

## Small Mammal Response to Post-fire Forest Succession in Northern Lower Michigan

### Abstract

Fire can drastically alter forest ecosystems, and this can have important impacts on small mammal abundance, demography and community composition. Forest fire reduces the vertical structure of a habitat and changes the vegetative composition and coverage, leading to a reduction in moisture and greater temperature extremes. These effects can be mediated by the presence of coarse woody debris. We selected a chronosequence of naturally and experimentally burned plots at the University of Michigan Biological Station (Michigan, USA) to investigate the relationships between post-fire succession and small mammal communities. We used vegetation/CWD surveys and 3 consecutive nights of live-trapping to characterize five plots covering a range of time since last burn (1917-1998). The percent of *Populus grandidentata* in a plot decreased with age while *Pinus spp.* and *Quercus rubra* increased in abundance with time since burning. We captured 3 species (*Peromyscus leucopus*, *Tamias striatus*, *Blarina brevicauda*), and observed significant differences between plots in the abundance, age structure and reproductive condition of *P. leucopus*. The presence of reproducing adults was significantly positively correlated ( $P=0.037$ ) with the presence of coarse woody debris. The high percentage of generally non-reproducing subadults in the intermediate plots may indicate a source-sink scenario, but the measured habitat variables were not sufficient to explain inconsistencies.

### Introduction

Michigan forests have experienced fire as a result of natural causes, Native American agriculture and intense logging in the 1800s (Burt Barnes pers. comm.). After 80 years of fire exclusion, land managers have reintroduced fire in the form of prescribed burning in an effort to maintain fire-adapted ecosystems and combat invasive species ([http://www.michigan.gov/dnr/0,1607,7-153-10370\\_12148\\_25071-70073--00.html](http://www.michigan.gov/dnr/0,1607,7-153-10370_12148_25071-70073--00.html)). It is important to understand the impact of fire on small mammal populations and communities because these animals (Muridae, Soricidae) play a variety of important roles in forest ecosystems, such as feeding on invertebrates, seeds, fruit, and lichen, disseminating seeds and mycorrhizal fungi, and serving as prey for a number of avian and mammalian predators (Carey and Johnson 1995).

Clearcutting and burning can drastically alter ecosystems, with the most severe fires burning much of the vegetative cover and soil organic matter. Because recently burned ecosystems lack dense cover, they tend to experience higher maximum and lower minimum temperatures than older stands, which can make the habitat unattractive to sensitive mammals (Kozlowski and Ahlgren 1974). The presence of downed woody material, which provides cover, moist microenvironments, runways, burrow sites and a substrate for food, leads to higher recolonization rates for rodents and insectivores during the first 10 years after burning (Fisher and Wilkinson 2005). Additionally, the redevelopment of vegetation structure is associated with the reappearance of small mammal species (Whelan 1995). Some mammals may utilize the edge of plots because they prefer to exploit multiple habitats (Kozlowski and Ahlgren 1974).

Post-fire forest succession influences small mammal population and community composition. Species richness of small mammals increases over time, but levels-off after the first 30-40 years (Whelan 1995). In early successional habitats, the lack of complex/layered vegetation may result in interspecific competition that was not present before the fire, leading to reduced numbers of all species and a change in dominance (Kozlowski and Ahlgren 1974). A source-sink scenario has been observed in some low-quality habitats created by fire, with more recently burned areas being dominated by non-reproducing individuals (Ecke et al. 2002; Buech et al. 1977 in Fisher and Wilkinson 2005).

We selected a chronosequence of naturally and experimentally burned plots at the University of Michigan Biological Station (UMBS) to investigate the relationships between post-fire succession and small mammal communities. Through live-trapping, we looked for changes in the abundance, diversity and community composition of small mammal species across the burn sequence. Additionally, we measured the age structure and reproductive status of individuals within each plot to look for the existence of a source-sink scenario. We also surveyed the vegetative cover and coarse woody debris (CWD) in each plot, which can be more important than the age since burn (Simon et al. 1998), so as to provide a mechanistic explanation for any observed differences in small mammal composition.

