flora*

1. Introduction: the problem of the seedless plants

I grew up in the Philippines, which is one of the richest places on earth for ferns. Recent checklists record on the order of 1,000 to 1,100 fern species in the archipelago, roughly a tenth of the world total, and a large share of them grow nowhere else (Copeland, 1958-1960; Pelser et al., 2011). Anyone who has walked a mountain trail in Luzon or Mindanao has brushed past tree ferns, filmy ferns on wet bark, and *Drynaria* clinging to trunks. That everyday abundance is the background to a question that I think has not been examined carefully enough within the Flood literature: how did ferns come through a global, year-long inundation at all?

The global Flood account requires that essentially the entire land flora present today traces back to survivors of a single year of inundation (Genesis 7:11-12; 8:13-14). For seed plants there is at least a clear route. Seeds are durable, many float or resist salt for a time, and the ark instructions concern food (Genesis 6:21), which the earlier chapters of Genesis tie specifically to seed-bearing plants (Genesis 1:11-12; 1:29). I want to be careful here, because the text does not actually command Noah to gather seed plants. It commands him to store food. My point is narrower: seed plants have an obvious mechanism of survival and re-establishment, whereas the seedless plants do not, and Flood models have generally assumed that ferns and their relatives rode out the year outside the ark.

Ferns are the largest group of seedless vascular plants. They do not make seeds at all. They disperse as microscopic spores and pass through a separate, free-living sexual stage before a new leafy plant can form. If ferns were not carried as protected propagules, then their survival through the Flood must have happened in one of three places: suspended in the water, resting in the bottom sediment, or riding on floating rafts of vegetation. In this paper I ask whether the first two of these, spore survival in water and in sediment, are supported by experiment. The answer, drawn from the one study that has actually tested it, is that they are far from optimal.

2. How ferns reproduce, and why the gametophyte is the weak point

To see why survival is not a trivial matter of a tough seed waiting out the water, it helps to recall how ferns actually reproduce (Figure 1). A mature fern, the sporophyte, carries clusters of sporangia on the underside of its fronds. Through meiosis these release enormous numbers of single-celled spores. A spore does not grow directly into a new fern. Instead it germinates into a gametophyte, also called a prothallus, a tiny green plate often only one cell thick and carrying little or no protective cuticle. The gametophyte bears the sex organs, and fertilization requires a film of liquid water through which the sperm can swim to the egg. Only after fertilization does a new sporophyte begin.

