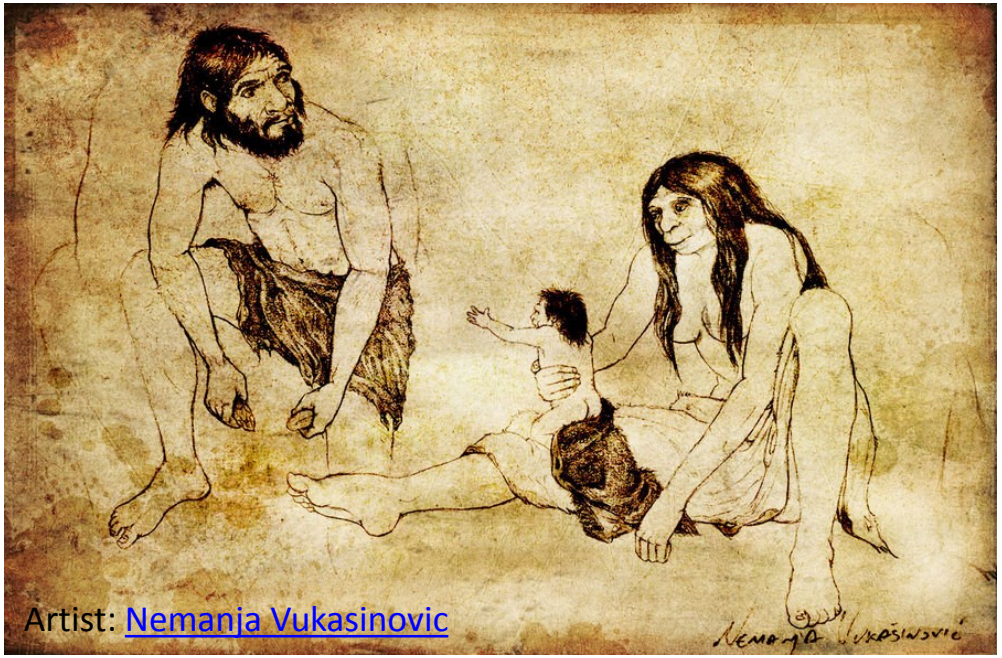
Marriage, Mortality, and Middle Paleolithic Families:

Implications of a Model-Based Analysis



Society for American Archaeology Annual Meeting
April 26, 2014

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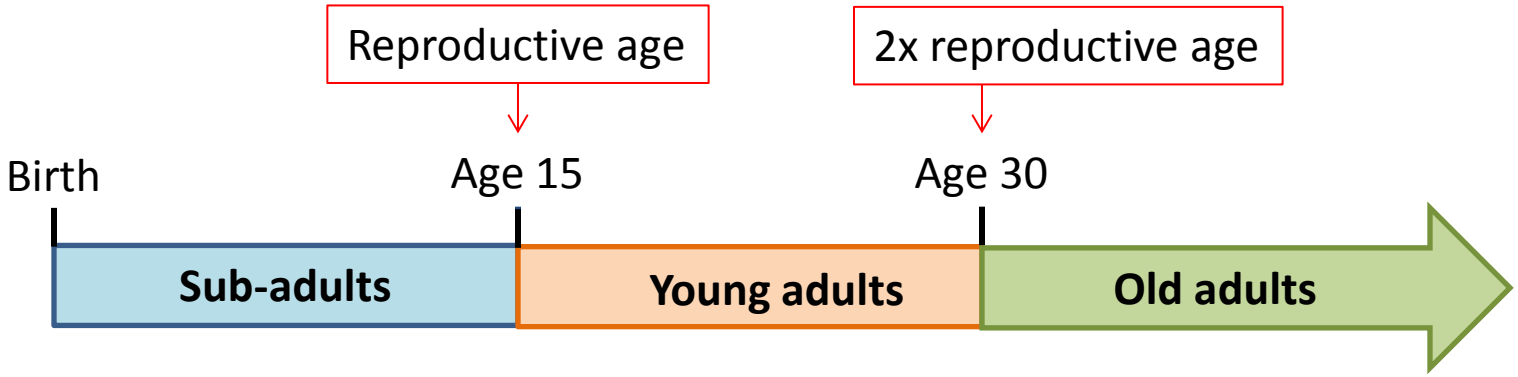
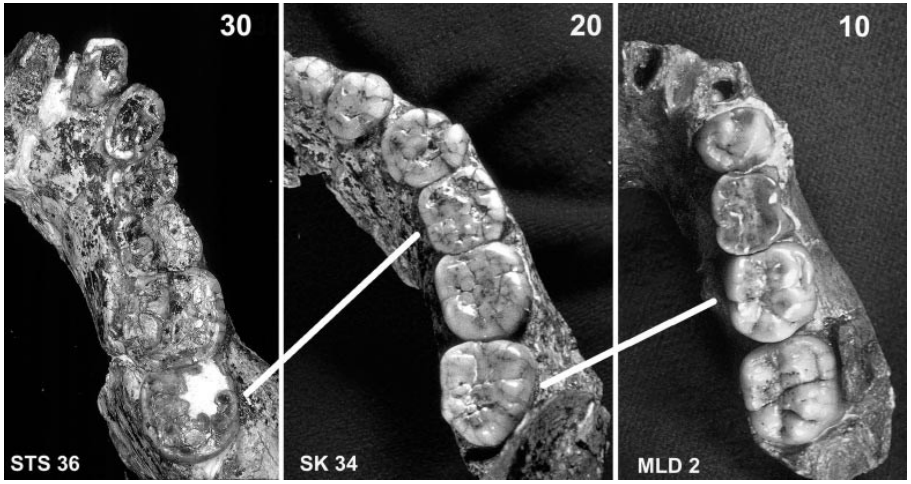
What I'm Going to Tell You

- The OY ratio: what it is, why it matters
- "Ethnographic" model settings unable to produce low OY ratios (< 1) like those of Neandertals
- Low OY ratios are produced by Middle Paleolithic mortality regime, but demographic viability decreases
- High adult mortality can be offset by several behaviors that enhance birthrate and infant survival
  - Large families
  - minimal restrictions on "marriage"
  - family economics different from those of ethnographic hunter-gatherers
- Model results concordant with several lines of archaeological/fossil data

The OY Ratio

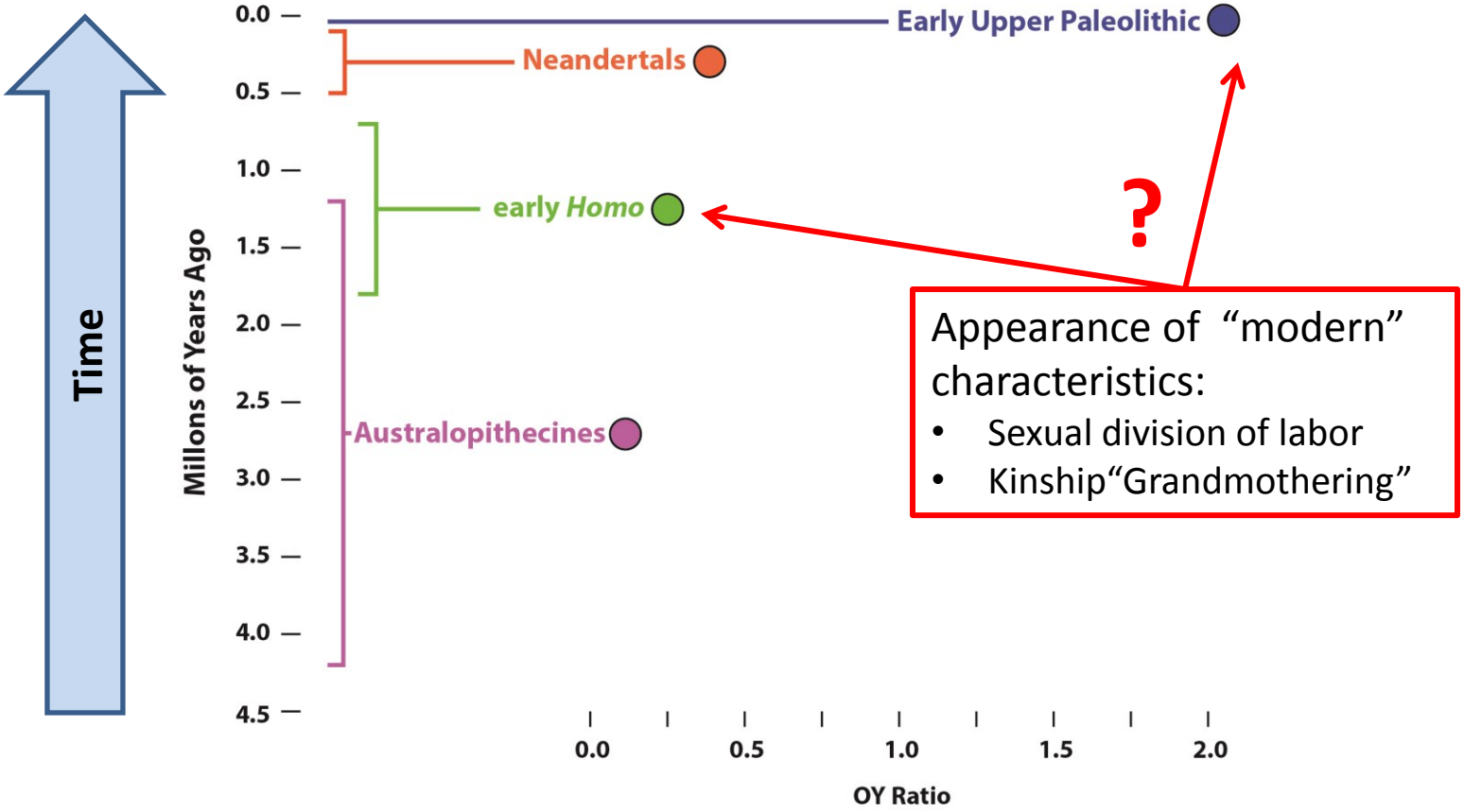




Fossils categorized by relative dental wear
(from Caspari and Lee 2004:10896)

$$\text{OY ratio} = \frac{n \text{ old adults}}{n \text{ young adults}}$$

OY Ratio: Change through time



OY ratio data from: Caspari, Rachel, and Sang-Hee Lee. 2004. Older age becomes common late inhuman evolution. *Proceedings of the National Academy of Sciences* 101(3):10895-10900.

More old adults

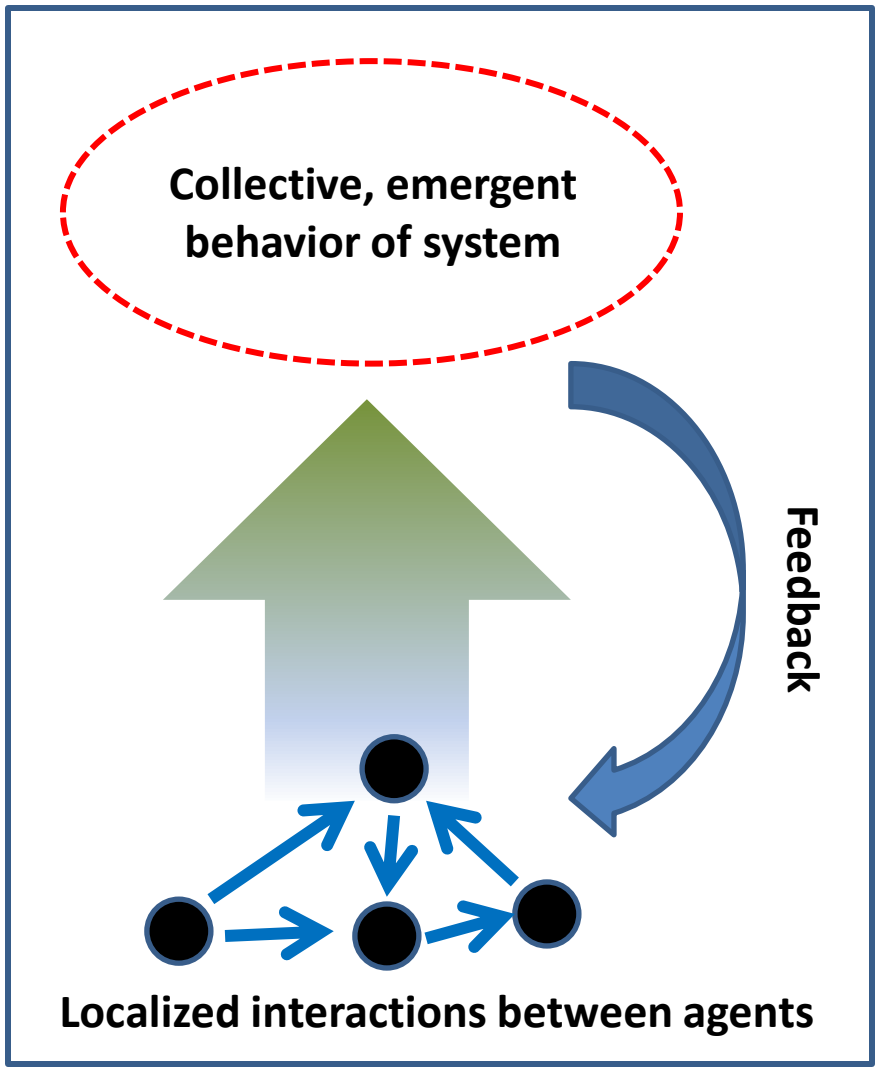
First question: what does the OY ratio mean?