## Materials and Methods

### *Study site*

Our study was conducted on a chronosequence of experimental and natural burn plots (see Fig. 1) located on UMBS property (Section 32, T37N, R3W; Cheboygan Co., northern lower Michigan). We chose five plots about 1 hectare in size – one from 1917 that burned naturally and four experimental burns (1936, 1954, 1980, 1998). All experimental burn plots were clear-cut, with the poor-quality timber and slash left on-site and burned. The 1998 burn also includes a deer exclosure and has undergone yearly aspen ramet clipping in some portions. The entire burn sequence is located on a high-elevation outwash plain characterized by excessively-drained, acidic, sandy soil. Pre-settlement, the area was an eastern white pine- red pine – eastern hemlock – northern red oak forest, but extensive logging and 40 years of frequent fires resulted in the dominance of Bigtooth aspen (*Populus grandidentata*) in early successional forests, and it maintains a noticeable presence in older forests as well (White 2000).

### *Vegetation and coarse woody debris*

We used a point-centered quarter sampling method (Anderson 2006) to survey canopy and subcanopy trees in each plot. Four transects 50m long and at least 10m apart, with 10m

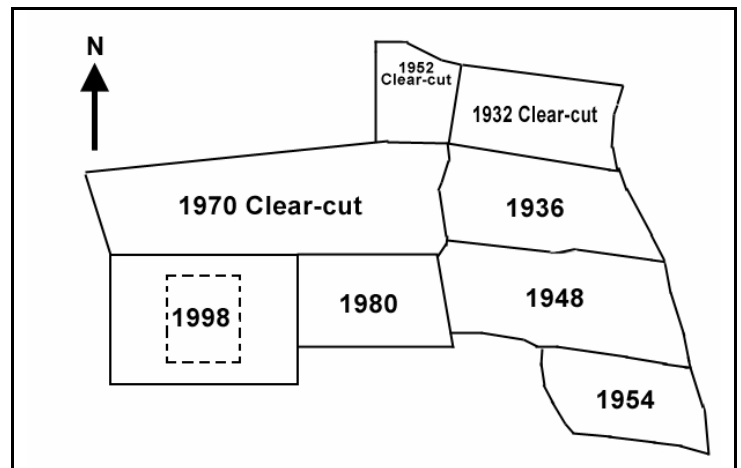


Figure 1. The 1998 Burn included a 50x80 deer exclosure. The 1917 plot was located to the south of the 1948 plot and to the west of the 1954 plot

between point trees, were laid on each plot. From each point tree, we recorded the diameter, distance from point tree and species of one canopy and one subcanopy tree encountered in each NW, NE, SW and SE direction.

Coarse woody debris (CWD) was surveyed along 4 transects in each burn plot. Transects were 50m long and at least 10m apart. We counted any piece of downed woody material greater than 3cm in diameter that crossed a transect and noted its size category: 3-10cm and >10cm.

### *Grids*

Trapping grids were set-up on each plot. For plots 1917-1980, trap lines were laid every 10m until reaching the edge of the plot, and folding Sherman live-traps (22.9 × 7.6 × 8.9 cm; H. B. Sherman Trap Co., Tallahassee, Florida, USA) were placed every 10m along the lines until reaching the plot border. We used the same procedure in the 1998 plot except no traps were laid in a 50x80 restricted area in the middle of the plot and some trap lines had portions located within the deer enclosure fence. The 1917 plot was 100x100m with 121 traps, the 1936 and 1954 plots were 70x80m with 72 traps, 1980 plot was 60x100m with 77traps, and the 1998 plot, excluding the restricted portion, was 5000 m<sup>2</sup> with 69 traps.

### *Trapping and processing*

Trapping was conducted for three consecutive nights starting 24 July 2006. Traps were laid out after 7pm the first night and loaded with oats. Each morning after 7:30am, traps with animals in them were removed during the day for processing, and empty traps were closed. We also noted the number of closed but empty, disturbed or missing traps in order to monitor the level of predator interference.

For each captured animal, we recorded the species, gender, reproductive status and weight. Additionally, a small portion of fur was clipped from a position on the back corresponding to one of the 5 plots, allowing us to determine if the animal was a recapture in the following days. *Peromyscus* and *Tamias* species were given oats and apples during the day, and *Blarina* were given worms. After 7:30pm, processed animals were returned to their trapping station, and all traps were re-set and loaded with oats

### *Statistical analyses*

All statistical tests were performed using SPSS 14.0 (SPSS, Inc., Chicago, Illinois, USA). Statistical comparisons were either a Chi-square test or a Spearmann Rank Correlation with a significance level of  $P \leq 0.05$ . The data collected on recaptured animals was not included in the analysis.

