LATE QUATERNARY EXTINCTIONS AND THE YOUNGER DRYAS

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Introduction

Extinctions of terrestrial fauna in radiocarbon or Libby time (the last 40,00 years), along with the extinction spasm of historic time, approach the conditions of a mass extinction of the Phanerozoic (Martin 1990). To date marine biota and freshwater biota are minimally unaffected and smaller species (mesofauna of 44 kg - 0.4 kg) and minifauna (<0.4 kg) suffer severe attribution only on oceanic islands. The pattern of extinction begins with losses of megafauna of the continents with America and Australia much more severely affected than Africa and Eurasia was established through radiocarbon dating (see reviews in Martin and Wright 1967, Martin and Klein 1984, and Stuart 1991).

The late Quaternary, an episode of severe climatic fluctuations in which normation conditions were glacial or stadial, and cooler, drier, depleted in CO_2 and with lowered sea level held sway for over 90% of elapsed time throughout the last 330,000 years (__________ 1990). This episode saw emergence of anatomically modern *Homo sapiens* (Klein 1989) and of most other living or late Quaternary extinct species. During this interval, climatic pulses of remarkably short duration (under 50 years) switched into cold or warm climates as revealed by thickness, CO_2 gas content and particulants in the Greenland ice core (Dansgaard, Allee et al.). A reversal of warm to cold North Atlantic water may be involved (Broeker). The environmental effects are best seen in the peat record of western Europe (Huntley) and are searched for throughout the globe (__________, Markgraf). At least one mammalian extinction in western Europe, that of the giant deer or Irish elk (*Megaloceros*) coincided with Younger Dryas cooling (Barnowski 19___, Stuart 1991) and of 30 late Quaternary genera in North America. At least 14 (*Mammuthus, Mastodon, Camelops, Equus, Nothrotherium, Sinilodon, Taurpolama, Arctodus, Euaratherium, Bootherium* and __________) terminate during or close to the time of Upper Dryas cooling. At least one genera extinction, that of Mylodon (*Glossotherium*) in South America, is coeval (Markgraf 1987).

Our purpose is to evaluate the Upper Dryas climatic signal and accompanying late glacial climatic change for its possible influence in forcing prehistoric extinctions of the last 40,000 years, as proposed for mammoth in particular (quick freeze model; Berger 19___). We will briefly review the extinction pattern in three parts of the globe, the Pacific Ocean, northern Eurasia, and North America. At stake is the proposition that late Quaternary climatic pulses coincide with extinction events in different regions and that late Quaternary climatic pulses do indeed create ecological crises for megaherbivores of the continents or large and small species at risk on oceanic islands.

Pacific Oceanic Islands and the Upper Dryas

Land faunal extinctions, especially of land birds and extirpation of nesting sea bird colonies has depleted island faunas of the Hawaiian archipelago by 50 to 80 percent within the last 2000 years (Olson and James 1982, 1984, 1990). On New Zealand all species of moas and roughly 30 percent of the and birds were lost within the last 1000 years (Cassells 1984, Anderson 1989, Millener 1981). Extinct pigeons, parrots and flightless rails and depletion of sea bird colonies has been discovered in prehistoric deposits, natural or cultural, on many other islands of the Pacific including Henderson (__________), Easter Island (Steadman), the Marquesas, the Cooks (Mangeri, Kirch and Steadman), French Polynesia (Steadman), Tonga (Eva, Steadman 1991), New Caledonia (Balovet and Olson) and New Ireland. Avian extinctions on New Ireland are all old and predate the Younger Dryas; all others postdate 10,000 years ago and are closely associated with early invasion or colonization of the islands in question. That human activity, whether by side effects including introduction of rats or avian diseases (malaria) and habitat destruction (fire) or by hunting (including surplus killing), the circumstances strongly suggest a direct or indirect cultural cause for most of the losses (Olson and James, Steadman, Anderson 1989).

This circumstance will not preclude the possibility of earlier extinctions, an extinction spasm above background levels driven by late Quaternary climate and environmental shifts. Such changes are especially evident on New Zealand where glacial age vegetation was more open, tree lines were depressed, glaciers expanded and sea level lowering connected the North and South Islands with a land bridge that has yielded fossil moas (Flemming 19___).