- Static measure derived from assemblages of fossils
- What is it telling us about the demography of living populations?
- Interpretation → need to link changes in demographic variables of living populations to changes in “dead” OY ratio
- Complex systems approach: systematic experimentation with an ABM

Demographic characteristics are emergent behaviors

Emergent behavior: self-organizing, collective behavior that is difficult to anticipate from knowledge of the individual agents' behavior (Boccara 2004:3)

- System-level behavior emerges from the "bottom up"
- Feedbacks from the "top down" affect lower levels of system



AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 00:00–00 (2014)

Mortality, Fertility, and the OY Ratio in a Model Hunter–Gatherer System

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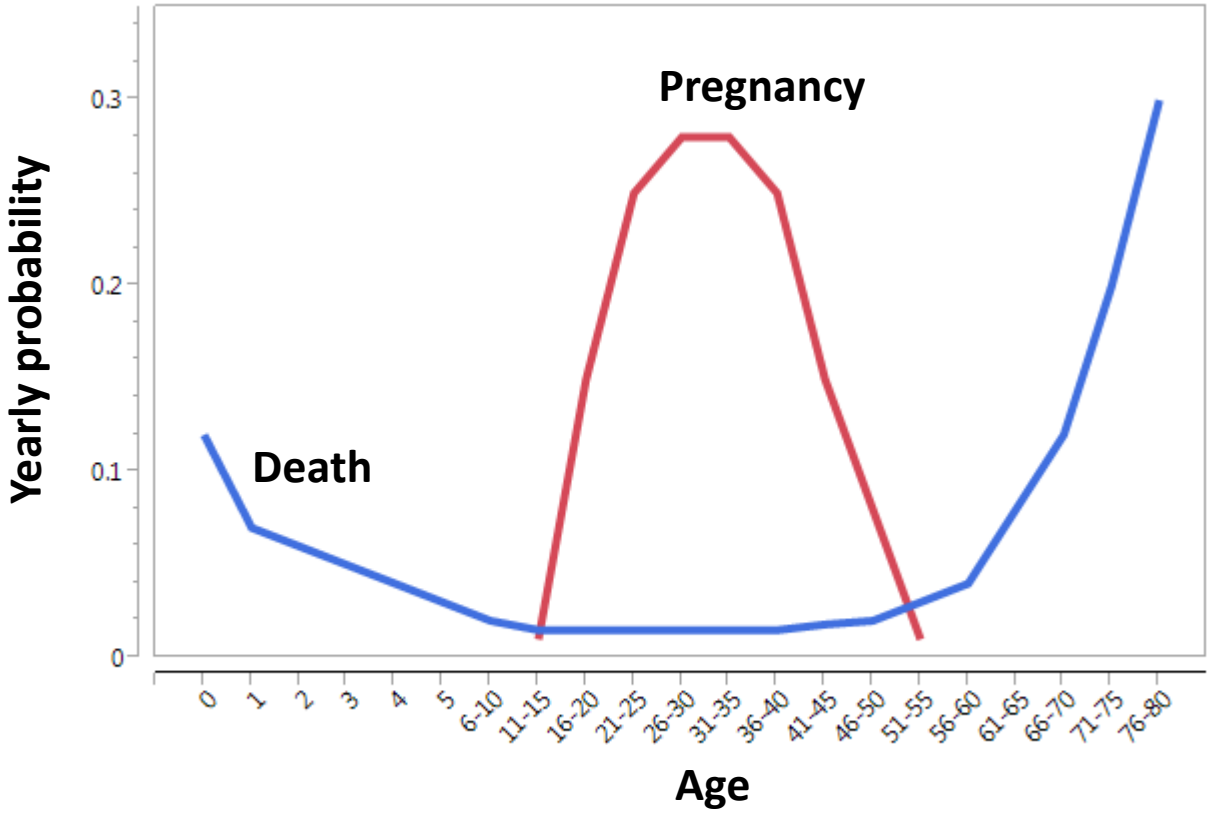
KEY WORDS paleodemography; demography; longevity; agent-based model; complex systems theory

ABSTRACT An agent-based model (ABM) is used to explore how the ratio of old to young adults (the OY ratio) in a sample of dead individuals is related to aspects of mortality, fertility, and longevity experienced by the living population from which the sample drawn from those populations (the dead OY ratio) that is consistent with that from empirically known ethnographic hunter–gatherer cases. The dead OY ratio is clearly related to the mean ages, mean adult mortality rates, and mean total fertility rates experienced by

- Paper at *AJPA* (currently in Early View)
- Model description and code (FN3D_V2) at www.OpenABM.org

Key model representations: birth and death

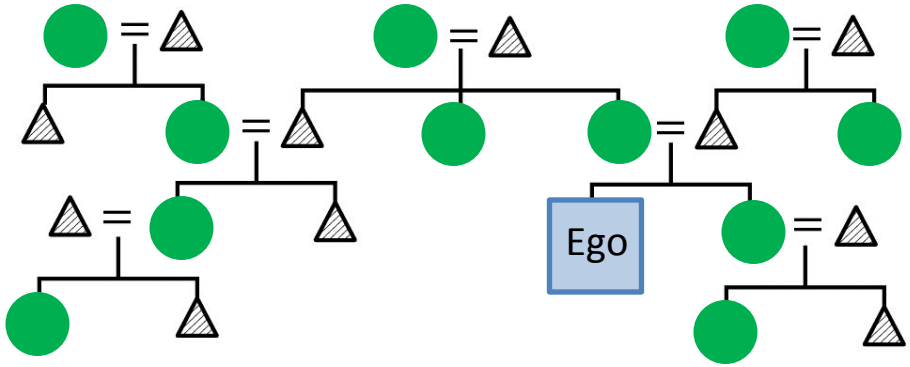
- Age-specific probabilities of pregnancy and death
- Base *pattern* is constant, probabilities adjusted as parameters



Key model representations: who can marry?

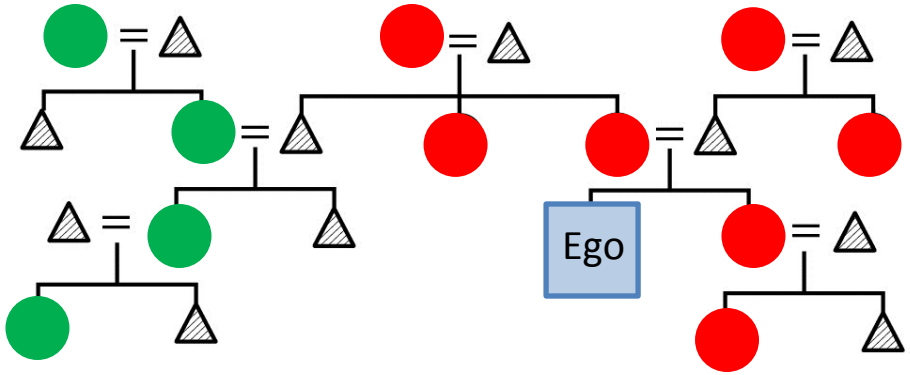
No restrictions based on kinship/descent

- Ego (male) **can marry** any female of reproductive age or older



"Basic" incest taboo

- Ego (male) **cannot marry** sister, mother, grandmother, aunts, nieces

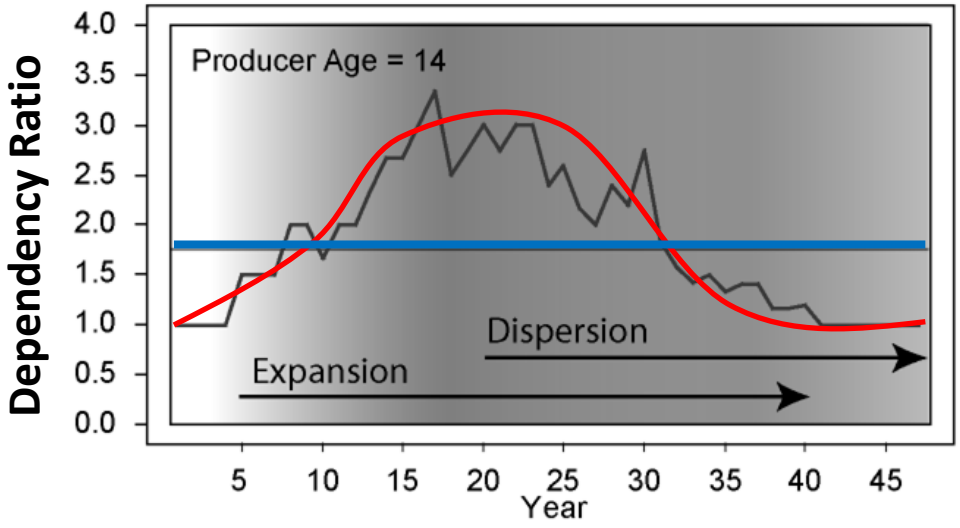


Key model representations: family economics

Dependency ratio = (number of consumers) / (number of producers)

Affects decisions about:

- Marriage (polygyny)
- Avoidance of pregnancy
- Infanticide

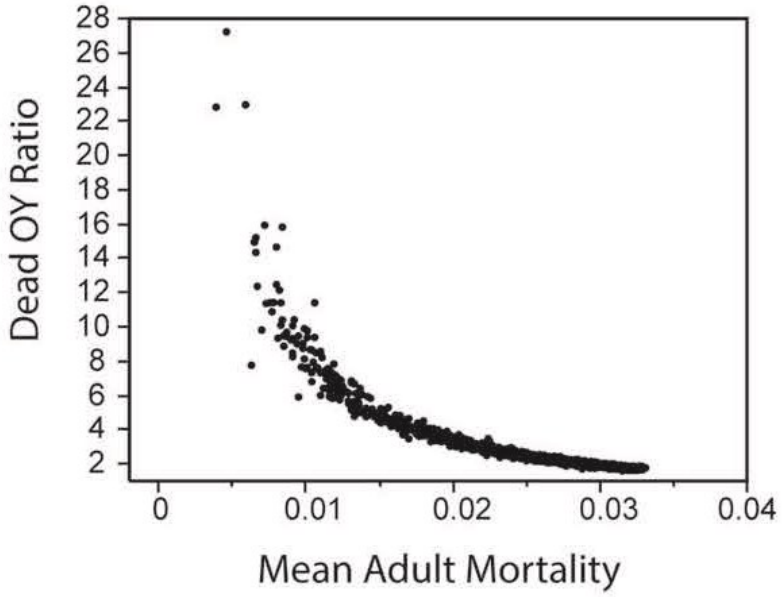


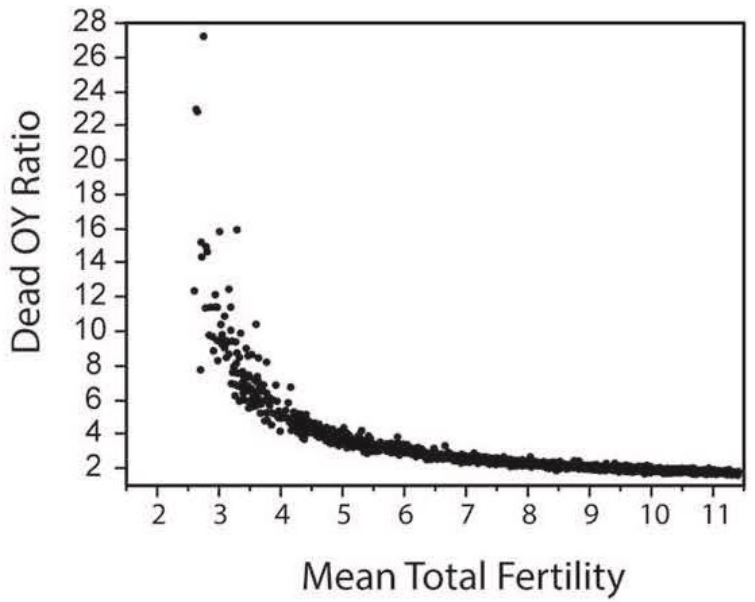
Role/effects of dependency ratio can be adjusted with several "levers:"

- Age at which children are counted as producers
- Value of dependency ratio that is sustainable (1.75)
- Weight of dependency ratio in economic calculations

Baseline model results: “ethnographic” settings

(White 2014)