## **Results**

### *Vegetation & Coarse Woody Debris*

The following species were encountered during our point-centered quarter sampling of the plots: Bigtooth aspen (*Populus grandidentata*), Northern red oak (*Quercus rubra*), Red maple (*Acer rubrum*), Eastern white pine (*Pinus strobus*), Red pine (*Pinus resinosa*), Paper birch (*Betula papyrifera*) and *Amelanchier spp.* *Populus grandidentata* was the most commonly encountered canopy and subcanopy tree overall, but its relative dominance varied between the burn plots, with plots 1917 and 1936 having the highest percentages of other species (see Fig. 2).

The total basal area increases with age of plot (see Fig. 3), reflecting the larger size of canopy and subcanopy trees in the oldest plots.

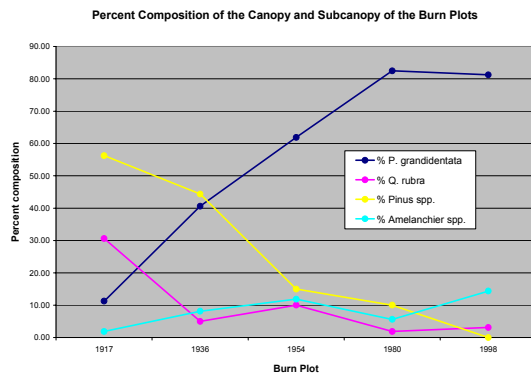


Figure 2.

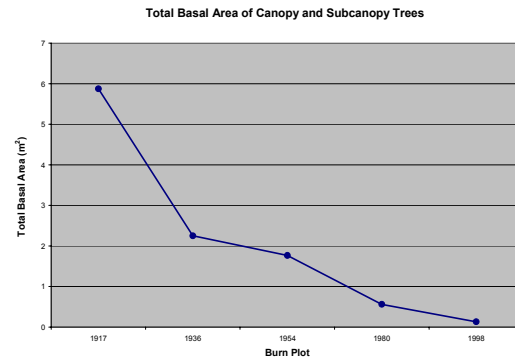


Figure 3.

The percent coverage by the most abundant tree species correlated well with the year of the burning in the plots. The percentage of *P. grandidentata* in a plot was significantly positively correlated with the year of the plot ( $R_s=0.9$ ,  $P=0.037$ ). Both the percent composition of *Pinus spp.* and *Q. rubra* were negatively correlated with the year of the plot ( $R_s=-1$ ,  $P=0.000$ ;  $R_s=-0.8$ ,  $P=0.104$ ). *Acer rubrum* also generally increased ( $R_s=0.7$ ,  $P=0.188$ ) with the year of the plot.

The amount of coarse woody debris >3cm in diameter differed significantly between plots ( $\chi^2 = 13.53$ ,  $d.f. = 4$ ,  $P<0.01$ ), with plots 1917 and 1998 having the most CWD (see Fig. 4).

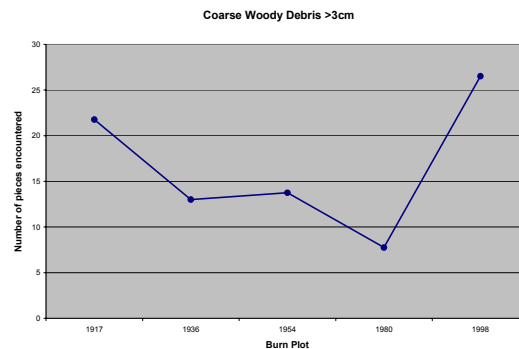


Figure 4.

### Captured animals

We captured a total of 136 individuals (not including recaptures) and 3 different species. *Peromyscus leucopus* ( $n=118$ ) was the most abundant. We also captured a few *Tamias striatus* ( $n=15$ ) and *Blarina brevicauda* ( $n=5$ ; may include recapture).