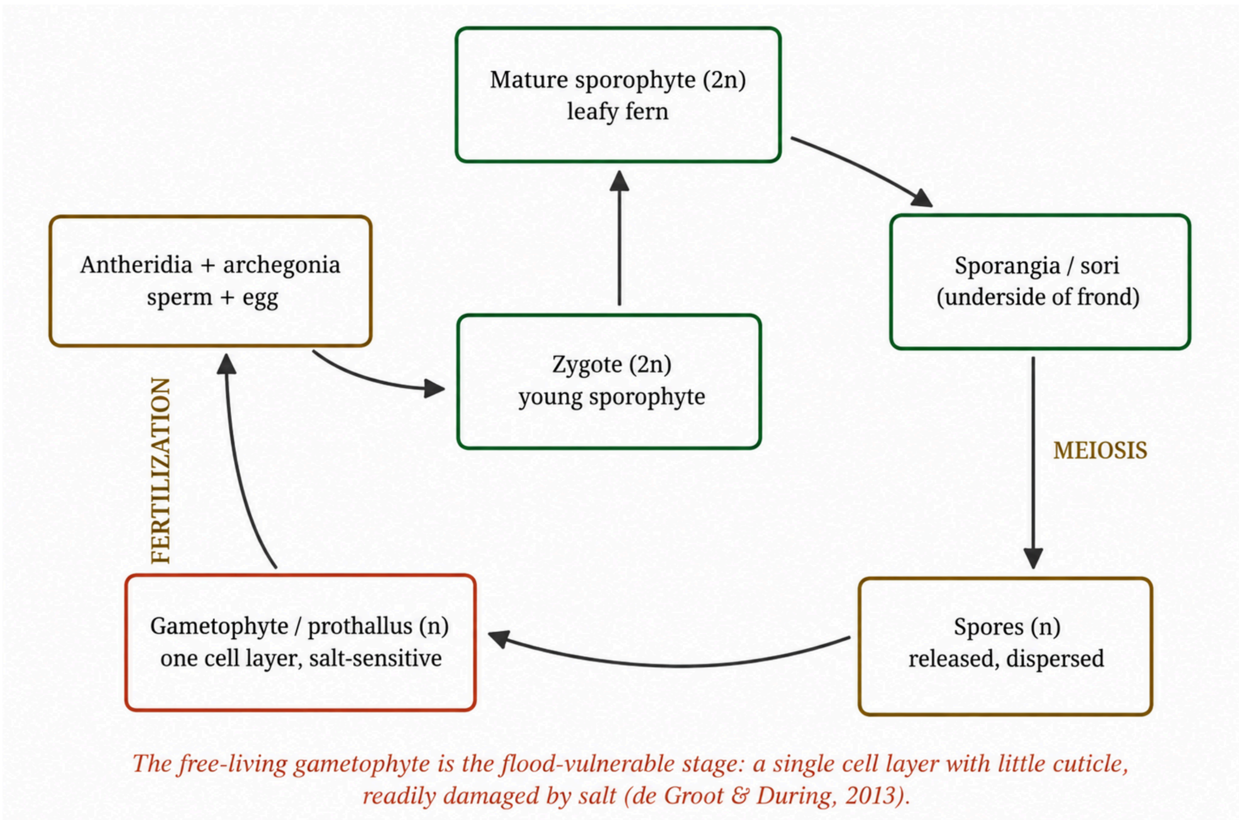

Figure 1. The fern life cycle, or alternation of generations. Two stages are exposed to the environment: the dispersed spore and, more delicately, the free-living gametophyte, which is essentially a naked sheet of cells and is readily damaged by salt.

This two-stage life cycle creates two points of vulnerability rather than one. The spore must survive; then the gametophyte must survive long enough to reproduce, and it must do so on whatever substrate is available. Ferns can and do form spore banks in soil, and these banks can persist and later regenerate lost populations (Dyer and Lindsay, 1992; Dyer, 1994). But those banks have been studied in ordinary terrestrial soils. They tell us little about spores held under water, still less under salt water, which is the condition that a global marine Flood actually imposes.

3. The experimental evidence: de Groot and During (2013)

To my knowledge, the only study that has directly tested fern spore survival under prolonged inundation, including saline inundation, is that of de Groot and During (2013), published in *PLoS ONE*. Their motivation was practical rather than theological. Large areas of the Netherlands are reclaimed sea floor, and the authors wanted to know whether a drained sea bottom could re-grow a fern flora from spores buried in its sediment. To find out, they ran storage experiments on three non-halophytic species, *Asplenium scolopendrium*, *Asplenium trichomanes* subsp. *quadrivalens*, and *Gymnocarpium dryopteris*, and they carried out a spore-bank analysis on nine sediment cores drilled from the bottom of a former inland sea.

The first result is one I want to report fairly, because it cuts against a lazy version of my own argument. Immersion by itself was not lethal. When spores were kept in plain fresh water rather than dry, germination was essentially unchanged for two of the three species, and for *Gymnocarpium* the wet-stored spores actually produced larger gametophytes (Figure 2a). Salt, not water, was the stressor. Rising salt concentrations lowered germination, gametophytes grown on saline media were smaller, and even after two full years in saline water a third to a half of the spores still germinated. In other words, fern spores are not instantly destroyed by salt water, and any argument that assumes they are would be overstating the case.