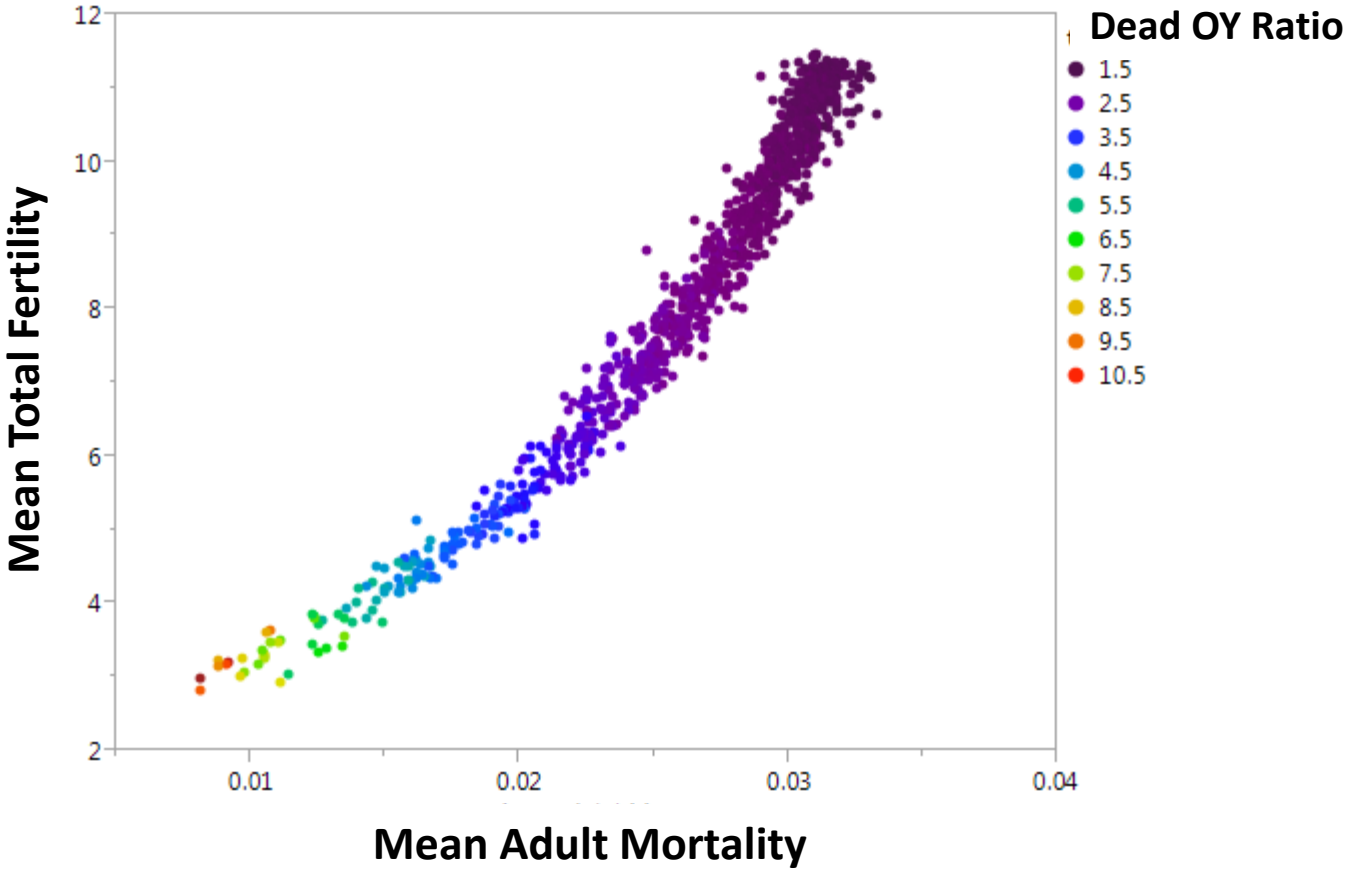




Dead OY ratio clearly related to mortality and fertility experienced by living model populations

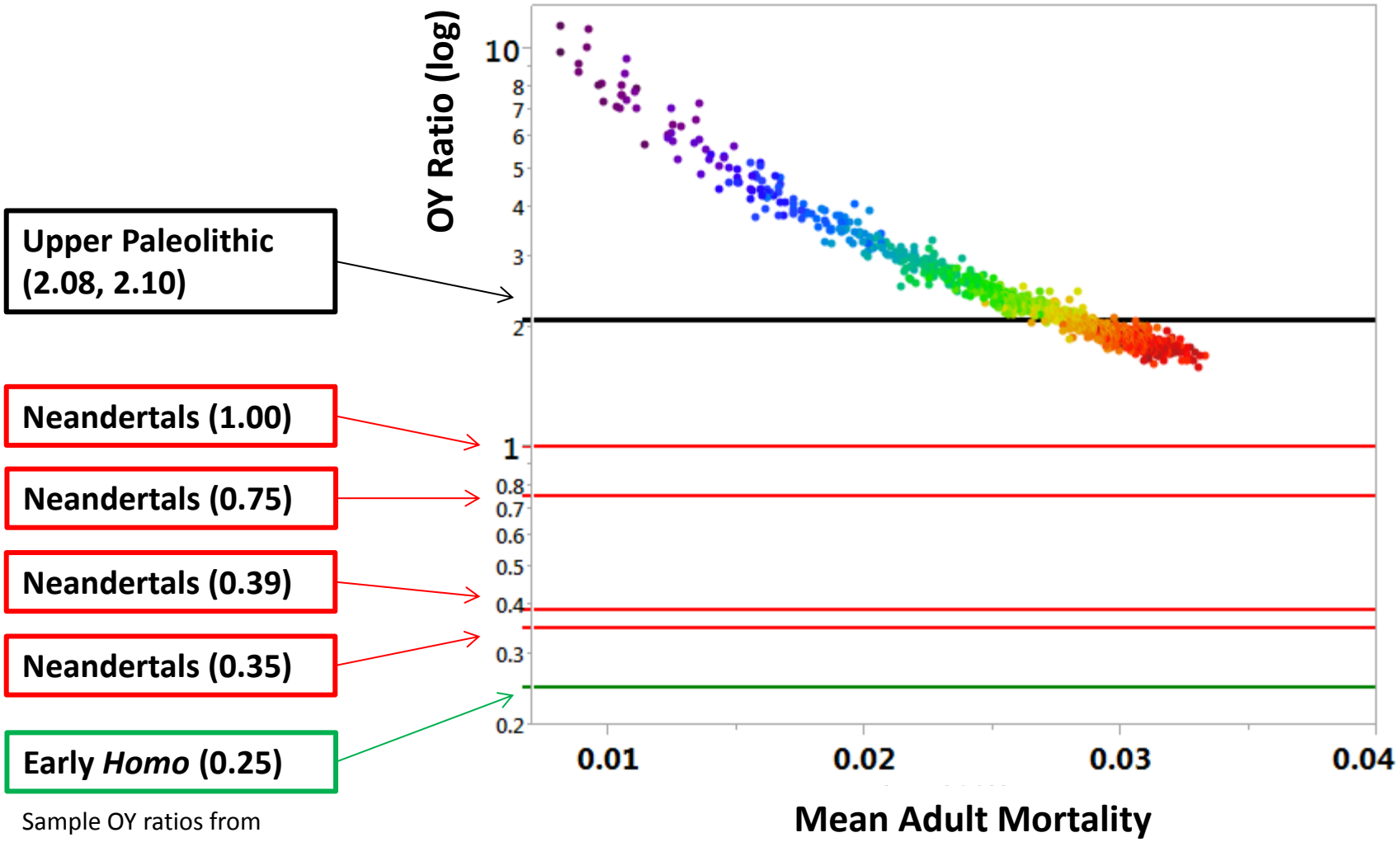
Baseline model results: “ethnographic” settings

(White 2014)



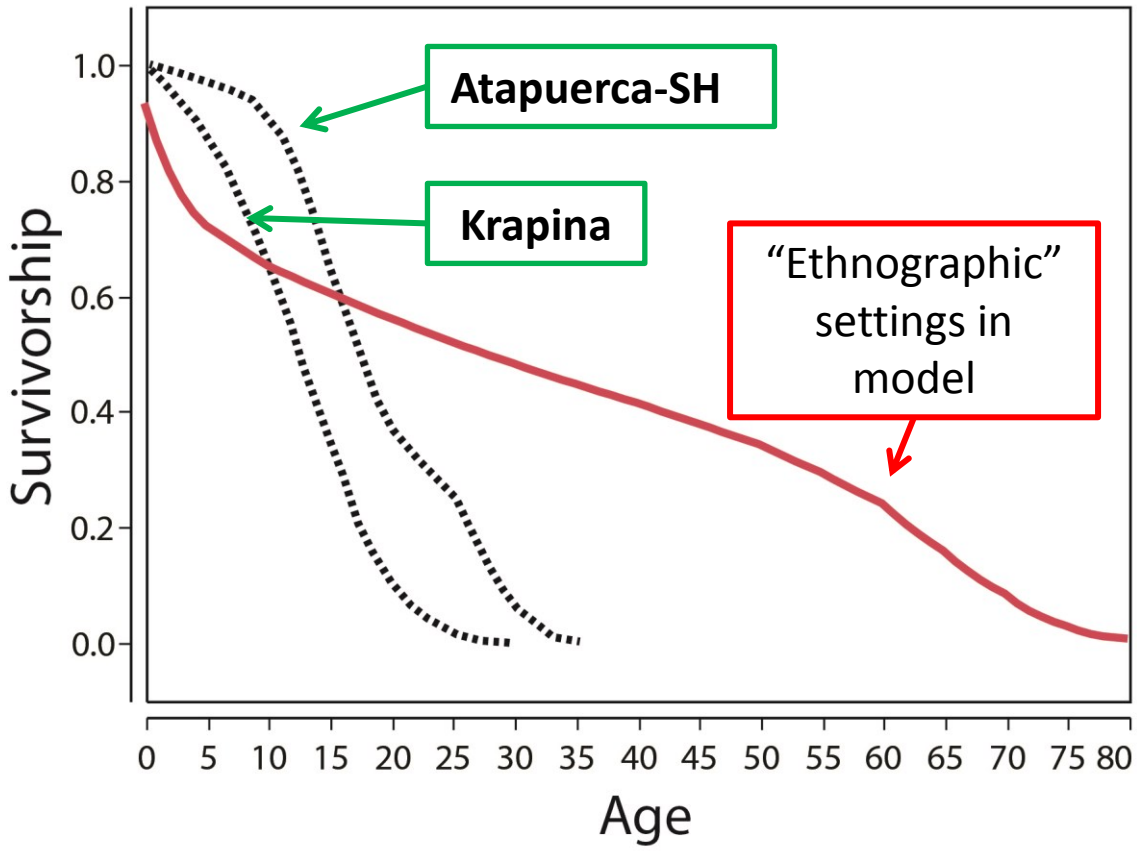
Lower OY ratios produced by populations with higher mortality and higher fertility

Model is incapable of producing OY ratios < 1 at "ethnographic" settings



Sample OY ratios from Caspari and Lee (2004) and Caspari and Lee (2005)

A different mortality regime during the Middle Paleolithic?

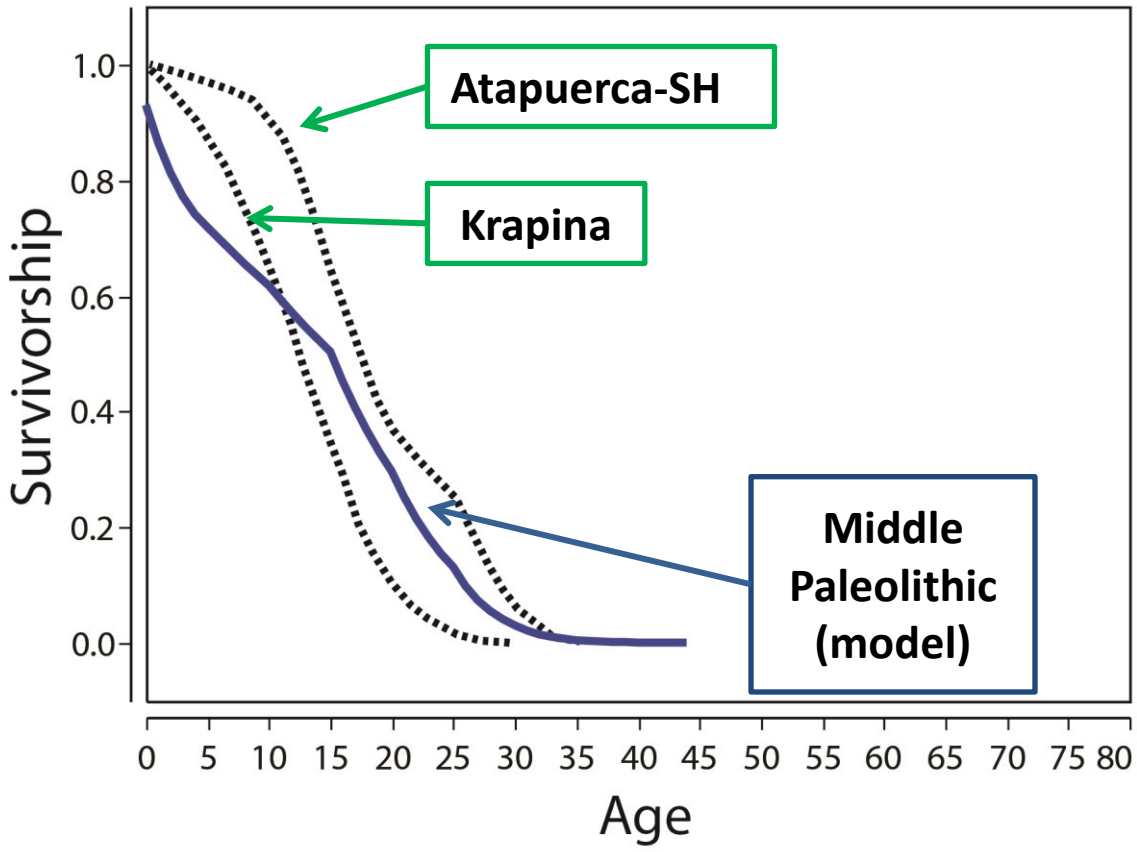


Two large fossil assemblages that can be used to estimate survivorship during the Middle Paleolithic:

- **Atapuerca-SH** (32 individuals)
- **Krapina** (83 individuals)

Dotted lines from: Bermúdez de Castro & María Elena Nicolás 1997:Figure 5.

A different mortality regime during the Middle Paleolithic?