On average, 49% of all captures on the 2<sup>nd</sup> and 3<sup>rd</sup> days were recaptures. All *P. leucopus* recaptured had been captured earlier in the same plot, except in the 1917 plot, where *P. leucopus* males were recaptured from the 1980 and 1954 plots as well. One *Tamias* captured in the 1980 plot was recaptured from the 1998 plot, but all other *Tamias* were recaptured in the same plot as their first capture. The majority of all recaptured individuals (77%) were non-reproducing (abdominal males or nipples tiny females), and this majority held for each plot.

In total, 154 traps were disturbed (see Table 1 for percent disturbed by plot), with the most likely predators being *Procyon lotor*, *Canis latrans* and *Martes americana*. One *M. americana* may have been sighted in the 1917 plot on the 2<sup>nd</sup> day of trapping. Plots 1936 and 1954 were severely disturbed on the 3<sup>rd</sup> day of trapping, with 31% and 42% of traps disturbed, respectively. *Canis lantrans* may have been responsible for disturbing the 1954 trap lines on the 3<sup>rd</sup> day.

Burn plot	1917	1936	1954	1980	1998
Percent of total traps disturbed	12%	16%	20%	10%	6%

Table 1.

In order to make comparisons across plots, we adjusted the number of individuals captured according to the following formula, which puts all of the numbers in terms of 121 traps and accounts for the effect of predator disturbance:

$$\text{Adjusted \#} = ((\text{Total \# individuals caught}) * (3 * 121)) / ((3 * \text{\#of traps in plot}) - (\text{total \#traps disturbed}))$$

#### Population characteristics

The abundance of *P. leucopus* was significantly different between plots ( $\chi^2 = 16.85$ ,  $d.f. = 4$ ,  $P < 0.005$ ), with noticeably fewer mice than expected in the 1954 and 1980 plots and more than expected found in the 1936 and 1998 plots (see Table 2). There was no significant variation across plots in the number of males and females ( $\chi^2 = 6.69$ ,  $d.f. = 4$ ,  $P < 0.25$ ), even though we often caught more males than females, especially in the 1980 plot.

Burn plot	1917	1936	1954	1980	1998
Adjusted number of <i>P. leucopus</i> captured	36	52	31	26	56

Table 2. The expected number of mice = 40.3 individuals.

The age structure of *P. leucopus* also varied significantly across burn treatments ( $\chi^2 = 20.2$ ,  $d.f. = 8$ ,  $P < 0.01$ ). There were more adults and fewer juveniles than expected in the 1917 plot, fewer adults and more subadults in the 1936 and 1954 plots and more juveniles and fewer subadults in the 1998 plot (see Fig. 5). While the distribution of weight classes did not vary significantly across plots ( $\chi^2 = 15.21$ ,  $d.f. = 4$ ,  $0.05 < P < 0.075$ ), they did roughly reflect the trends in the age data. There was a smaller percentage of *P. leucopus* in the 15.1-20g category (roughly subadult) for the 1998 plot, a larger percentage of  $>20.1$ g *P. leucopus* (roughly adult) in the 1998 plot than expected, and more *P. leucopus* in the 15.1-20g category than expected for the 1936 plot.

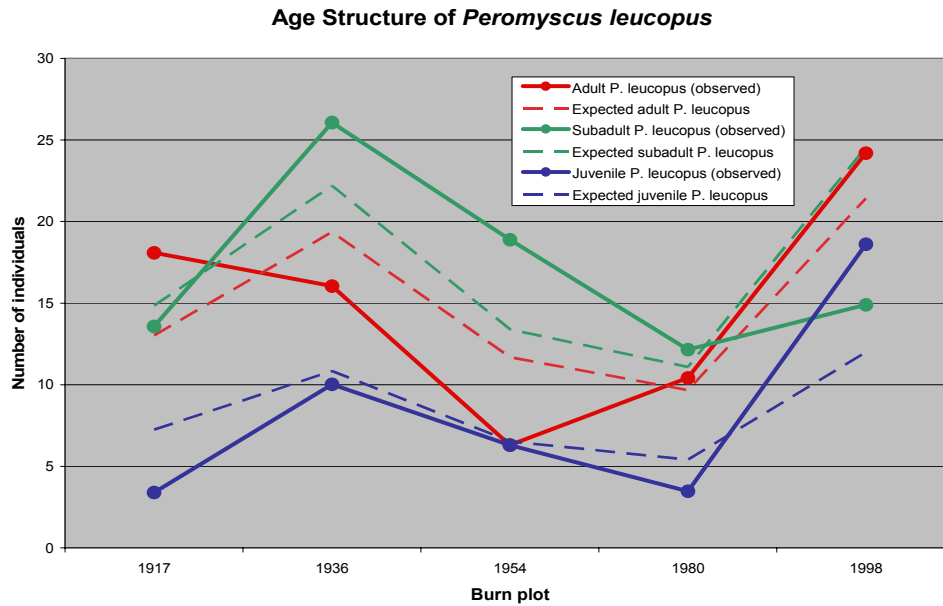


Figure 5.