Moas are abundant as fossils in a variety of deposits, including bogs and swamps, dunes and loess, coastal middens and caves (Anderson 1989). Cave deposits and loess are often of pre-Holocene age, thus old enough to reveal extinctions had an extinction event taken place. Anderson (1989, p. _____) notes that no evolutionary change is seen in Quaternary moas, i.e. no change or loss in morphology. The large genera (*Dinosaurs, Emeus, Eurayapterix*, and *Metalapterix*) can all be traced into late glacial age sediments with no apparent attrition at the time (Millener, Anderson).

On other oceanic islands the fossil record of late glacial climatic and environmental change is less well known, although life zone displacement of 1200 m is inferred on Hawaii (Porter 19___). Drier conditions are evident in the late glacial pollen record of the Galapagos (Colinvaux 19___) and Easter Island (Flenley _____). To detect a possible late glacial extinction spasm, it is necessary to have a fossil fauna that predates the event in question, in this case a hypothetical Younger Dryas pulse or other climatic crisis 12,000-10,000 years ago.

Beyond New Zealand suitable fossil land faunas predating the Holocene are few. They include Anatu Cave on Eva, Tonga archipelago (Steadman 1991), Malalu Head, Oahu, Hawaiian archipelago (James 19___) and ___________, New Hebrides (Steadman _____). While in an archaeological context the latter fauna cannot be eliminated as a possible Upper Dryas or Late Glacial event since fossil faunas of Holocene ___________ the Younger Dryas are unknown and survival into the Younger Dryas is possible. In the case of Anatu Cave and Malalu lake the fossil record is quite uniform with no obvious losses predating late Holocene human arrival.

In both the Galapagos and on Eva Steadman estimated background extinction rates of endemic land birds at 0.0-3 per millennium. Radiocarbon dates of 20,000 years old on the rosy petrel from Santa Cruz in the Galapagos indicate an extirpation or subsequently, possibly in the Upper Dryas. Unlike other oceanic islands, the Galapagos suffered no losses of native land bird populations until historic colonization (early 1800s; Steadman 1981). However, most of the 50,000 identified vertebrate remains are Holocene in age and the assembled forms of lava tube fossils may all be too young to exclude possibility of an Upper Dryas extinction event. To the extent that in ___________ background extinction rates can be estimated for species, they approach zero for New Zealand moas, range from negligible to 3.0 per millennium for land birds in Eva, and zero to 3.0 per millennium for land vertebrate of the Galapagos. No extinction spasm has been detected on islands such as Oahu, Eva, and North and South Islands of New Zealand where late Quaternary fossil forms older than the Holocene have been excavated.

Eurasia

The classic stratigraphy of late-glacial deposits from brick yards on bog deposits in Denmark yielded a fourfold sequence following deglaciation; Bolling - Older Dryas - Allerod - Younger Dryas - Preboreal (beginning of Holocene). The Dryas was named for its macrofossils including an arctic-alpine member of the Rosaceae, *Dryas octoretala*. Dryas age sediments were typically inorganic lake clays, the Allerod muds were organic (gyttja) and enclosed pollen indicated warmed conditions from herb (non-arboreal) pollen in the clays to birch and pine (arboreal) pollen in the organic muds. The intensity of the Allerod warm up was reflected in its beetle fauna (Coope _____) and summary warming temperature diagrams indicated the attainment of Holocene temperatures by Allerod time 12,000-11,000 radiocarbon years ago (see Fig. _____). The Upper Dryas return to tundra conditions has long been correlated with the central Scandinavian moraine. Upper Dryas reversal is less evident in central and eastern Europe than in Scandinavia and Britain. The warm-cold-warm pulses, Bolling - Older Dryas - Allerod - Younger Dryas - Holocene are widely dated by radiocarbon dating. There is no obstacle to matching these events with the extinction chronology of western Europe.

Large animals typical of the Quaternary can be divided into cold and warm faunas, woolly mammoth; wholly rhinoceros, cave bear and cave hyena in the former with straight tusked elephant, hippopotamus, rhinoceros (*Dicerorhinos*) and giant deer in the warm faunas. Long before radiocarbon dating the two faunas were used in interpreting biostratigraphy (Zeuner 19___) and at least as early as the time of Darwin and Lyell it was apparent that extinctions had been relatively gradual with warm faunas predeceasing cold ones. Straight tusked elephants and

Dicerorhinos can be traced to the early part of the last glaciation in Italy, hippo to a later date, perhaps the height of last glaciation in the Levant, and giant deer into the late-glacial of Ireland and Scotland. Only the latter survived long enough to be a potential victim of Upper Dryas changes.