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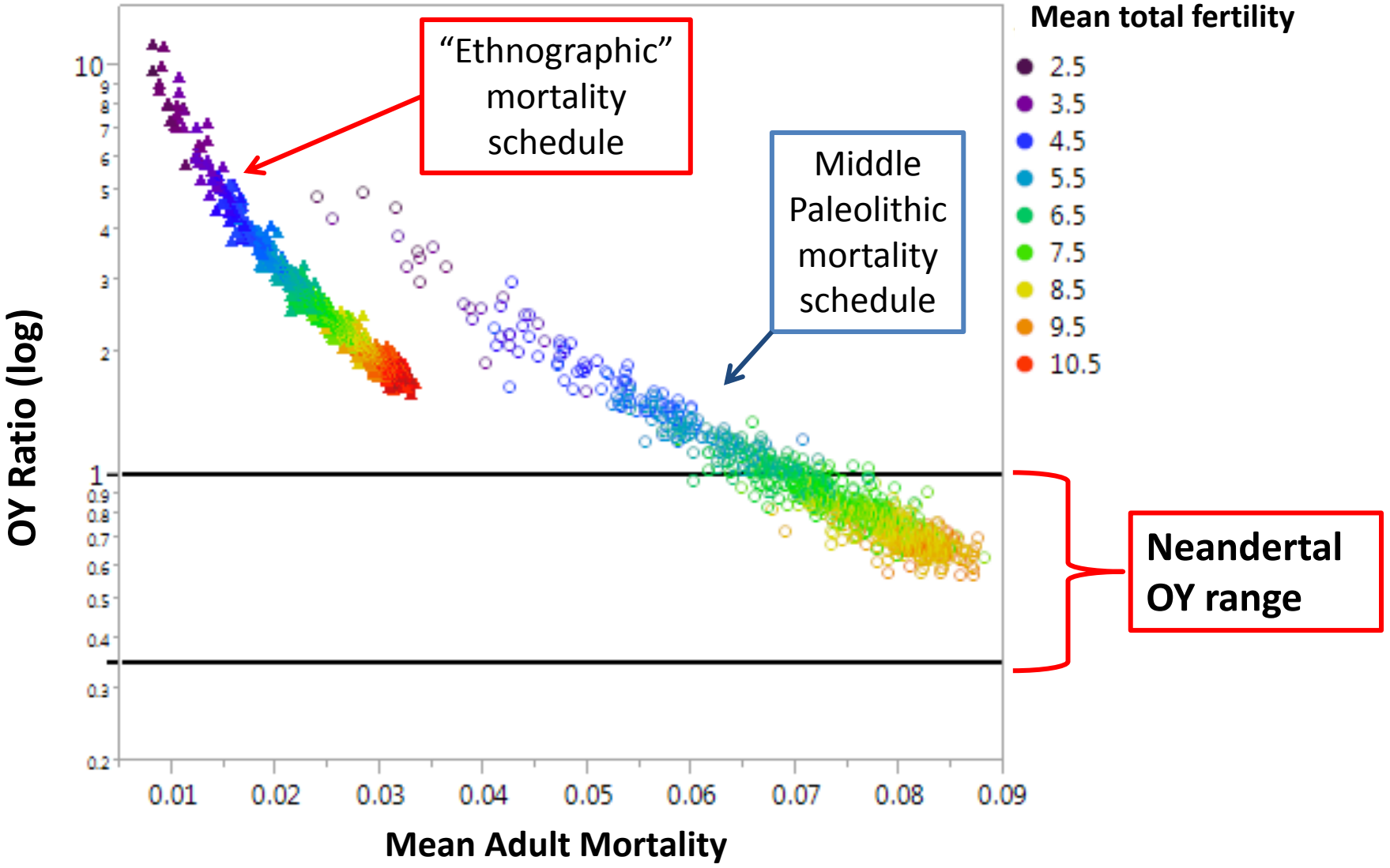
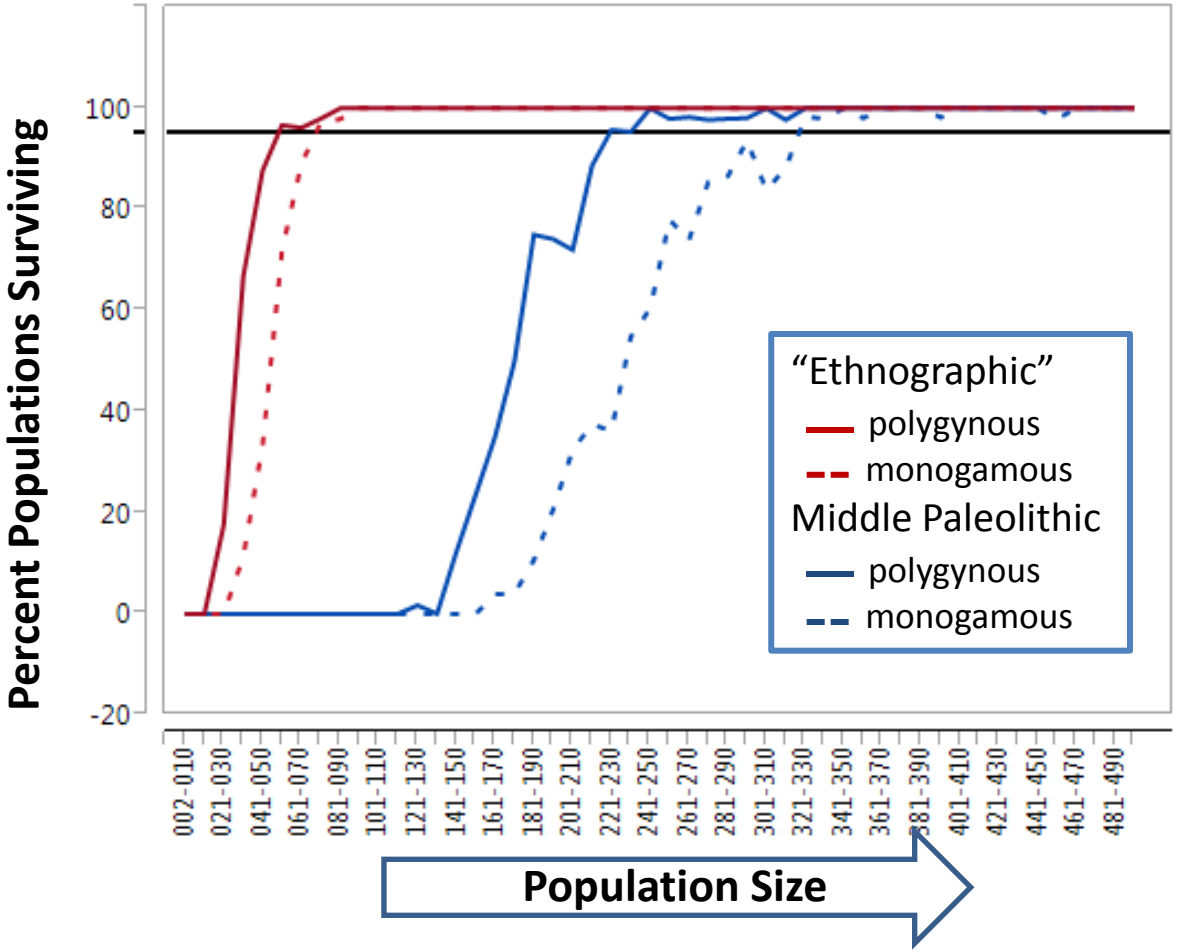
MP mortality can produce low OY ratios

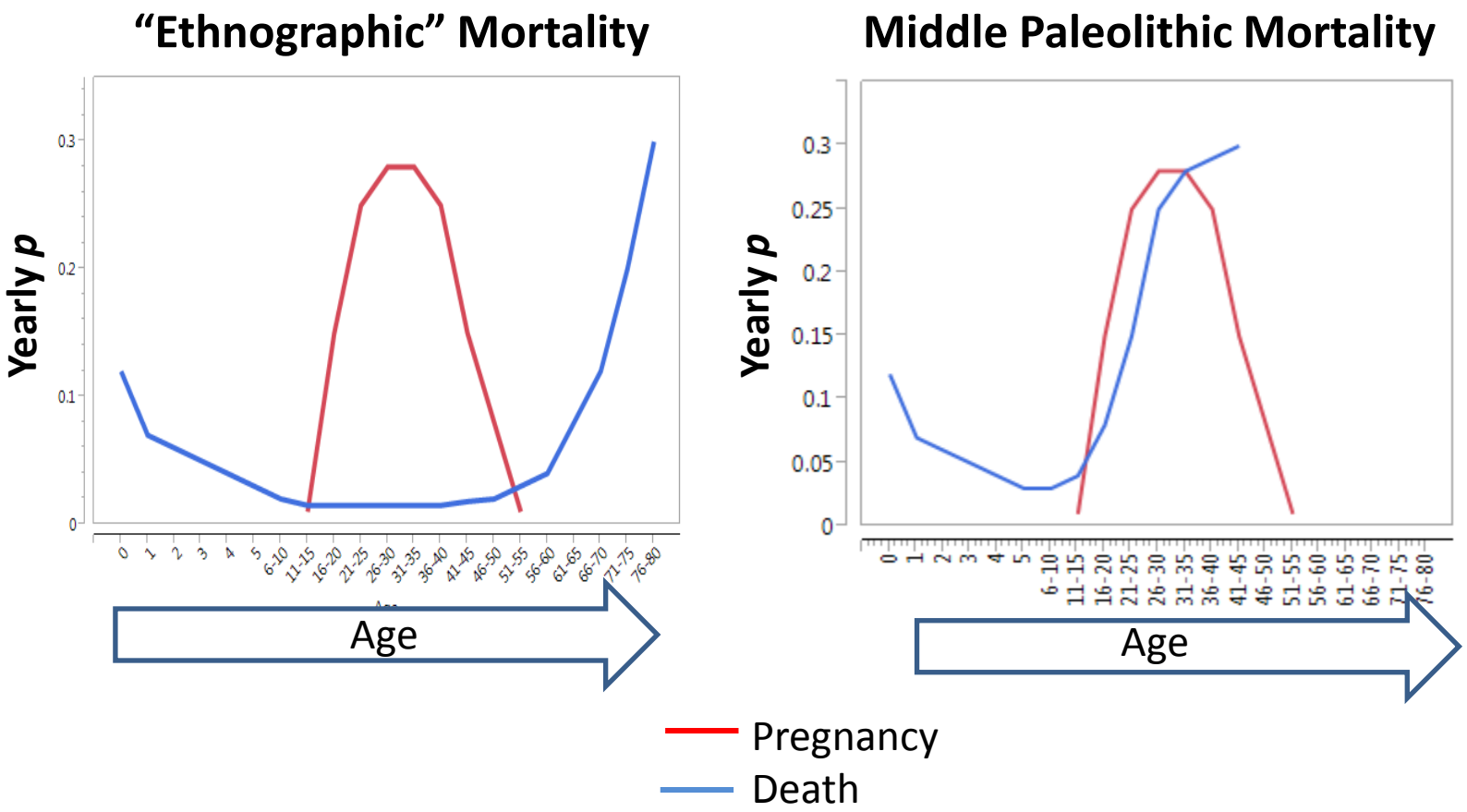


But demographic viability also goes down



Under MP mortality regime, populations must be about 3x larger to be demographically viable (i.e., survive 1000 years 95% of the time), other things being equal

Key problem: high adult mortality truncates the mean female reproductive span



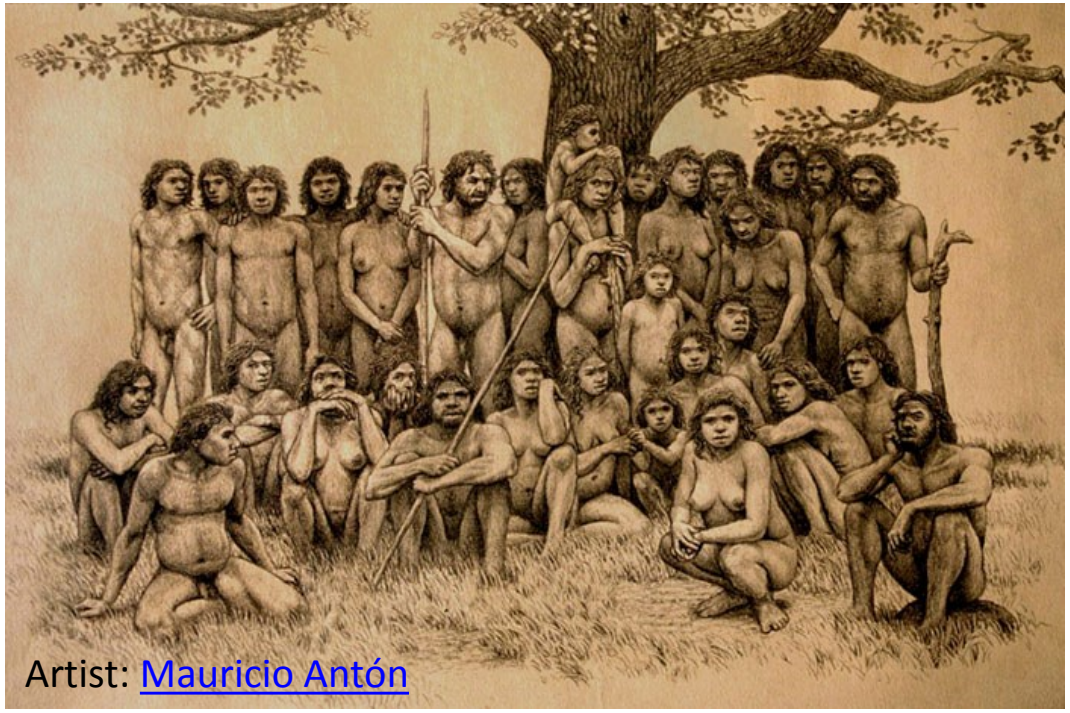
All other things being equal . . .