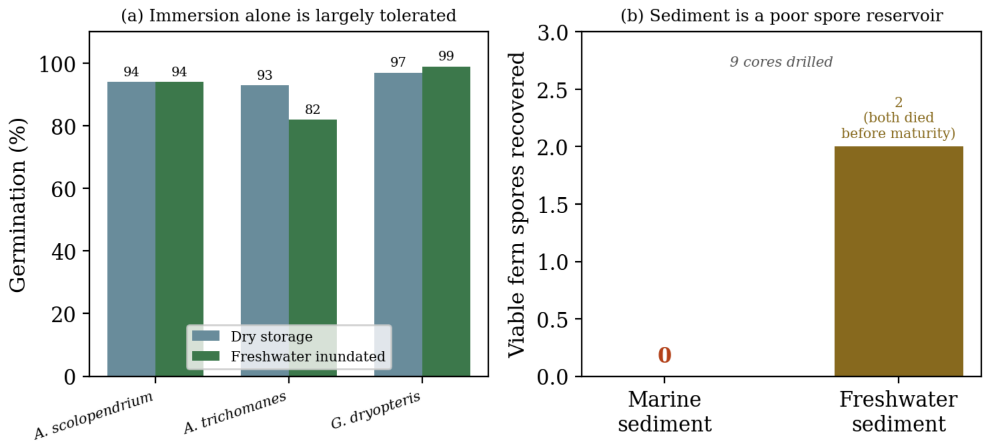

Figure 2. Key results of de Groot and During (2013). (a) Germination after one month of dry versus freshwater-inundated storage for the three tested species: immersion alone is largely tolerated (values from their Table 1). (b) Viable fern propagules recovered from nine real sediment cores: none from the marine layer, and only two tiny gametophytes from the freshwater layer, both of which died before maturity.

The decisive result, however, came from the real sediments (Figure 2b). Across nine cores, the marine sediment layer yielded not a single viable fern spore. The freshwater layer yielded only two very small gametophytes, both identified as *Thelypteris palustris*, and both died before they could mature. On the strength of this, the authors concluded that marine sediments, and probably even freshwater sediments, are of little value as long-term reservoirs of fern diversity, and that re-vegetation of a drained sea floor would depend almost entirely on fresh spores blown in by wind after the land had dried. That last clause is the one that matters most for the Flood question, and I return to it below.

4. Implications for a global, year-long, saltwater inundation

Three features of the de Groot and During results bear directly on a global Flood. First, the Flood was overwhelmingly marine. Standard sea water is close to 35 g/L of salt, whereas the long-term storage in the experiment used a milder 10 g/L. The most Flood-like reservoir the authors examined, the actual marine layer, is also the one that produced zero viable fern spores. If anything, real Flood conditions would be harsher than what was tested, not gentler.

Second, and I think most tellingly, the authors identify the route by which a drained sea floor does get re-vegetated: not from spores that survived in the mud, but from fresh spores carried in by wind from surrounding land that was never submerged. A global Flood removes exactly that escape. If the whole earth is under water, there is no un-submerged land upwind to supply the fresh spore rain. The mechanism that rescues a Dutch polder is unavailable to a global Flood by definition. What is left is precisely the reservoir that failed, survival in the sediment.

Third, even granting a spore that germinates on the newly drained surface, the gametophyte then has to develop, and fertilization has to succeed, on a salt-laden substrate. The experiment showed that saline conditions shrink gametophytes and, in one genotype, killed all of them. A naked sheet of cells attempting to complete a swimming-sperm fertilization on a salt flat is not a promising picture. Taken together, the study does not merely fail to support fern survival through a marine year, it points the other way.

5. The evolutionary and paleobotanical record of ferns

There is a further difficulty that does not depend on the salt experiments at all, and it comes from the fossil record of ferns themselves (Figure 3). On the standard paleobotanical account, ferns are ancient. Their earliest members appear in the Devonian, more than 350 million years ago. They dominate parts of the Carboniferous coal forests. The great radiation of the leptosporangiate ferns, the lineage that includes the vast majority of living species, begins in the Cretaceous, apparently as an ecological response to the newly risen flowering plants, and continues through the Cenozoic to produce the roughly 10,500 species recognized today, more than 80 percent of them in a single order, the Polypodiales (Smith et al., 2006; Schuettpelz and Pryer, 2009; PPG I, 2016; Pryer et al., 2004; Christenhusz and Chase, 2014).