While the cold faunas lasted much longer than most of the warm fauna, its disappearance was also gradual, although more rapid than that of the warm fauna. Woolly mammoths are scarce or absent in France and Spain at the height of last glaciation 18,000 years ago. They endure in England until 12,500 years ago, longer than had been thought (Lister 19___), and records of similar age are reported from Germany (Gunnesdorf _____), France, Switzerland and Russia (Stuart 1991). Fossils of mammoth are unknown from the Danish late glacial and from Sweden after 12,500 years ago (Birkland 19___). Upper Dryas changes apparently postdate mammoth decline in western Europe and the Ukraine.

Recent work by Sher and Sherizanky includes post Upper Dryas radiocarbon dates on mammoth on the Arctic coast of Russian including the Taimyr Peninsula, with an especially interesting mid Holocene extinction of dwarf mammoths on Wrangel Island (4000 yr BP) accompanied by slightly later extinction of musk oxen (unknown historically in Eurasia until recently reintroduced from Alaska and Canada) 3000 years ago in the Taimyr Peninsula.

Whatever the effect of the Upper Dryas reversal, the pulse of Eurasian extinctions seems largely, if not entirely, independent of any short term effect. In the case of the giant deer depleted on less ____________ forage production has been invoked as detrimental to giant deer survival (Barnowski _____). If so, one must account for failure of continental giant deer population to find suitable pastures to the south and east, where they once occurred. There is in fact no way to know whether the Upper Dryas landscape was actually less favorable for deer populations than the Allerod. Earlier paleontologists had invoked closed forest as inhibiting movements of large antlered animals, leading to their extinction (Guild 19___).

Islands in the Mediterranean also serve like islands in the Pacific, as partial monitors of potential Upper Dryas effects on extinction. While the chronology of Mediterranean extinction is more variable than had been thought by Hunter (1976) and Martin (1984), with dwarf hippo surviving on Cyprus until 9500 yr BP and goat antelope on the Ballerics until perhaps 4000 yr BP. The extinction of dwarf straight tusked elephants on Mediterranean Islands is till undated by defensible ^{14}C dates. A climatically driven late glacial extinction pulse remains possible, although dwarf hippo on Cyprus and goat antelope on Majorca survived it. Apart from the case of giant deer in western Europe, there is no apparent chronological alignment between megafaunal extinctions in Eurasia and the Upper Dryas.

North America

South of the North American ice sheet detailed radiocarbon records are available for an increasing number of the 30 genera and perhaps 50 species of large animals that disappeared in the late Quaternary. With occasional uncertain exceptions (*Camelops* in Wyoming), none of the extinct genera and few of the extinct species are found with archaeological material postdating Clovis age (11,000 ± 200; Haynes 1991). No stratified natural deposits of 10,500 or younger, radiocarbon dated following critical protocol, have yielded extinct fauna.

Radiocarbon dates on perishable animal remains or otherwise "acceptable" dates in good association point toward 10,000-12,000 as the time for extinction of the well dated genera (see Table ___; also Stuart 1991). The North American extinctions appear at least roughly concordant with Allerod into Upper Dryas oscillation; and North American paleogeography has been scrutinized for environmental conditions that might stress the fauna that was lost (Grahm _____, Lundelius _____, Haynes _____). Unlike the case of the Pacific and northern Eurasia (including the Mediterranean Islands) there is less difficulty in aligning many extinctions with the Allerod/Upper Dryas oscillation. Although some of the species lost may have been "warm loving" like tapir and shasta ground sloths, and some "clod loving" like Harrington's extinct mountain goat and ____________ headed musk ox, there is no biostratigraphic separation of cold or warm faunas with separate extinction chronologies as in western Europe.

Neither is there evidence of late survival of arctic or subarctic populations into the Holocene, as in the case of Siberian mammoth or musk ox. If anything, extinct mammoth from

Alaska disappeared slightly earlier rather than later than populations in the lower 48 states (Guthrie 19___, Dixon 19___, p. _____).

More than half of the North American extinctions remain to be determined by sufficient critical dates to be certain that they disappear concurrently with mammoth, mastodon, camel and horse (Grayson 19___). However, the more numerous extinct genera, more likely to be susceptible to critical study and dating driven by interest in terminal occurrences (for example Martin 1987), are all closely synchronous in the Allerod-Upper Dryas interval and one may examine this interval for possible forcing functions.

No late glacial reversal or oscillation