- Populations experiencing “Middle Paleolithic” mortality require much larger sizes to be demographically viable (to mitigate stochasticity in birth and death)

- In a dispersed “ethnographic” hunter-gatherer system, that would probably mean increased emphasis on mechanisms for forming and maintaining social networks, etc.

- Does that resonate with our general view of the Neandertal record?

What enhances viability of small hunter-gatherer systems under the high adult mortality conditions of the Middle Paleolithic?

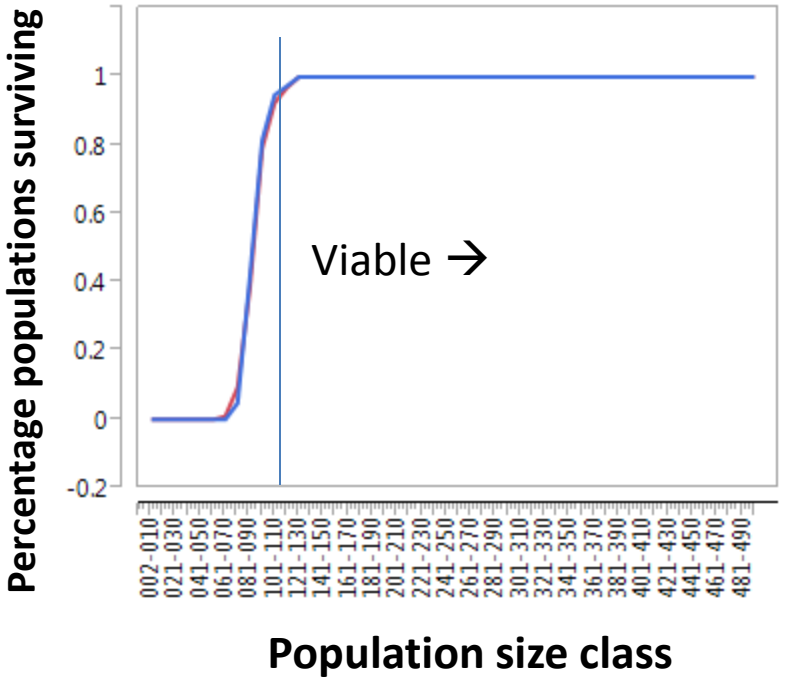


Fertility, fertility, fertility

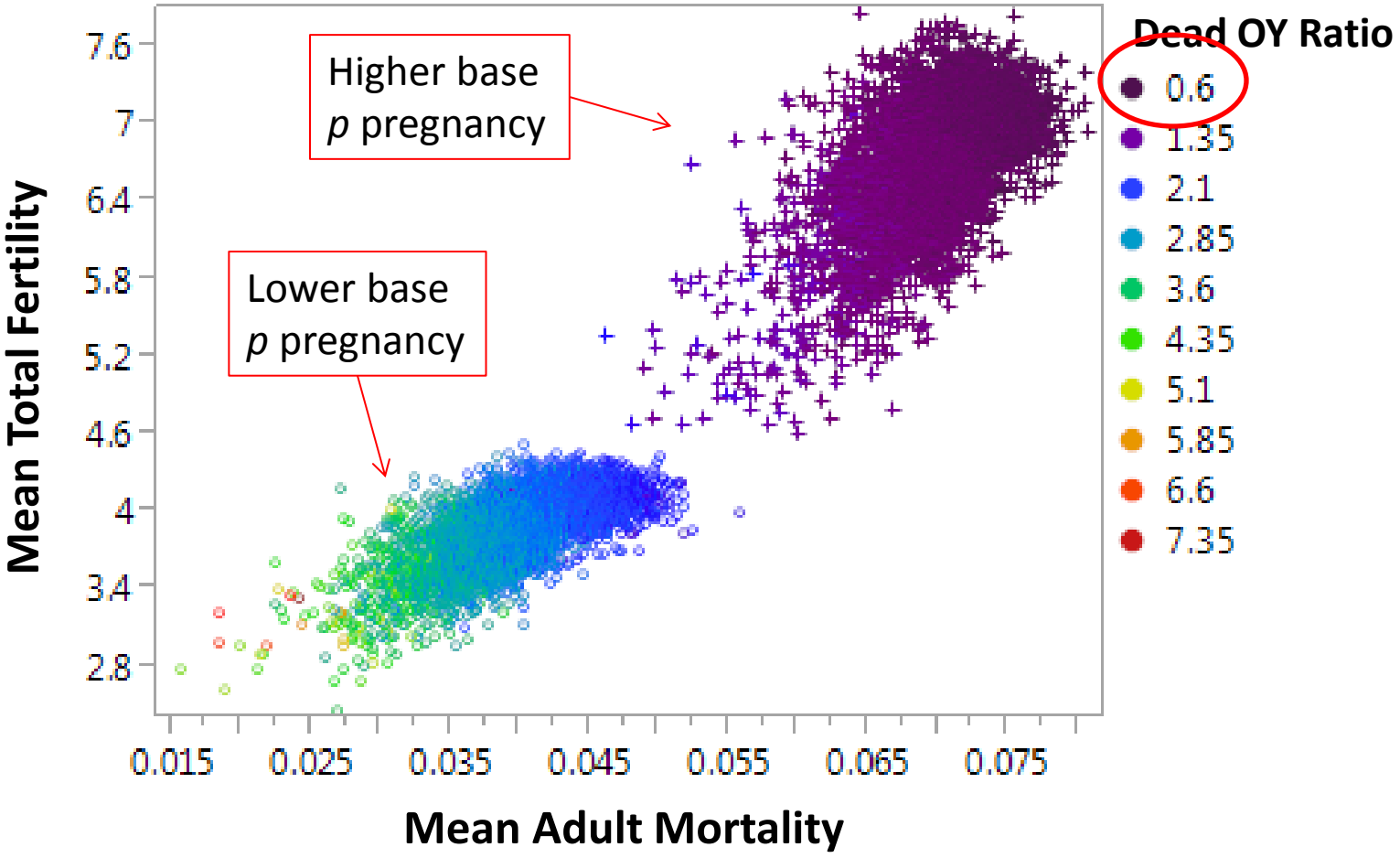
As fertility increases, the population size required for viability decreases

Lower fertility:
viable at 220 people

Higher fertility:
viable at 110 people



Fertility: Higher fertility associated with lower OY ratios



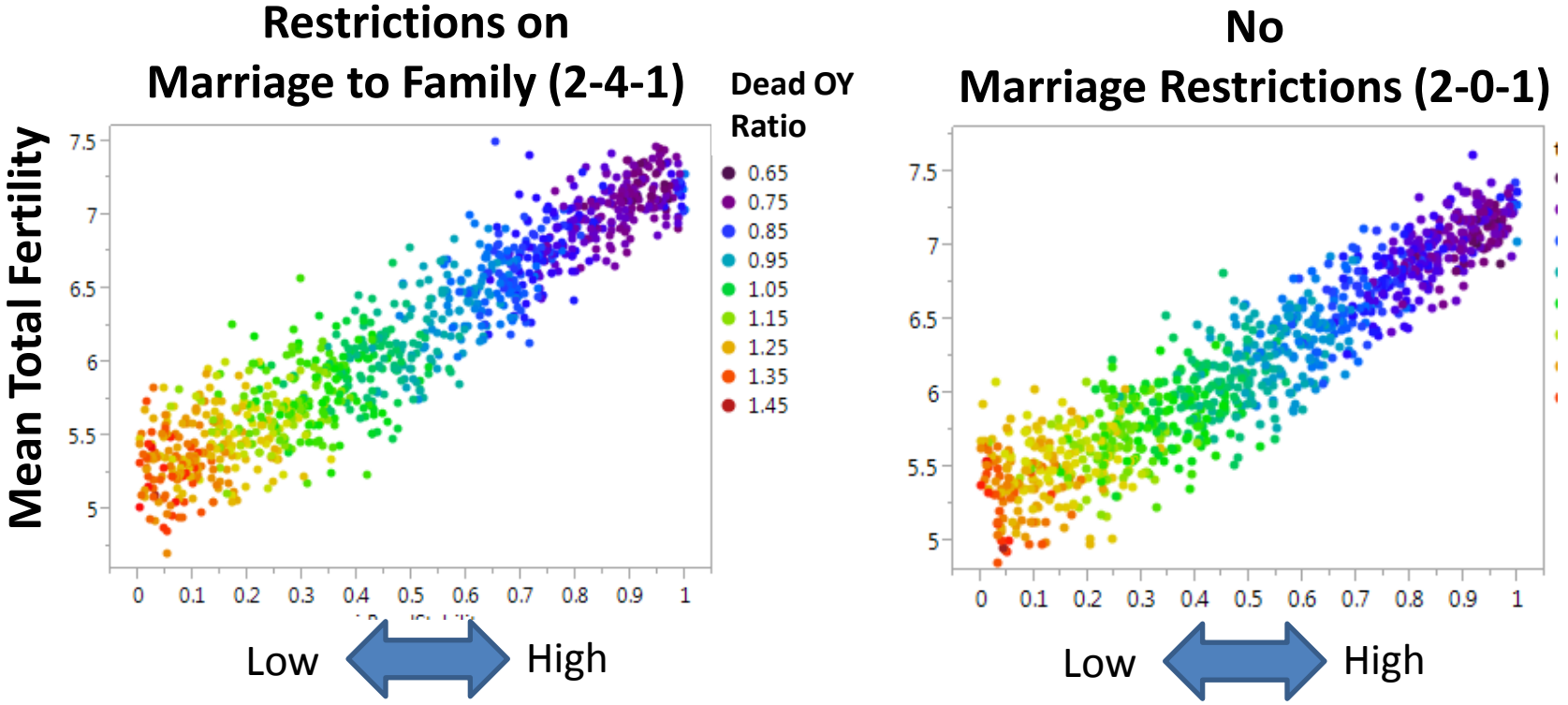
We're going in the right direction

- Let's assume female reproductive physiology is a constant (same gestation period, same overall age-specific **pattern** of fertility, same duration of postpartum amenorrhea, etc.)

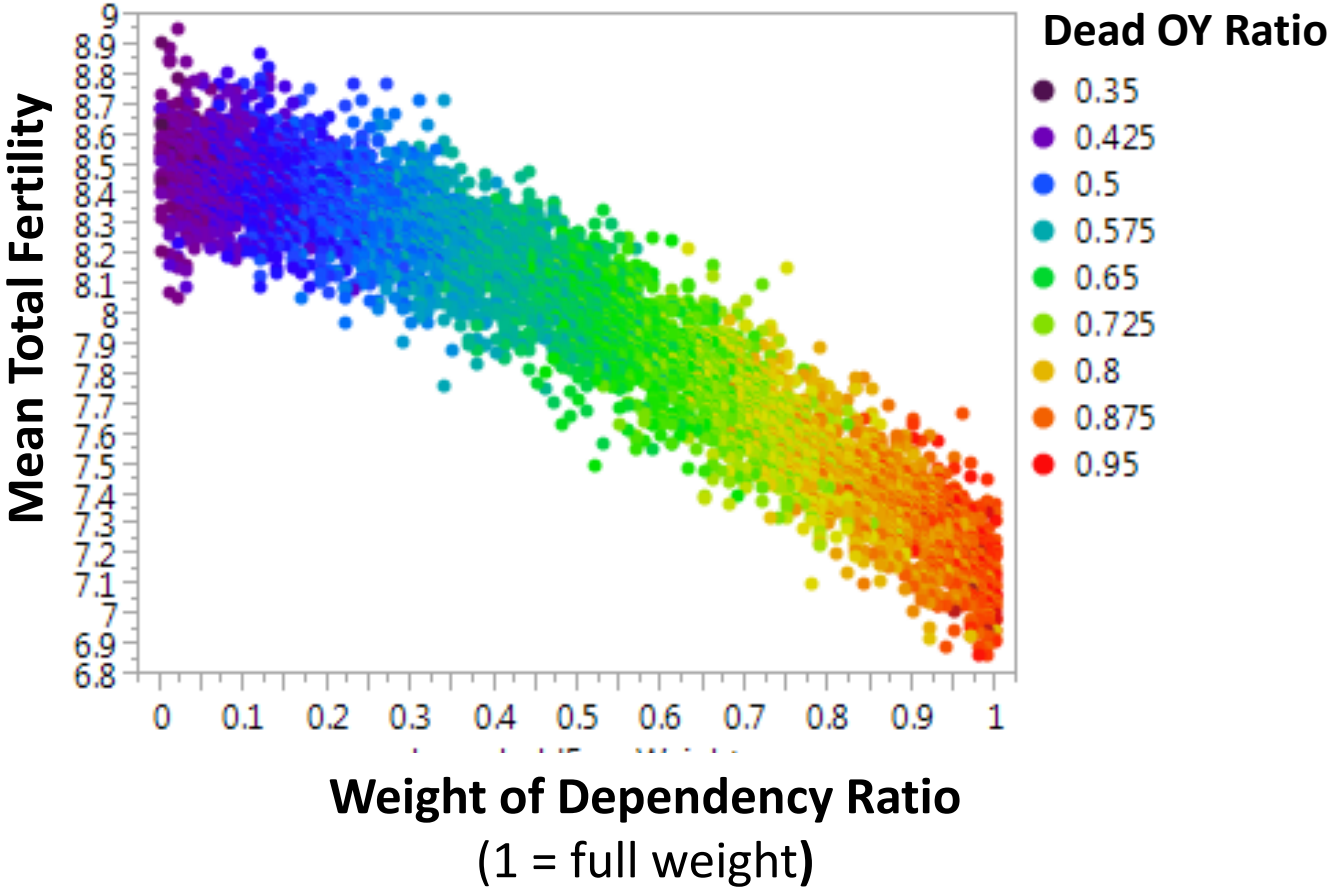
- How do **behavioral** differences/conditions affect fertility and the OY ratio?