We also found variation across plots in the reproductive status of *P. leucopus*. There was a significant difference in the percent of scrotal versus the percent of abdominal males ( $\chi^2 = 11.32$ ,  $d.f. = 4$ ,  $P < 0.025$ ) and in the percent of females with tiny nipples versus those with enlarged nipples ( $\chi^2 = 11.19$ ,  $d.f. = 4$ ,  $P < 0.025$ ). The 1936 plot had many more females with tiny nipples and more abdominal males than expected. The 1917 plot had more females with enlarged nipples than expected, and the 1980 plot had more abdominal males than expected. Figure 6 demonstrates that non-reproductive males and females tended to be in the same plot and visa versa. The highest numbers of reproductive individuals (reproductive adults and subadults combined) were found in the 1917 and 1998 plots.

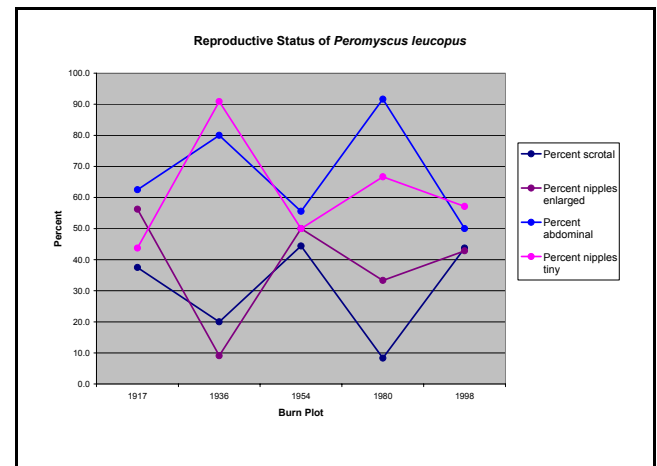


Figure 6.

### *Influence of habitat characteristics*

Spearman-Rank Correlations indicated a relationship between CWD and reproductive status of *P. leucopus*. The amount of CWD >3cm in each plot was significantly negatively correlated with the percent of abdominal males in a plot ( $R_s = -0.9$ ,  $P = 0.037$ ) and was also somewhat positively correlated with the percent of scrotal males ( $R_s = 0.7$ ,  $P = 0.188$ ). There may also be a slight correlation between CWD and the reproductive status of female mice, with non-reproductive individuals in the plots with less CWD (percent nipples tiny:  $R_s = -0.6$ ,  $P = 0.285$ ; percent nipples enlarged:  $R_s = 0.6$ ,  $P = 0.285$ ).



## Discussion

The burn chronosequence exhibited a progressive change in habitat, with the number of years since burning being highly correlated with the canopy and subcanopy composition of the forest community. The percent of *P. grandidentata* in a plot decreased with age while *Pinus spp.* and *Q. rubra* increased in abundance with time since burning. Because we only captured 3 different species (*P. leucopus*, *T. striatus*, *B. brevicauda*), we were not able to conduct a rigorous investigation of changes in species diversity. However, we did observe significant differences between plots in the abundance, age structure and reproductive condition of *P. leucopus*. In general, there were more subadults in the intermediate-age plots, more adults in the oldest plot and more juveniles in the most recently burned plot than expected. Overall, there was a higher percentage of reproductive females in the 1917 plot, a higher percentage of non-reproducing *P. leucopus* in the intermediate plots and no deviation from the expected values for the youngest plot.

The most coarse woody debris and the highest number of reproductive individuals were found in the 1917 and 1998 plots. This pattern is supported by the significant correlation of high levels of CWD with the presence of scrotal males. Further research should investigate the extent to which *P. leucopus* utilize CWD for nest-sites, runways, foraging, etc. in the burn plots. Casual observation indicated that several burrows were located near CWD and that large numbers of insects, a preferred food for *P. leucopus* (Wolff et al. 1985), were present beneath the debris in the 1998 plot.