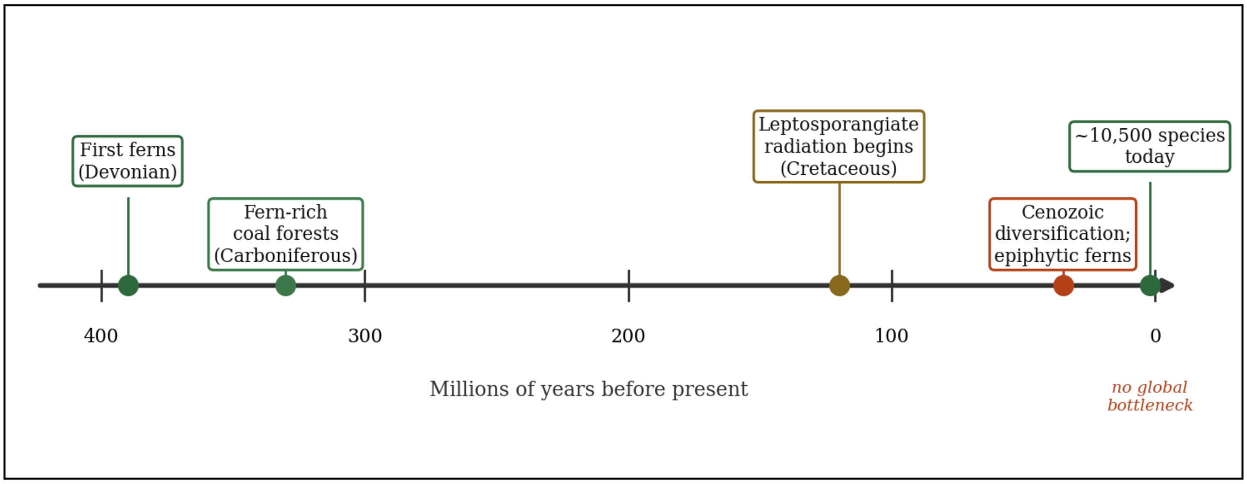

Figure 3. The fern fossil and phylogenetic record, in outline. Fern lineages appear, dominate, and diversify in an ordered succession across hundreds of millions of years, with the largest radiation postdating the rise of flowering plants. There is no single stratigraphic layer at which a whole flora is replaced.

The pattern is not a single recent burst. It is a long, continuous, stratigraphically ordered turnover of lineages, tracked independently by fossils and by the spore and pollen succession that palynologists read from sedimentary cores. A literal Flood model has to reinterpret these strata as deposits of the Flood year and its aftermath, and it then has to explain, within that compressed frame, both the ordered succession of fern types and the survival of the modern diversity through a marine year that, as section 3 showed, the ferns are poorly equipped to endure. I do not think the year-long Flood, combined with poor spore survival, naturally predicts the continuity and richness we actually observe. The two lines of evidence, the experimental and the paleobotanical, point the same way.

7. Conclusion

Ferns are seedless, and on the usual Flood model they were not carried as propagules but had to survive the inundation on their own. The one direct experimental test we have indicates that marine sediments retain essentially no viable fern spores, that prolonged salt exposure cripples the gametophyte, and that a drained sea floor re-vegetates mainly from fresh wind-borne spores, a source a global Flood does not provide. The paleobotanical record adds a long, continuous fern history with no recent global break. None of this proves that fern survival was impossible, and I have tried not to overstate it. But it does show that a central requirement of the global Flood account, the persistence and recovery of the seedless plants, rests on a mechanism that the available evidence does not support and in places positively contradicts. At minimum, the question deserves the direct experimental attention it has not yet received: full-strength sea water, year-long trials, and honest tests of the raft hypothesis. Until then, the ferns remain an unresolved difficulty for a literal global year-long Flood.

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Scripture citations are to the Book of Genesis (1:11-12; 1:29; 6:19-21; 7:11-12; 8:13-14).