- Consider three things that affect family size/composition:
  - Stability of male-female pair bonds
  - The "weight" of the dependency ratio
  - The age at which children make a contribution to subsistence

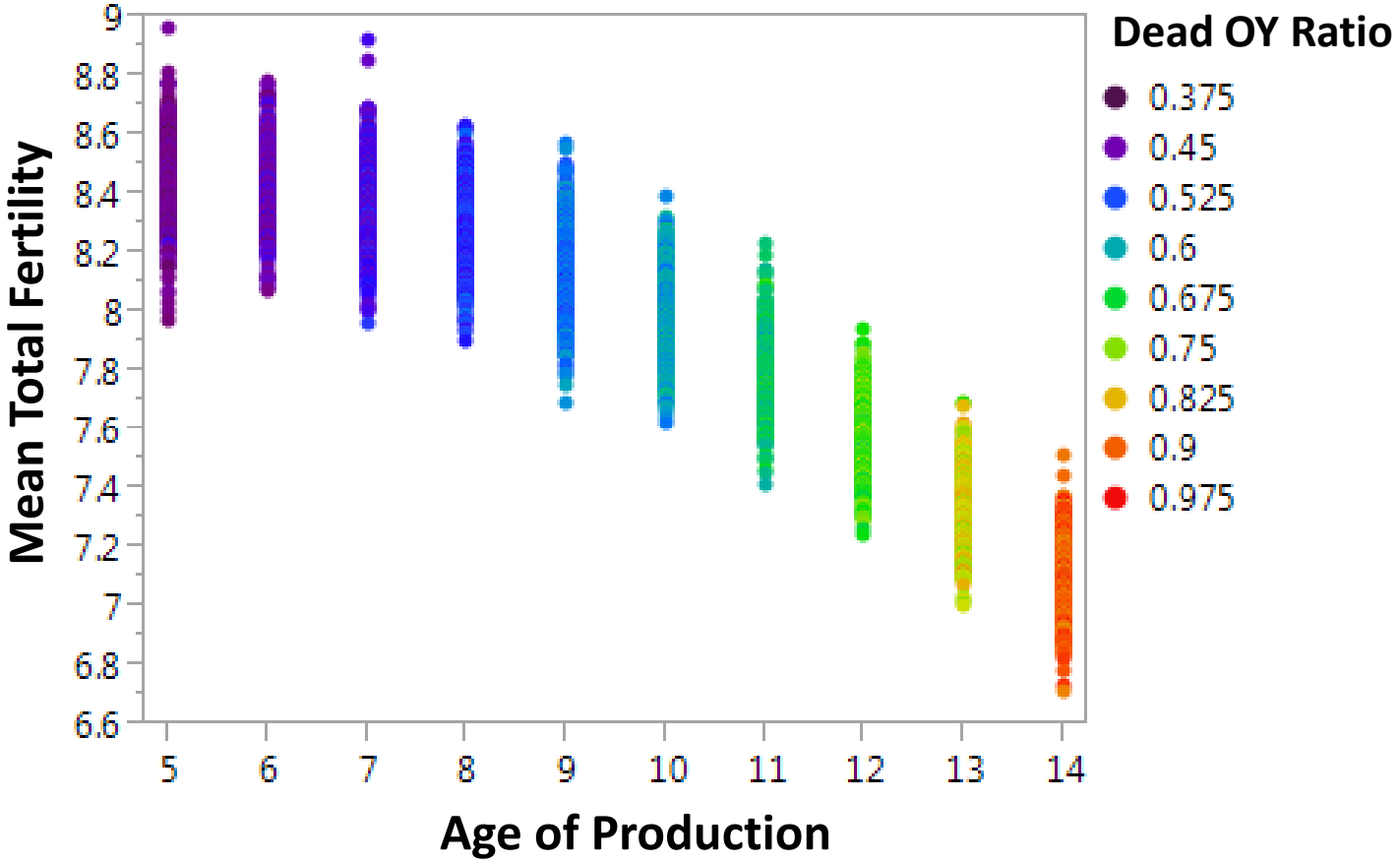
Pair Bonding: Greater stability associated with higher fertility and lower OY ratios



Household Economics: Less weight on the dependency ratio associated with higher fertility and lower OY ratios



Household Economics: Lower age at production associated with higher fertility and lower OY ratios

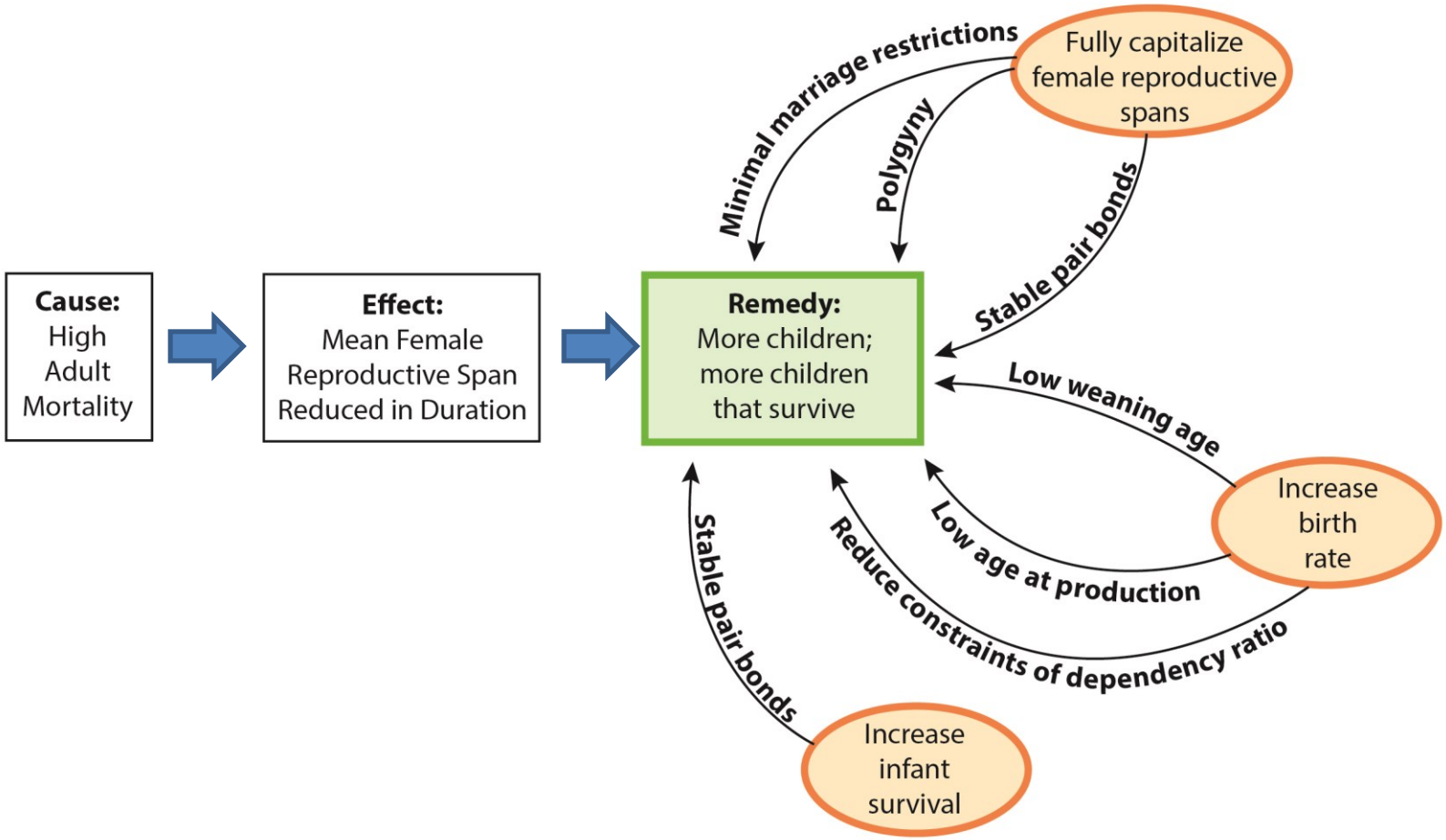


A recipe for enhancing viability under high mortality conditions:

- **Capitalize on the entire duration of the female reproductive span**
  - Mitigate stochasticity of sex ratio in small populations by maximizing "marriage" flexibility (polygyny; minimal descent/kinship restrictions)
  - Ensure that reproductively viable females are not mate-less (stable pair bonds)
- **Increase the birthrate**
  - Low interval between births (weaning age)
  - Low age at production (resource choice; rapid growth/development)
  - Lessen weight of dependency ratio (alternative division of labor?)
- **Increase infant survival**
  - Invest in offspring (stable pair ponds)

More children; more children that survive

“Goals” and behaviors for enhancing fertility



Can we model such a system?

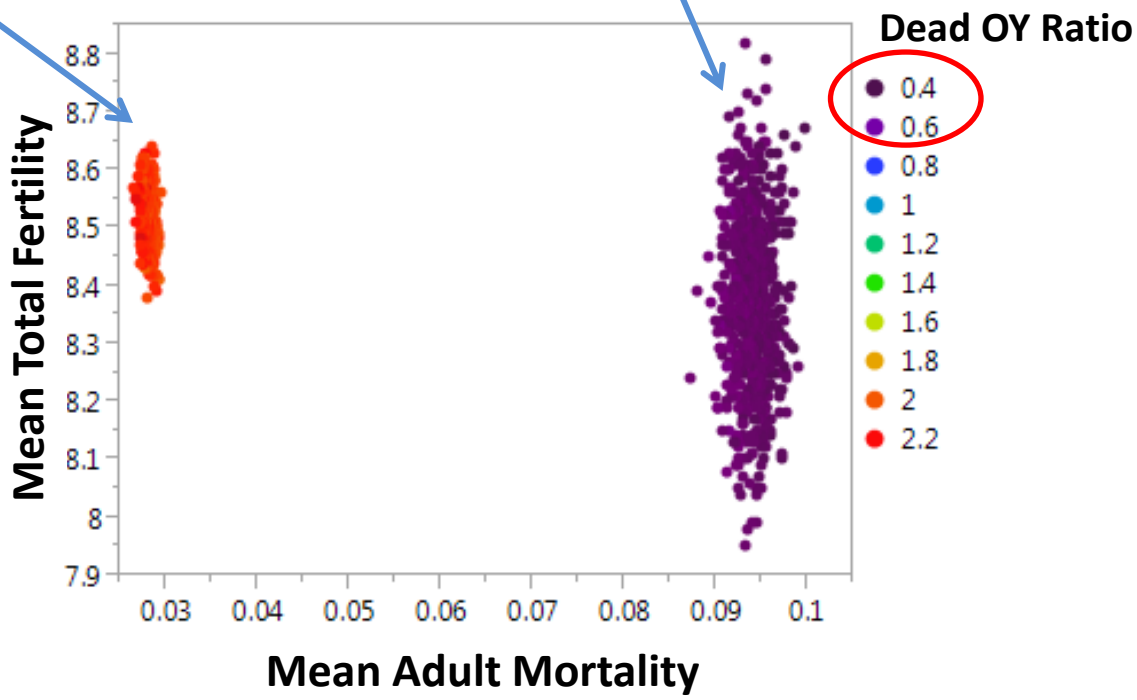
Components:

- Polygyny allowed
- Minimal restrictions on forming pair bonds (family prohibitions: grandparents, parents, siblings, children)
- High base probability of pregnancy
- Low age at production (10 years of age?)
- High stability of pair bonds (0.99)
- Medium weight of dependency ratio (0.5)

Model results

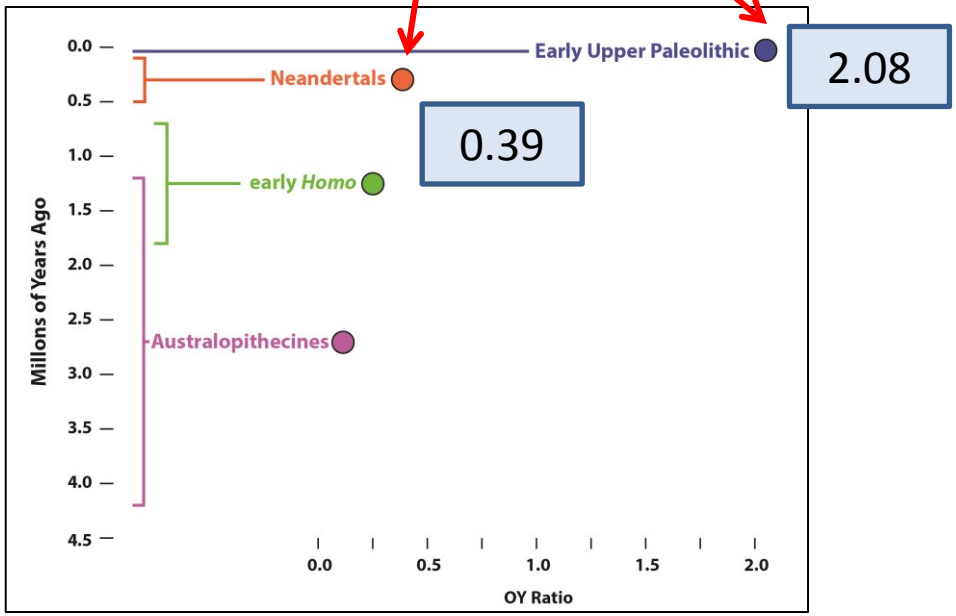
"Ethnographic" conditions (*n*=575 runs):
-polygynous
-kin-based marriage restrictions
-stable pair bonds (0.99)
-ethnographic mortality schedule
-full "weight" of dependency ratio
-age of production = 14 years