We were not able to confirm the existence of a source-sink scenario occurring in the intermediately aged plots. However, the high percentage of subadults (the age for emigration) paired with the low overall *P. leucopus* abundance and dearth of high quality food sources (few oaks, pines and CWD), makes this a plausible explanation for some of the variation between plots. However, caution must be taken when determining what sort of habitat is acceptable for *P. leucopus* since they are capable of living at high densities across a wide-variety of habitats (Lackey 1978), and they are flexible in their food preferences (Drickamer 1976). Additional research should incorporate a ground cover survey in order to account for the presence and quality of fruiting shrubs, since these could comprise a major part of the diet of *P. leucopus* during certain parts of the year.

The 1998 plot may have been a more suitable habitat than originally expected (supporting high numbers of adults) due to the large amount of coarse woody debris, which has the potential to provide food/foraging habitat, thermal regulation and shelter. Additionally, the presence of *P. grandidentata* may have accelerated the recovery of the 1998 plot because aspen can occupy a site quickly after fire (through root-suckering) and aspen groves create more moderate temperature and moisture conditions (Burt Barnes, personal communication).

We did not observe much movement between plots. When we did capture individuals, they were males that had traveled from the intermediate plots to the 1917 plot, matching the literature findings that males often travel longer distances (Hirth 1959).

One important area requiring further investigation is the influence of post-fire succession on the suitability of habitat for the predators of small mammals. For example, martens are often found in the old growth stage (76 years+), but rarely in other habitats (Fisher and Wilkinson 2005). The 1998 plot could have supported higher numbers of reproducing individuals and juveniles due to reduced levels of predation as compared to the 1917 plot. Overall, very little is known about the effects of fire on carnivores (Fisher and Wilkinson 2005), but the prevalence of

disturbance in our trap lines indicates that predators are an active component of the burn plots. Different rates of predation could have an important impact on *P. leucopus* demography across plots.

### Acknowledgements

We thank Burt Barnes for allowing access to the 1998 plot and for providing Master's theses and other information regarding the history of the burn plots. We are also grateful to Phil Myers and Stephanie Seto for their guidance during all aspects of this project.

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### Appendix I: Summary of results by plot

	1917	1936	1954	1980	1998
Vegetation	11% <i>P. grandidentata</i> , 31% <i>Q. rubra</i> , 57% <i>Pinus</i> spp., 2% <i>A. rubrum</i> ; 5.9 m <sup>2</sup> basal area	41% <i>P. grandidentata</i> , 5% <i>Q. rubra</i> , 44% <i>Pinus</i> spp., 8% <i>A. rubrum</i> ; 2.2 m <sup>2</sup> basal area	62% <i>P. grandidentata</i> , 10% <i>Q. rubra</i> , 15% <i>Pinus</i> spp., 11.9% <i>A. rubrum</i> ; 1.8 m <sup>2</sup> basal area	83% <i>P. grandidentata</i> , 2% <i>Q. rubra</i> , 10% <i>Pinus</i> spp., 5.6% <i>A. rubrum</i> ; 0.56 m <sup>2</sup> basal area	81% <i>P. grandidentata</i> , 3% <i>Q. rubra</i> , 0% <i>Pinus</i> spp., 14% <i>A. rubrum</i> ; 0.13 m <sup>2</sup> basal area
CWD	23 pieces CWD	13 pieces CWD	13.75 pieces CWD	7.75 pieces CWD	26.5 pieces CWD
Traps disturbed	Traps 12% disturbed, marten sighting	Traps 16% disturbed	Traps 20% disturbed	Traps 10% disturbed	Traps 6% disturbed
Abundance	36 mice/ 363 traps = 10%	52 mice/ 363 traps = 14%	31 mice/ 363 traps = 8.5%	26 mice/ 363 traps = 7%	56 mice/ 363 traps = 15%
Age structure	More adults, fewer juveniles than expected	More subadults, fewer adults than expected	More subadults, fewer adults than expected	Age class as expected	Fewer subadults and more juveniles than expected
Reproductive status	More NENL females	More NTNL females and ABD males than expected	Repro didn't vary from E	More ABD males than expected	Repro status as expected