"Middle Paleolithic" conditions (*n*=759 runs):
-polygynous
-family-based marriage restrictions
-stable pair bonds (0.99)
-Middle Paleolithic mortality schedule
-half "weight" of dependency ratio
-age of production = 10 years



Model results

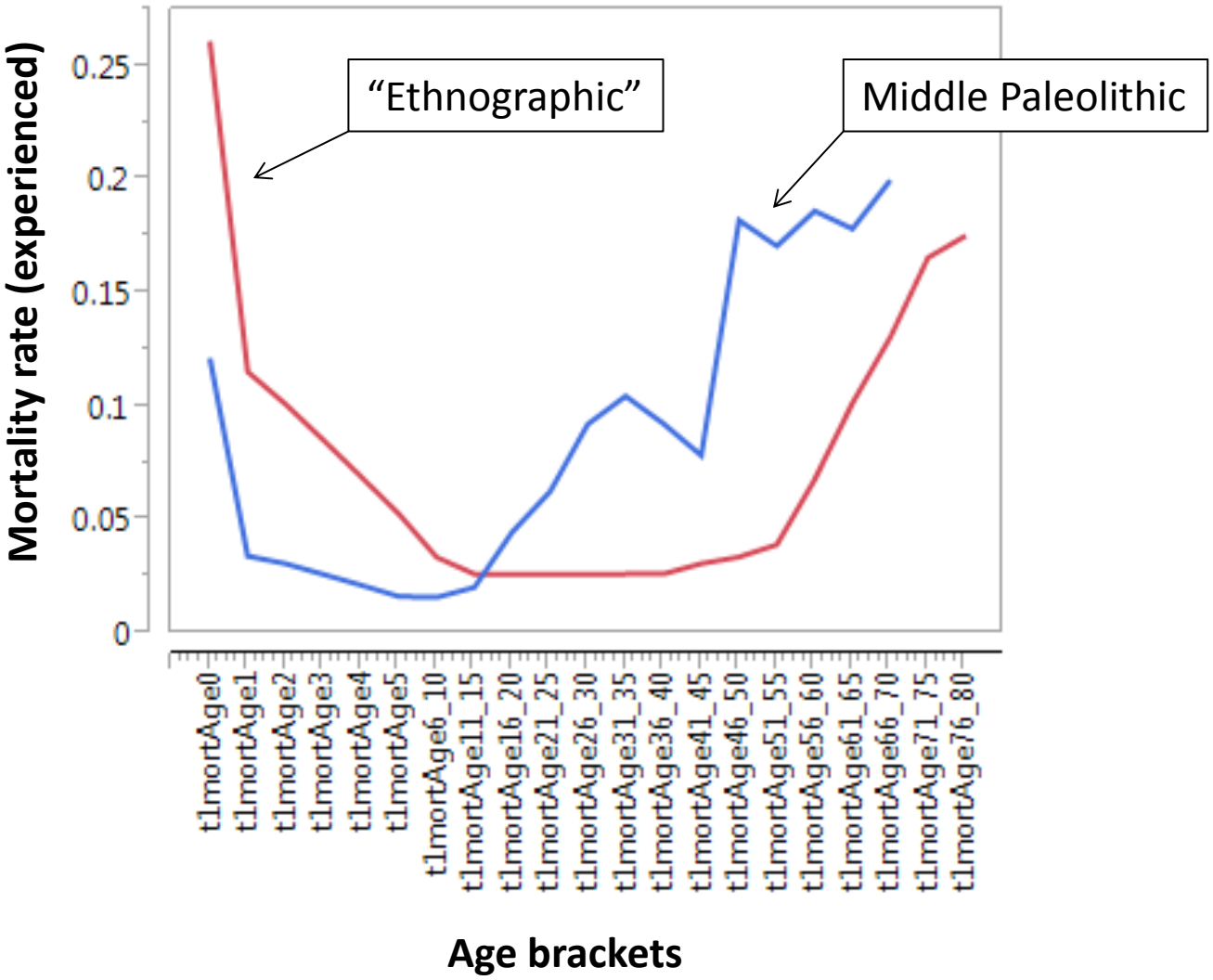
Condition	Mean OY Ratio	Mean Percent Polygynous Marriage	Mean Family Size	Mean Total Fertility	Mean Fertility (All)	Mean Inter-Birth Interval	Mean Infant Mortality
Ethnographic	2.09	16.4	3.6	8.5	5.5	3.6	0.26
Middle Paleolithic	0.49	36.3	4.6	8.4	3.0	3.3	0.12



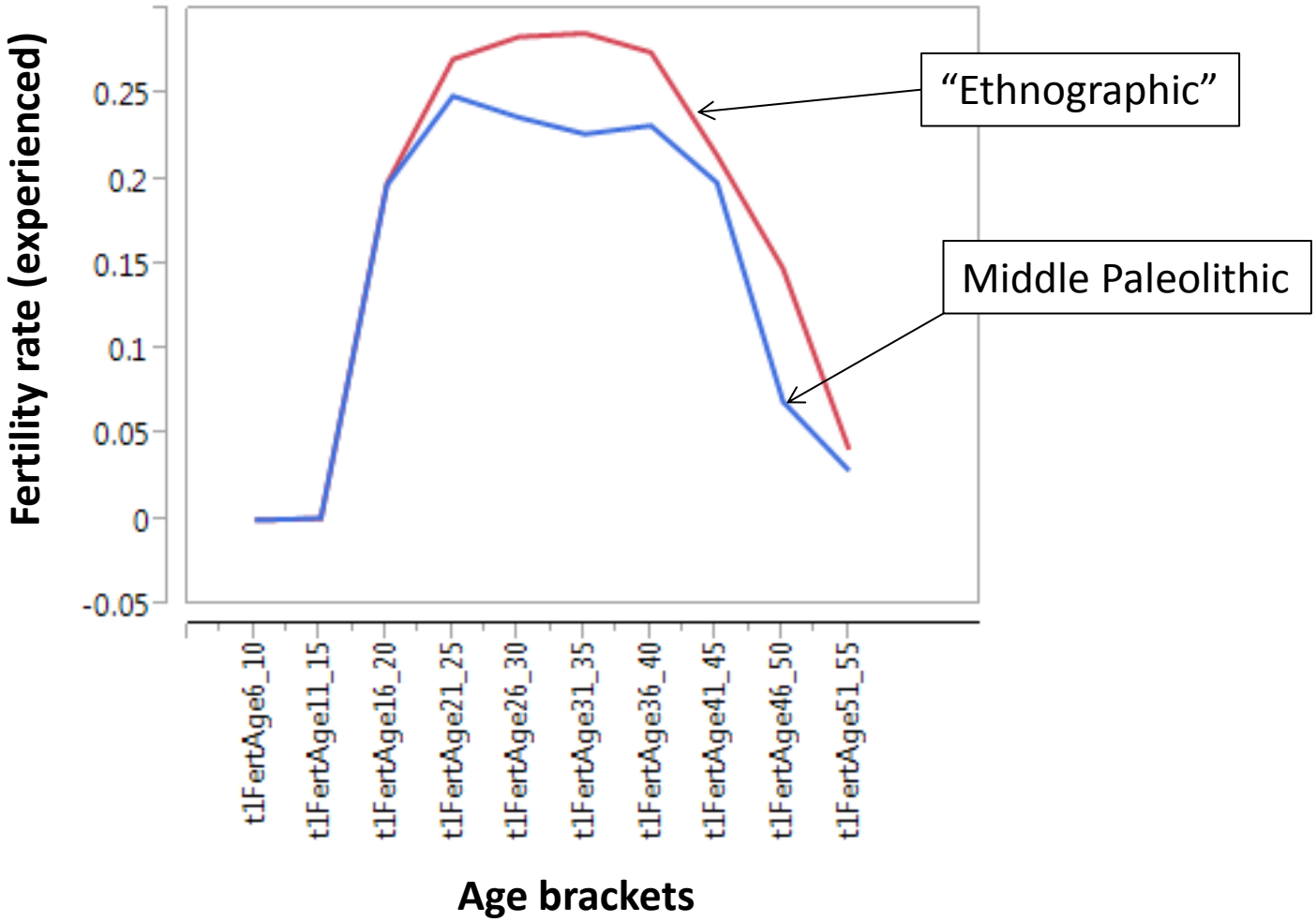
Middle Paleolithic:

- Larger families
- Higher percentage of polygynous marriage
- Shorter inter-birth interval
- Lower infant mortality

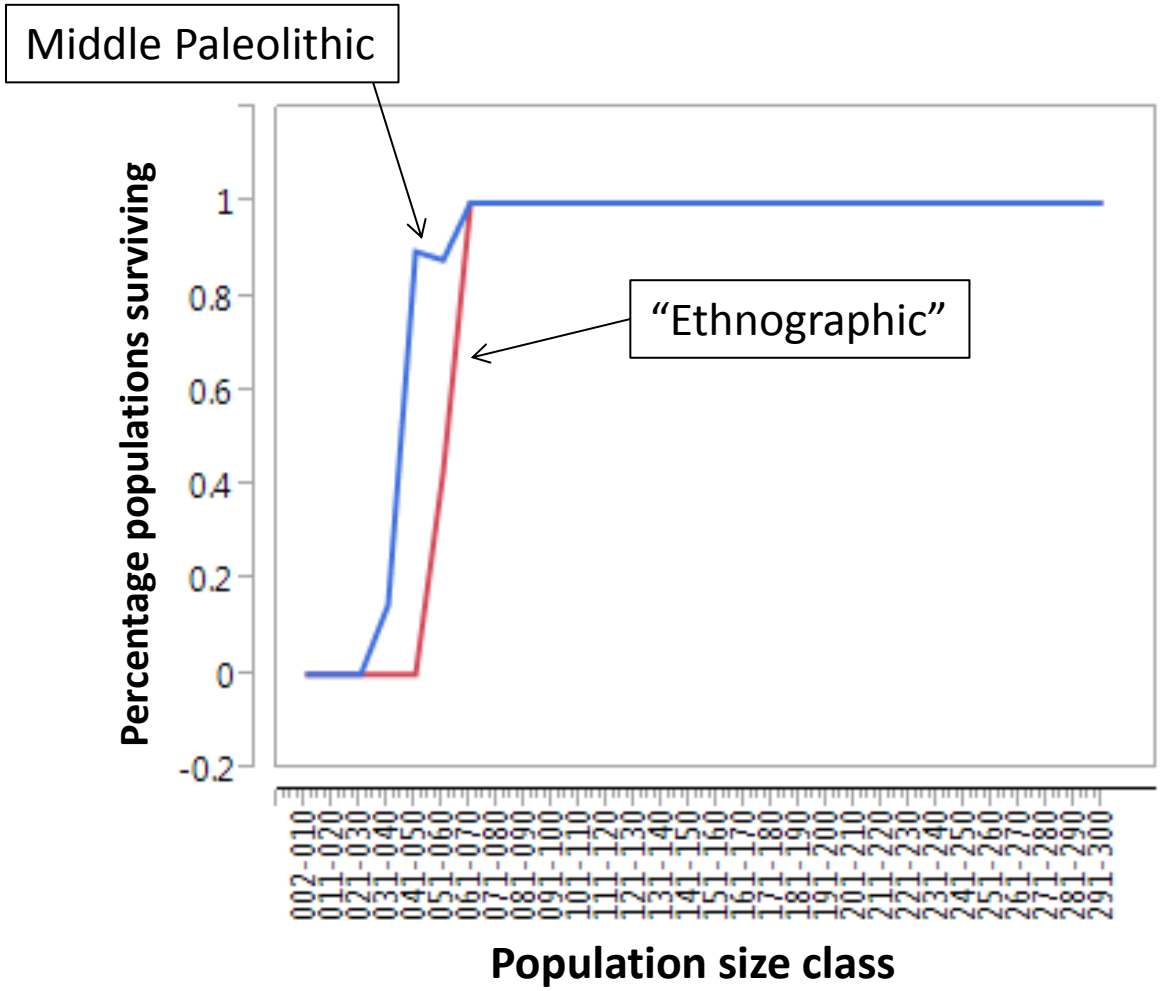
Model results: age-specific mortality outcomes



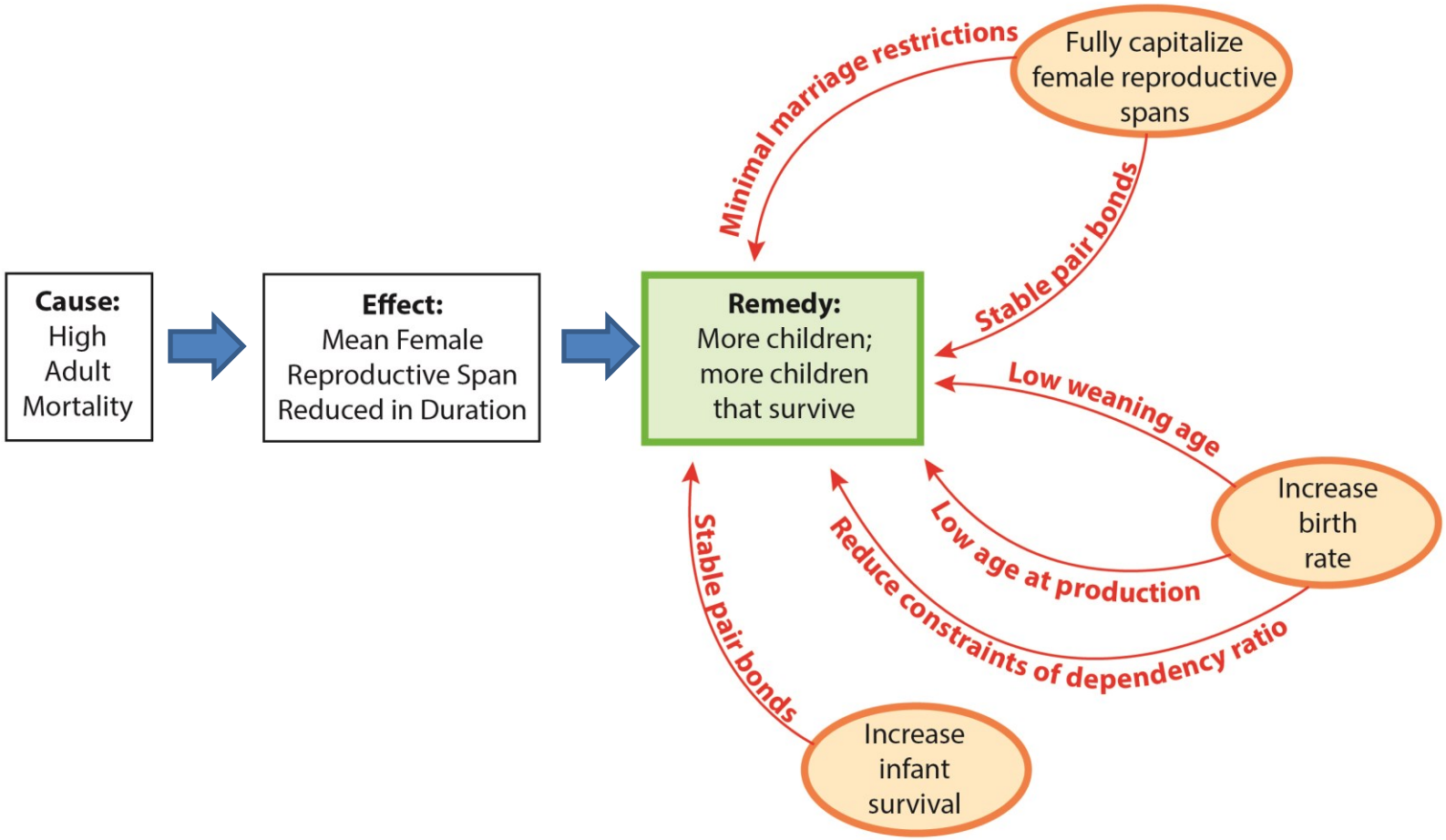
Model results: age-specific fertility outcomes



Model results: viable population size



Comparisons with other lines of evidence



Stable pair bonds

- **Contribution to viability:**
  - Maximize capitalization of female reproductive span (birth rate)
  - Paternal investment in offspring (survival rate)

- **Evidence:**
  - Genetics at El Sidrón → patrilocality (Lalueza-Fox et al. 2011)
  - Part of ancestral condition? (australopithecines? early *Homo*?)

Illustration by Sonia Cabello

Neandertal early weaning?

- **Contribution to viability:**
  - Increase birth rate by reducing inter-birth interval

- **Evidence:**
  - *For:* Barium distribution in Neandertal tooth (Austin et al. 2013)
  - *Against:* earlier onset of anterior tooth wear in Upper Paleolithic (Skinner 1997)

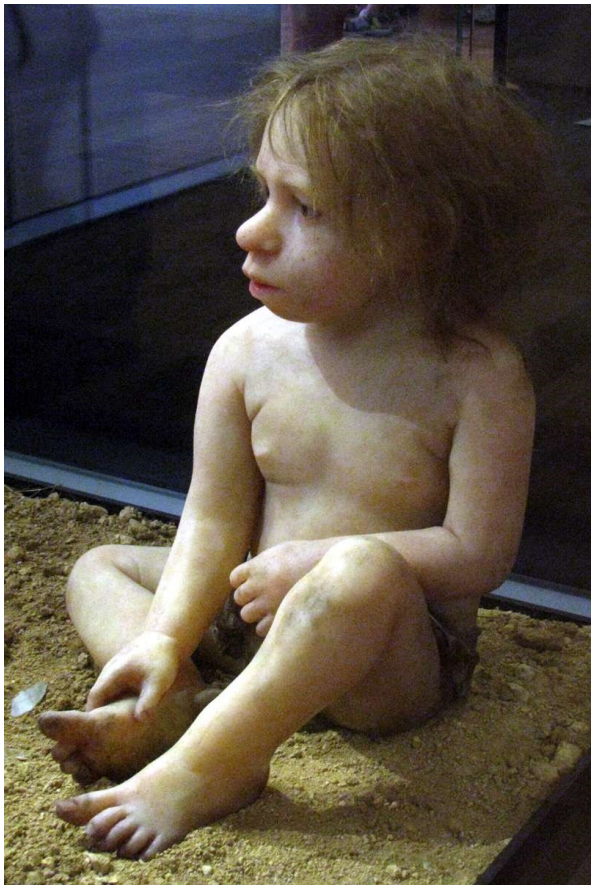
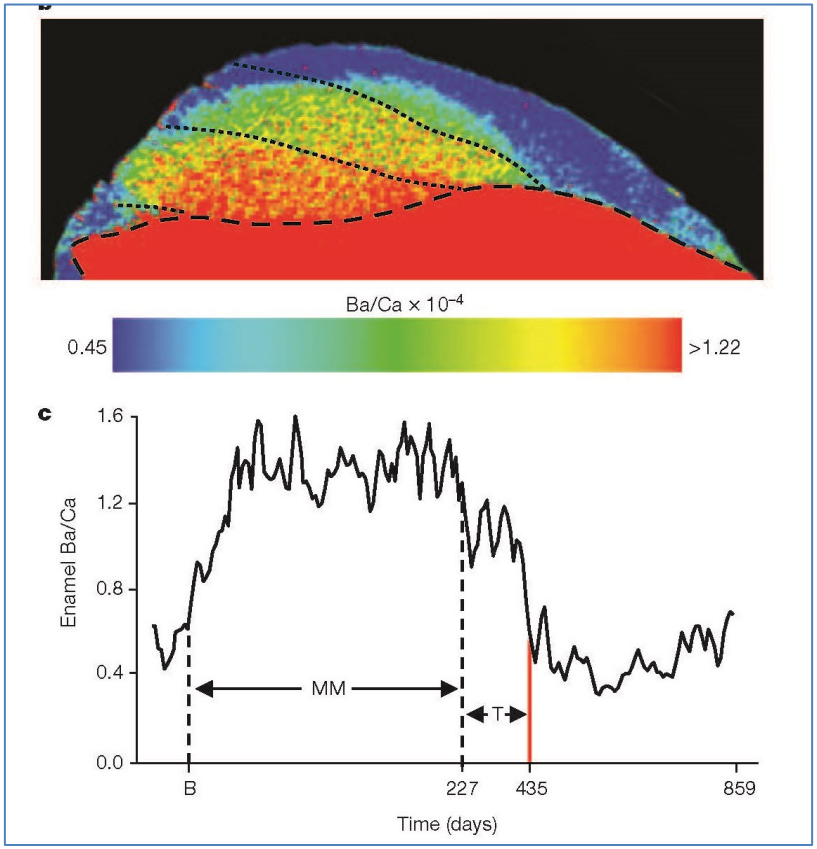


Photo of display at Musée National de Préhistoire, Les Eyzies

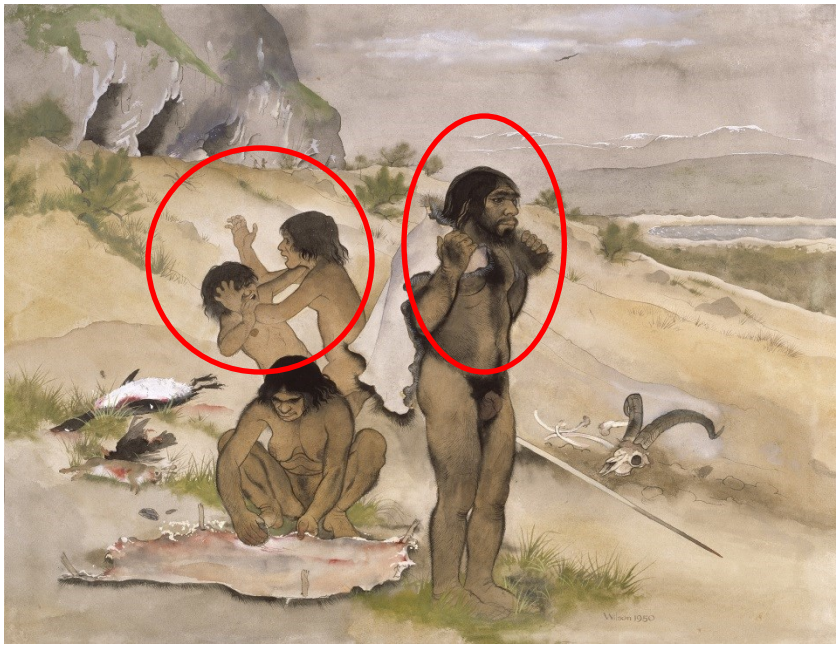
Neandertal early weaning?



From: Austin et al. 2013:Figure 3

" . . . dietary transitions in a Middle Palaeolithic juvenile Neanderthal, which shows a pattern of exclusive breastfeeding for seven months, followed by seven months of supplementation. After this point, Ba levels in enamel returned to baseline prenatal levels, indicating an abrupt **cessation of breastfeeding at 1.2 years of age**" (Austin et al. 2013:216).

Low age at production of Neandertal children(?)



Homo neanderthalensis, Neanderthal Man by Maurice Wilson

- **Contribution to viability:**
  - Reduced "cost" of children, increase in potential birth rate
- **Evidence:**
  - Rapid growth and development? (e.g., Guatelli-Steinberg et al. 2005; Smith et al. 2007; Smith et al. 2010)
  - Diet and activity patterns? (e.g., Bocherens et al. 2005; Buck and Stringer 2013; Kuhn and Stiner 2006)

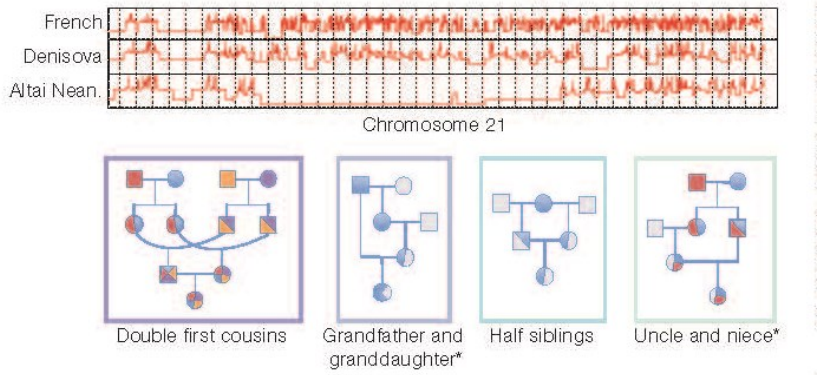
Sexual division of labor within the Neandertal "family" (?)

Sculpture by Alfons and Adrie Kennis

"It appears that Neandertal males, females, and juveniles alike participated in a narrow range of economic activities that centered on obtaining large terrestrial game. This apparent **absence of regular economic differentiation** in Middle Paleolithic cultures . . . (Kuhn and Stiner 2006:953-954).

". . . there are good reasons for assuming that **such divisions were just as strongly developed, if not more so, as those among ethnographic hunter/gatherers**" (Hayden 2012:21).

Minimal restrictions on “marriage”



Above: taken from Figure 3 of Prüfer et al. (2014:45)

- **Contribution to viability:**
  - Maximize capitalization of female reproductive span (birth rate)
- **Evidence:**
  - Genetics of Neandertal female from Altai Mountains suggest closely related parents (Prüfer et al. 2014)

“We present a high-quality genome sequence of a Neanderthal woman from Siberia. We show that **her parents were related at the level of half-siblings and that mating among close relatives was common among her recent ancestors**” (Prüfer et al. 2014:43)

Conclusions

- Under high adult mortality regime, viability of small populations can be enhanced by behaviors that increase fertility

- Model-based analysis suggests:
  - Neandertal families were large
  - Restrictions on “marriage” were minimal
  - Male-female pair bonds were relatively stable
  - Inter-birth interval was short

- **Concordant with several lines of fossil/archaeological data**

And there are a few other pieces that seem to fit: e.g., the burial of infants/children

" . . . we argue that a close attachment and particular attention to [Neandertal] children is a more plausible interpretation of the archaeological evidence, explaining an **unusual focus on infants and children in burial** . . ." (Spikins et al. 2014)

Burial 1 from Dederiyeh Cave

Future analysis

- Details of family life
  - division of labor/dependency ratio: what are the alternatives to the ethnographic model?
  - how to represent economic contributions/activities?
- How families are knit into the fabric of Neandertal societies
  - family size distribution, interactions
  - social network implications
  - spatial aspects of demography
- Implications for the earlier Paleolithic

Acknowledgments

- University of Michigan Center for the Study of Complex Systems (computational resources)
- Nemanja Vukasinovic (artist on cover slide)
- Caroline VanSickle (a generally useful person to know)

Presentation available online at www.andywhiteanthropology.com

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